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Assessment of Heavy Metal Contamination in Different Vegetables Grown in and Around Urban Areas

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ABSTRACT

Heavy metals such as cadmium, copper, lead, chromium and mercury are important environmental pollutants, particularly in areas with high anthropogenic pressure. Their presence in the atmosphere, soil and water, even in traces can cause serious problems to all organisms and heavy metal bio accumulation in the food chain especially can be dangerous to the human health. Heavy metals intake by human populations through food chain has been reported in many countries. As human activities increases, especially with the increases in the modern technologies, pollution and contamination of the human food chain has become inevitable. International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in the food items due to an increased awareness of the risk these metals pose to food chain contamination. Heavy metals are very harmful because of their non-biodegradable nature, long biological half lives and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their solubility in water. Even low concentrations of heavy metals have damaging effects to man and animals because there is no good mechanism for their elimination, from the body. Heavy metals are persistent environmental contaminants which may be deposited on the surfaces and then adsorbed into the tissues of vegetables. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environment as well as from contaminated soil. In this study we have reviewed the problem of heavy metal contamination in different vegetables as per the findings of various researchers in different parts of the world.

Key words: Heavy metals, vegetables, contamination, health hazards, accumulation

INTRODUCTION

Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, vitamins, minerals and fibers required for human health. They also act as neutralizing agents for acidic substances formed during digestion (Thompson and Kelly, 1990). As human activities increases, especially with the application of modern technologies, pollution and contamination of the human food chain has become inevitable. Heavy metals uptake by plants grown in polluted soils has been studied to a considerable extent (Wong, 1996; Wong *et al.*, 1996; Sukreeyapongse *et al.*, 2002; Yusuf *et al.*, 2003). Heavy metal exposure is not an entirely modern phenomenon: Historians have cited the contamination of wine and grape drinks by lead-lined jugs and cooking pots as a contributing factor in the "decline and fall" of the Roman Empire and the Mad Hatter character in Alice in Wonderland was likely modeled after nineteenth-century hat makers who used mercury to stiffen hat material and frequently became psychotic from mercury toxicity. Human exposure to heavy metals has risen dramatically in the last 50 years however, as a result of an exponential increase in the use of heavy metals in industrial processes and products.

Heavy metal contamination in vegetables cannot be underestimated as these food stuffs are important components of human diet. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Marshall, 2004; Radwan and Salama, 2006; Wang *et al.*, 2005; Khan *et al.*, 2008). International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk, these metals pose to food chain contamination (Radwan and Salama, 2006).

There is much to be learned about the immune response to cancer. Current and future developments will add to the list of techniques used, understanding gained and techniques successfully developed. These constitute an exciting albeit occasionally heartbreaking growth area in nuclear medicine (Hazra *et al.*, 1995, 1990). Some techniques have been used on attempts to exploit specificity of the antigen antibody reaction (Hazra *et al.*, 1997, 1996).

Strictly speaking, heavy metals are defined as those with higher density than 5 mg mL^{-1} (Jarup, 2003) but the collective term now includes arsenic, cadmium, chromium, copper, lead, nickel, molybdenum, vanadium and zinc. Some interest also exists in aluminium, cobalt, strontium and other rare metals. Physiologic roles are known for iron (haemmoeties of heamoglobin and cytochromes), copper (amine oxidases, dopamine hydrolase and collagen synthesis), manganese (superoxide dismutase), zinc (protein synthesis, stabilization of DNA and RNA) with low requirements of chromium (glucose homeostasis). Other heavy metal ions are not believed to be essential to health even in trace amounts.

The heavy metals cadmium, lead and mercury are common air pollutants, being emitted mainly as a result of various industrial activities. Although the atmospheric levels are low, they contribute to the deposition and build-up in soils. Heavy metals are persistent in the environment and are subject to bioaccumulation in food-chains. Cadmium exposures are associated with kidney and bone damage. Cadmium has also been identified as a potential human carcinogen, causing lung cancer. Lead exposures have developmental and neurobehavioral effects on fetuses, infants and children and elevate blood pressure in adults. Heavy metals such as cadmium, lead and mercury are common air pollutants and are emitted (predominantly into the air) as a result of various industrial activities. One of the consequences of the current stage of industrialization and the demand for improved quality of life has been increased exposure to air pollution coming from industrial activities, traffic and energy production (WHO, 2007).

Sources of heavy metal pollution in vegetables: Rapid and unorganized industrialization and urbanization have contributed to the elevated levels of heavy metals in the urban environment of the developing countries such as China (Wong *et al.*, 2003) and India (Tripathi *et al.*, 1997; Khillare *et al.*, 2004; Sharma *et al.*, 2008a, b). Heavy metals are non-biodegradable and persistent environmental contaminants which may be deposited on the surfaces and then adsorbed into the tissues of the vegetables. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environment as well as from contaminated soils (Khairiah *et al.*, 2004; Al-Jassir *et al.*, 2005; Kachenko and Singh, 2006; Singh and Kumar, 2006; Sharma *et al.*, 2008a, b).

Water contamination by heavy metals in some areas is practically inevitable due to natural process (weathering of rocks) and anthropogenic activities (industrial, agricultural and domestic effluents). Waste water from the industries of mining, electroplating, paint or chemical laboratories often contains high concentrations of heavy metals, including Cadmium (Cd), Copper (Cu) and lead (Pb). These elements, at concentrations exceeding the physiological demand of the plants, not only could administer toxic effect in them but also could enter food chains, get biomagnified and pose a potential threat to human health (Sugiyama, 1994). Heavy metal contamination of agricultural soils from wastewater irrigation is of serious concern since it has implications on human health. A study carried out by Mensah *et al.* (2008) in Ghana using water to which Cd and Pb had been added to irrigate cabbage, carrots and lettuce revealed that Cd and Pb concentrations increased with irrigation water concentrations significantly with p-value of Cd<0.0001 and for Pb<0.05.

It has been established that heavy metals in soil are associated with various chemical forms that relate to their solubility which directly bear on their mobility and biological availability (Xian, 1989). Heavy metals in soluble form have high relation to their uptake by plants (Miller and Mcfree, 1983). Vegetables can absorb metals from soil as well as from deposits on the parts of the vegetables exposed to the air from polluted environments (Haiyan and Stuanes, 2003). Emission of heavy metals from the industries and vehicles may be deposited on the vegetable surfaces during their production, transport and marketing. Al-Jassir *et al.* (2005) have reported elevated levels of heavy metals in vegetables sold in the market of Riyadh city in Saudi Arabia due to atmospheric deposition. Recently, Sharma *et al.* (2008a, b) have reported that atmospheric deposition can significantly elevate the levels of heavy metals contamination in vegetables commonly sold in the markets of Varanasi, India.

In many developing countries it is a common practice to grow vegetables along banks of rivers passing through urban centres. Waters of such rivers have often been reported to be polluted by heavy metals (Mashauri and Mayo, 1990; Kashem and Singh, 1999; Othman, 2001). The extent of absorption of the elements by the plant depends on among other things, the nature of the plant, chemical constitution of the pollutant, concentration of the element in the soil, pH and the interaction with other metals (Zurera-Cosano *et al.*, 1989).

The uptake and bioaccumulation of heavy metals in vegetables is influenced by many factors such as climate, atmospheric depositions, the concentrations of heavy metals in soils, the nature of soil and the degree of maturity of the plants at the time of the harvest (Scott *et al.*, 1996; Voutsa *et al.*, 1996). Air pollution may pose a threat to post harvest vegetables during transportation and marketing, causing elevated levels of heavy metals in the vegetables. (Sharma *et al.*, 2008a). Elevated levels of heavy metals in vegetables are reported such as long term uses of treated and untreated waste water (Sharma *et al.*, 2006, 2007; Adeniyi, 1996; Sinha *et al.*, 2005). Other anthropogenic sources of heavy metals include the addition of manures, sewage sludge, fertilizers and pesticides which may affect the uptake of heavy metals by modifying the physico-chemical properties of the soil such as pH, organic matter, bioavailability of heavy metals in the soil (Yusuf and Osibanjo, 2006). Whatmuff (2002) and McBride (2003) found that increasing concentrations of heavy metals in soil increased the crop uptake. Cultivation areas near highways are also exposed to atmospheric pollution in the form of metal containing aerosols. These aerosols can be deposited on soil and absorbed by the vegetables or alternatively deposited on the leaves and fruits and then absorbed.

Hazardous effects of heavy metals on human health: Heavy metals are very harmful because of their non-biodegradable nature, long biological half lives and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their solubility in water. Now a day's heavy metals are ubiquitous because of their excessive use in industries. Factors associated with the possible health effects of exposure to cadmium, lead and mercury have been investigated over many years in occupational settings, using experimental animals and humans exposed to environmental pollution. The types of adverse health effect are known to a great extent but, because of the very strong influence of confounding factors, it is very difficult or almost impossible to find thresholds for some outcomes such as impairment of cognitive functions in children exposed to lead or mercury.

Chronic low level intakes of heavy metals have adverse effects on human beings and other animals due to the fact that there is no effective mechanism for their elimination from the body (Bahemuka and Mubofu, 1999). Metals such as lead, mercury, cadmium and copper are cumulative poisons. These metals cause environmental hazards and are reported to be exceptionally toxic (Ellen *et al*., 1990). Vegetables take up metals by absorbing them from contaminated soils, as well as from deposits on parts of the vegetables exposed to the air from polluted environments (Zurera-Cosano *et al*., 1989).

Prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (WHO, 1992; Jarup, 2003). Some heavy metals such as Cu, Zn, Mn, Co and Mo act as micronutrients for the growth of animals and human beings when present in trace quantities, whereas others such as Cd, As and Cr acts as carcinogens (Freig *et al*., 1994; Trichopoulos *et al*., 1997). Hg and Pb are associated with the development of abnormalities in children. Gibb and Chen (1989), Pitot and Dragan (1996). Hartwig (1998), Saplakoglu *et al*. (1997) have reported that long term intake of Cd caused renal, prostrate and ovarian cancers. Food is the main source of cadmium exposure in the general population (representing >90% of the total intake in non-smokers). In heavily contaminated areas, dust resuspension can constitute a substantial part of the crop contamination and exposures via inhalation and digestion. Cadmium is accumulating in soils and catchments under certain environmental conditions, thus increasing the risk of future exposure through food.

The intake of heavy metal can lead to altering of humans and animals healthiness state. Thus, the carcinogenic effects generated by continuous consumption of fruits and vegetables loaded with heavy metals such as Cd, Pb or even Cu and Zn are known. This may be related to the incidence of gastrointestinal cancer (Trichopoulos *et al*., 1997; Turkdogan *et al*., 2002) and cancer of the pancreas, urinary bladder or prostate (Waalkes and Rehm, 1994). The sad thing about the pollution of the environment with heavy metals is that they can only be transformed from one oxidation state or organic complex to another (Lone *et al*., 2008; Jing *et al*., 2007). Once the environment becomes polluted with Zinc, it begins its journey to man's body (Islam *et al*., 2007; Okoronkwo *et al*., 2005) by been readily absorbed by plants (Kos *et al*., 2003) which are subsequently consumed by man. The transfer of cadmium from soil to the food-chain depends on a number of factors, such as the type of plant, the type and pH of the soil and the zinc and organic matter content in the soil. Cadmium adsorption to soil particles is greater in neutral or alkaline soils than in acidic ones and this leads to increased cadmium levels in the solution.

Knowledge of Zn toxicity in humans is minimal. The most important information reported is its interference with Cu metabolism (Barone *et al*., 1998; Gyorffy and Chan, 1992). The symptoms that an acute oral Zn dose may provoke include: Tachycardia, vascular shock, dyspeptic nausea, vomiting, diarrhea, pancreatitis and damage of hepatic parenchyma (Salgueiro *et al*., 2000).

Lead is a toxic element that can be harmful to plants, although plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. Lead is a well-known neurotoxin. Impairment of neurodevelopment in children is the most critical effect. Exposure in utero, during breastfeeding and in early childhood may all be responsible for the effects. Lead accumulates in the skeleton and its mobilization from bones during pregnancy and lactation causes exposure to fetuses and breastfed infants. In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human (Wierzbicka, 1995). The introduction of Pb into the food chain may affect human health and thus, studies concerning Pb accumulation in vegetables have increasing importance (Coultate, 1992).

Exposure to potentially toxic metals from dust inhalation or soil ingestion is usually modeled simply as the concentration of a contaminant measured in the soil multiplied by the quantity of dust inhaled or soil ingested (Konz *et al.*, 1989). This is a conservative approach to estimate dose because the bioaccessibility of heavy metals adsorbed on ingested soil is not 100% (Ruby *et al.*, 1999). However, predicting exposure to potentially toxic metals from consumption of food crops is more complicated because uptake of metals by plants depends on soil properties and plant physiologic factors. This leads to much larger uncertainties associated with estimating potential doses through food chains compared to the uncertainties associated with other exposure pathways such as soil ingestion and dust inhalation (McKone, 1994).

According to Hough *et al.* (2004) under Part IIA of the Environmental Protection Act 1990, the UK government favors a “suitable for use” approach to redevelopment (DETR, 2000). Land is contaminated only if the current or intended use of a site has the potential to cause an unacceptable health risk to human occupants or to the environment. Under the UK Town and Country Planning Act 1990 (DETR, 2000), this approach requires that land be assessed for redevelopment on a site-specific basis. At present, concentrations of metals in the soil are compared to metal-specific trigger values (termed maximum contaminant levels or maximum contaminant concentrations in North America). In the past these trigger values were based on total contaminant concentration in the soil (ICRCL, 1987). More recently, the introduction of Contaminated Land Exposure Assessment (CLEA) (DEFRA and Environment Agency, 2002a) in April 2002 has replaced these trigger values with generic soil guidance values (SGVs) (DEFRA and Environment Agency, 2002b). The SGVs are considered a significant improvement on the previous ICRCL values and for Cd at least, soil pH categories are employed where food plants are to be grown. Where a soil exceeds the SGV, it is recommended that a risk assessment or remediation measure be conducted for the site in question (DEFRA and Environment Agency, 2002b). Additionally, exceeding of an SGV indicates that some further risk management action should be undertaken. However, the use of single trigger values or SGVs for most scenarios may represent a poor indication of the risk associated with a specific site. There is therefore a requirement for site-specific risk assessment based on commonly measured geochemical and population parameters (Hough *et al.*, 2004).

The risk of contaminants accumulating in soil, environment and crops due to sewage water, fertilizer and pollutants is of serious concern. Heavy metals have been reported to produce mutagenic, teratogenic, neurotoxic and carcinogenic effects even at very low concentrations. (Das, 1990; Al-Saleh *et al.*, 1996; Waalkes *et al.*, 1999). Human beings have also been reported to develop several disease like cardiovascular, tubular dysfunction in kidneys and nervous disorders due to metal toxicity (Friberg *et al.*, 1986; WHO, 1996).

Recent findings of heavy metal contamination in vegetables in different countries: High accumulation of lead, chromium and cadmium in leafy vegetables due to atmospheric deposition have been reported by Voutsa *et al.* (1996) and De Nicola *et al.* (2008).

The levels of heavy metals in vegetables (zinc, manganese, copper and lead) in vegetable (*Talinum triangulare*) collected from dump sites of Lagos, Nigeria were found to be high due to vehicular emission Adeniyi (1996). Okunola *et al.* (2008) studied the concentration of Cd and Zn in the soil and vegetation along some roadsides at Nigeria and concluded from the results that automobiles are a major source of these metals along the roadside environment. The magnitude of heavy metal deposition on vegetable surfaces varied with morpho-physiological nature of vegetables (Singh and Kumar, 2006). Demirezen and Aksoy (2006) have reported higher concentrations of lead, cadmium and copper in *Abelmoschus esculentus* collected from urban areas of Kayseri, Turkey as compared to those from rural areas. The partitioning of heavy metals is well known, with accumulation of greater concentrations in the edible portions of leafy or root crops than the storage organs or fruits (Jinadasa *et al.*, 1997; Lehoczky *et al.*, 1998; Sharma *et al.*, 2006).

Yusuf and Oluwole (2009) reported that urban activities in Lagos have elevated the levels of heavy metals in urban atmospheric deposits which consequently increased the concentrations of heavy metals in *Talinum triangulare, Celosia argentea, Amaranthus viridis, Cucurbita maxima* and *Corchorus olitorius* during marketing. Variations in the magnitude of reductions in heavy metal contamination due to washings of vegetables also depicted variations in heavy metal deposition at various market sites. They further suggested that to reduce the health risk, vegetables should be washed properly before consumption as washing can remove a significant amount of aerial contamination from the vegetable surfaces.

Sharma *et al.* (2009) have generated data on heavy metal pollution in and around Varanasi city of India and associated health risk assessment for the consumer's exposure to the heavy metals. They proposed the hypothesis that the transportation and marketing of vegetables in contaminated environment may elevate the levels of heavy metals in vegetables through surface deposition has been proved through this study. The consumption of vegetables directly from production areas might be less hazardous to human health in comparison to those from polluted open market areas. Heavy metals have a toxic impact but detrimental impacts become apparent only when long-term consumption of contaminated vegetables occurs. It was suggested that regular monitoring of heavy metals in vegetables and other food items should be performed in order to prevent excessive buildup of these heavy metals in the human food chain. Appropriate precautions should also be taken at the time of transportation and marketing of vegetables.

Odai *et al.* (2008) studied the concentration levels of heavy metals in vegetables grown on urban waste dumpsites. This study was carried out on three waste dumpsites in Kumasi where vegetables cultivation (cabbage, lettuce and spring onions) are practiced. Crops and soil samples were collected and analyzed for the presence of four heavy metals: Cadmium, lead, copper and zinc. The levels of the two most toxic heavy metals were far higher in the vegetables than the WHO/FAO recommended values and the transfer factors of these two metals were also the highest suggesting that consumption of vegetables grown on such sites could be dangerous to human health.

Chove *et al.* (2006) carried out a study to determine the levels of two heavy metals, Lead (Pb) and Copper (Cu), in two popular leafy vegetables grown around Morogoro Municipality in Tanzania. Vegetable samples of Pumpkin leaves (*Cucurbita moschata*) and Chinese cabbage (*Brassica chinensis*) were collected from three sites and analyzed for their concentrations of the two metals using an Atomic Absorption Spectrophotometer The results showed that the levels (mg/100 g dry weight) ranged from 0.885 to 1.39 for Copper and 0.05 to 0.315 for Lead. The levels of Lead and Copper varied between the vegetable varieties and from site to site. There was a significant difference ($p<0.05$) in levels of the two metals across the sites but there was no significant difference ($p>0.05$) in the levels of Copper between the two vegetable varieties from all the three sites. There was a significant difference ($p<0.05$) in the levels of Lead between the vegetable varieties. The levels of both Lead and Copper in the two vegetables were found to be below the maximum permissible levels recommended by FAO/WHO for the two metals in vegetables.

Srinivas *et al.* (2009) collected the air, soil and vegetable samples from Industrial, Semi-urban and rural areas of Visakhapattanam and were analyzed for Pb, Zn, Ni and Cu. The rural area is free from contaminant sources and is treated as control. From each representative area composite samples of Tomato, Lady's finger, Capsicum and leafy vegetable Bimli were collected and analyzed for Pb, Zn, Ni and Cu. The air environments in Industrial and Semi-Urban areas are enriched with the four trace metals but the concentrations were within the permissible levels. This indicates that, despite the close proximity of the agricultural lands to high emitting industrial sources, soils do not seem to have been contaminated by atmospheric deposition. Remarkable differences were observed between the trace metal content in vegetables of rural areas with semi-urban and industrial areas. In industrial area Nickel, Zinc were reported in higher concentrations in tomato and capsicum where as in semi urban area the concentration of Cu is 2-3 times higher in tomato and lady's finger on comparison with the rural vegetables. Based on the air accumulation factor and concentration factor calculations, the trace metals of Pb and Zn in industrial and semi-urban areas were found to be receiving the contributions from both atmospheric and soil inputs in all the four crops.

Maleki and Zarasvand (2008) conducted a study for determining the levels of four different heavy metals [Cadmium (Cd), Lead (Pb), Chromium (Cr) and Copper (Cu)] in various vegetables [leek (*Allium ampeloprasum*), sweet basil (*Ocimum basilicum*), parsley (*Petroselinum crispum*), garden cress (*Lepidium sativum*) and tarragon (*Artemisia dracunculus*)] cultivated around Sanandaj City. The contributions of the vegetables to the daily intake of heavy metals from vegetables were investigated. One hundred samples (20 samples per month) were collected for five months. Atomic absorption spectrometry was used to determine the concentrations of these metals in the vegetables. The average concentrations of each heavy metal regardless of the kind of vegetable for Pb, Cu, Cr and Cd were 13.60±2.27, 11.50±2.16, 7.90±1.05 and 0.31±0.17 mg kg^{-1}, respectively. Based on the above concentrations and the information of National Nutrition and Food Research Institute of Iran, the dietary intake of Pb, Cu, Cr and Cd through vegetable consumption was estimated at 2.96, 2.50, 1.72 and 0.07 mg day^{-1}, respectively. It is concluded that the vegetables grown in this region are a health hazard for human consumption.

The contents of lead (Pb), Copper (Cu), Chromium (Cr), Zinc (Zn) and Cadmium (Cd) in various leafy vegetables viz., spinach, coriander, lettuce, radish, cabbage and cauliflower grown in an effluent irrigated fields in the vicinity of an industrial area of Faisalabad, Pakistan were assessed using atomic absorption spectrophotometer (Farooq *et al.*, 2008). The contents of Cu, Zn, Cr, Pb and Cd were below the recommended maximum acceptable levels proposed by the Joint FAO/WHO Expert Committee on Food Additives. The leaves of spinach, cabbage, cauliflower, radish and coriander contained higher concentrations of Cu (0.923 mg kg^{-1}), Cd (0.073 mg kg^{-1}), Cr (0.546 mg kg^{-1}), Zn (1.893 mg kg^{-1}) and Pb (2.652 mg kg^{-1}) as compared to other parts of each vegetable. The results from this study suggested that significant differences existed in the elemental concentrations among the vegetables analyzed that might be in due part to the geological status of the area under investigation and the ability of plants and their specific parts to accumulate metals as well.

Abdullahi *et al.* (2009) determined quantitatively the concentration of Cd, Cr and Pb in onion leaves samples using the atomic absorption spectrometry. A total of 16 onion leaves each were collected from both the study and control sites for analysis. The heavy metals, Cd, Cr and Pb in onion leaves of study sites were found in the range of 0.667-0.933, 3.870-7.870 and 5.870-7.537 mg kg^{-1}, respectively while the results of control sites showed values ranging from 0.583-0.700, 0.447-0.842 and 3.833-7.333 mg kg^{-1} for Cd, Cr and Pb, respectively. The trend of abundance of heavy metals in both sites followed the same sequence: Pb > Cr > Cd. The metal levels in both sites are higher than WHO/EU recommended limits with exception of Cd. The high levels of the metals suggest that effluent water irrigated fields could be indicative of bio-accumulation of the metals in the leaves, consequently putting the consumers of this vegetable crop at health risk.

Lacatusu and Lacatusu (2008) assessed the quality of vegetables and fruits grown within heavy metal polluted environment in Romania. They have found that unlike vegetables, the accumulation of heavy metals in fruits is low because a large proportion of heavy metals absorbed by trees are stored in other organs, especially in leaves. The medium value of total and mobile heavy metal content (Cd, Cu, Pb, Zn) in most samples exceeds the maximum allowable limits.

Al-Jassir *et al.* (2005) assessed the deposition of heavy metals on green leafy vegetables sold on road sides of Riyadh city, Saudi Arabia. In this study the levels of lead, cadmium, copper and zinc were determined in washed and unwashed green leafy vegetable samples. The result of this study in comparison with PTDI values indicates that intake of heavy metals through leafy vegetables would not mean a health hazard for consumers but gets significance in the light of reported daily intake of Cd and Pb through diet in the country. A comparison was made with some reported test vegetables from different countries, showing the concentration of heavy metals in them (Table 1, 2).

In Table 1, levels of copper and zinc and in Table 2 levels of lead and cadmium in various vegetables are compared on the basis of studies carried out by different researchers for countries like Egypt India, Pakistan, Tanzania, Nigeria and Greece.

Suruchi and Jilani (2011) have investigated the accumulation of air borne heavy metals in edible parts of vegetables in the selected areas of Agra, India. Three samples of vegetables were taken and the concentrations of Pb, Cd, Cr, Ni and Zn were determined in washed and unwashed test samples by AAS. The result obtained from this analysis revealed high concentration of toxic elements in unwashed samples than the washed samples.

Table 1: Comparison of copper and zinc in vegetables published form different parts of world

	Heavy metal concentrations (mg kg^{-1})															
	Nigeria[a]		Egypt[b]		Pakistan[c]		Pakistan[d]		India[e]		India[f]		Egypt[g,h]		Tanzania[i]	
Vegetable	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn
Spinach	-	-	4.48	20.9	-	-	0.92	0.46			-	-	1.18	-	0.72-1.37	4.08-4.81
Lettuce	0.72	2.30	1.97	9.76	-	-	0.85	0.74	-	-	-	-	0.92	-	0.25-0.58	1.48-1.59
Tomatoes	0.36	1.00	1.83	7.69			-	-	-	-	1.75	-	-	-	-	-
Onion	7.30	17.3	1.49	11.4			-	-			-	-	-	-	-	-
Cauliflower	-	-	-	-	-	-	0.32	0.68	35.72	63.63	-	-	-	-	-	-
Lady's Finger	-	-	-	-	-	-	-	-	18.02	45.96	5.85	-	-	-	-	-

[a]Onianwa *et al.* (2001), [b]Radwan and Salama (2006), [c]Parveen *et al.* (2003), [d]Farooq *et al.* (2008), [e]Sharma *et al.* (2009), [f]Srinivas *et al.* (2009), [g]Dogheim *et al.* (2004), [h]Hussein and Bruggeman (1997) and [i]Bahemuka and Mubofu (1999)

Table 2: Comparison of lead and cadmium in vegetables published form different parts of world

	Heavy metal concentrations (mg kg^{-1})															
	Egypt[a]		Egypt[b]		Pakistan[c]		Pakistan[d]		India[e]		India[f]		Greece[g]		Tanzania[h]	
Vegetable	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd
Spinach	0.56	0.03	0.34	0.11	-	-	2.251	0.035	1.44	1.96	-	-	-	0.052	0.30-0.59	0.03-0.06
Lettuce	0.07	0.01	0.58	0.07	-	-	2.411	0.049	-	-	-	-	-	0.052	0.36-0.38	0.03-0.04
Tomatoes	-	-	0.26	0.01	1.56	0.33	-	-	-	-	3.5	-	-	0.018	-	-
Onion	-	-	0.14	0.02	0.06	0.07	-	-	-	-	-	-	-	0.032	-	-
Cauliflower	-	-	-	-	-	-	1.331	0.064	1.56	2.57	-	-	-	-	-	-
Lady's Finger	-	-	-	-	-	-	-	-	1.03	1.41	1.3	-	-	-	-	-

[a]Onianwa *et al.* (2001), [b]Radwan and Salama (2006), [c]Parveen *et al.* (2003), [d]Farooq *et al.* (2008), [e]Sharma *et al.* (2009), [f]Srinivas *et al.* (2009), [g]Karavoltsos *et al.* (2002) and [h]Bahemuka and Mubofu (1999)

Arora *et al.* (2008) carried out a study to assess levels of different heavy metals like iron, manganese, copper and zinc, in vegetables irrigated with water from different sources. The results indicated a substantial build-up of heavy metals in vegetables irrigated with wastewater. The range of various metals in wastewater-irrigated plants was 116-378, 12-69, 5.2-16.8 and 22-46 mg kg^{-1} for iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn), respectively. The highest mean levels of Fe and Mn were detected in mint and spinach whereas the levels of Cu and Zn were highest in carrot. The present study highlights that both adults and children consuming vegetables grown in wastewater-irrigated soils ingest significant amount of these metals. However, the values of these metals were below the recommended maximum tolerable levels proposed by the FAO and WHO (1999).It was summarized in 53rd Meeting, Rome, June 1-10, 1999. However, the regular monitoring of levels of these metals from effluents and sewage, in vegetables and in other food materials is essential to prevent excessive build-up of these metals in the food chain. Waste water contains substantial amount of toxic heavy metals which creates problems (Chen *et al*., 2005; Singh *et al*., 2004). Excessive accumulation of heavy metals in agricultural soils through waste water irrigation may not only result in soil contamination but also effect food quality and safety (Muchuweti *et al*., 2006).

Singh *et al.* (2010) in their study for risk assessment of heavy metal toxicity found that waste water irrigation led to the accumulation of heavy metals in soil and consequently into the vegetables. Heavy metal concentrations varied among the test vegetables which reflect the difference in their uptake capabilities and their further translocation to edible portion of the plants. Consequently, concentrations of Cd, Pb and Ni have crossed the safe limits for human consumption in all the vegetables. Percent contribution of fruit vegetables to daily human intake for Cu, Ni, Pb and Cr was higher than that of leafy vegetables. Target hazard quotient of heavy metals also suggests that the test vegetables had potential for human health risk due to consumption of plants grown in the area having long term use of treated and untreated waste water for irrigation. Consumption of these vegetables with elevated levels of heavy metals may lead to the high level of body accumulation leading to related health disorders.

Current technologies used to decrease dietary toxicity of heavy metals: Some micro-organism-based remediation techniques, such as bioremediation, show potential for their ability to degrade and detoxify certain contaminants. Although these biological systems are less amenable to environmental extremes than other traditional methods, they have the perceived advantage of being more cost-effective.

Bioremediation can be defined as any process that uses micro-organism, fungi, green plants or their enzymes to return the natural environment altered by contaminants to its original condition. Bioremediation technologies can be generally classified as *in situ* or *ex situ*. *In situ* bioremediation involves treating the contaminated material at the site while *ex situ* involves the removal of the contaminated material to be treated elsewhere. Some examples of bioremediation technologies are bioventing, landfarming, bioreactor, composting, bioaugmentation, rhizofiltration and biostimulation. Not all contaminants, however, are easily treated by bioremediation using microorganisms. For example, heavy metals such as cadmium and lead are not readily absorbed or captured by organisms. The assimilation of metals such as mercury into the food chain may worsen matters. Phytoremediation is useful in these circumstances because natural plants or transgenic plants are able to bioaccumulate these toxins in their above-ground parts which are then harvested for removal (Meagher, 2000).

Phytoremediation refers to the natural ability of certain plants called hyper accumulators to bioaccumulate, degrade or render harmless contaminants in soils, water or air. Phytoremediation is considered a clean, cost-effective and non-environmentally disruptive technology, to remove heavy metals from polluted lands. Green plants were proposed for *in situ* soil phytoremediation which has become an attractive topic of research and development. However, one major disadvantage of phytoremediation is that it requires a long-term commitment as the process is dependent on plant growth, tolerance to toxicity and bioaccumulation capacity (Table 3).

Table 3: Phytoremediation with suitable examples of pollutants with their potential plants

Process	Function	Heavy metal	Medium	Plants	References
Phytoextraction	Remove metals pollutants that accumulate in plants. Remove organics from soil by concentrating them in plant parts	Cd, Pb, Zn, As,	Soil and Groundwater	*Viola baoshanensis*, *Sedum alfredii*, *Rumex crispus*, Helianthus annus, Alfalfa, poplar, Juniper, fescue, Indian mustard, Cabbage	Macek *et al.* (2000) Zhuang *et al.* (2007)
Rhizofiltration	Roots absorb and	Zn, Pb, Cd, As	Groundwater	*Brassica juncea*, *Helianthus annus* (Sunflowers)	Dushenkov *et al.* (1995) Verma *et al.* (2006)
Phytostabilization (Immobilization)	Use of plants to reduce the bioavailability of pollutants in the environment	Cu, Cd, Cr, Ni, Pb, Zn	Soil	*Anthyllis vulneraria*, *Festuca arvernensis*, *Koeleria vallesiana* *Armeria arenaria*, *Lupinus albus* Hybrid poplar, Grasses	Vazquez *et al.* (2006)

Sarma (2011) reviews the recent advances of phytoremediation technology using hyperaccumulator plants addressing both potential and limitations, physiological and molecular aspects and provides a broad overview of most important genes which have been correlated to metals hyper accumulation and tolerance, evidence of the effect of heavy metal on biomass productions, plant biochemical, antioxidant defense system and discusses the prospects of transgenic plants in phytoremediation of heavy metals.

Arsenic using the Sun flower (H*elianthus annuus*), or the Chinese Brake fern (*Pteris vittata*), a hyper accumulator. Chinese Brake fern stores arsenicin its leaves. Cadmium using Willow (S*alix viminalis*). In the year of 1999, one research experiment performed by Greger and Landberg, 1999 suggested Willow (*Salix viminlais*) has a significant potential as a phytoextractor of Cadmium (Cd), Zinc (Zn) and Copper (Cu). As willow has some specific characteristics like high transport capacity of heavy metals from root to shoot, huge amount of biomass production, can use also for production of bio energy in the biomass energy power plant. Cadmiumandzinc, using Alpine pennycress (*Thalaspi caeyulescens*), a hyper-accumulator of these metals at levels that would betoxicto many plants. On the other hand, the presence of copper seems to impair its growth. Lead, using Indian Mustard (*Brassica juncea*), Ragweed (*Ambrosia artemisiifolia*), Hemp Dogbane (*Apocynum cannabium*), or Poplar trees which sequester lead in its biomass.

The response of plants to high concentrations of metals varies across a broad spectrum from toxic reaction to tolerance; some plants are obligate metallophytes with a physiological requirement for elevated metal contents in soils (Nedelkoska and Doran, 2000). Of those plant species that actively accumulate metals i.e., hyper accumulators store metals in their tissues at concentrations far exceeding those in the environment. Heavy metal contents in hyper accumulators are at least 100 times those found in nonhyperaccumulator plants grown in soil under the same conditions (Brooks, 1998). The number of confirmed hyper accumulating species is expanding rapidly and includes about 300 plants that hyper accumulate nickel, 26 cobalt, 24 copper, 16 zinc and 11 manganese. Hyper accumulators of selenium, thallium, cadmium, lead and uranium have also been reported (Brooks, 1998).

The removal of different kinds of heavy metals including Cu, Zn, Ni and Cr by free and immobilized microalgae has been well demonstrated by Han *et al*. (2006). An adsorption-desorption cycle was developed for repeated uses of the algal beads (micro-algal beads) for the removal and recovery of heavy metals. Workers reported that alginate immobilized *C. vulgaris* beads effectively removed Cu (more than 95% removal) from industrial wastewater, the adsorbed Cu was completely eluted with 0.1 M HCl and the binding sites of algal beads were released for further treatment.

Phytovolatilization involves the use of plants to take up contaminants from the soil, transforming them into volatile forms and transpiring them into the atmosphere (USEPA, 2000). It is defined as the use of plants, both terrestrial and aquatic, to absorb, concentrate and precipitate contaminants from polluted aqueous sources in their roots. Rhizofiltration can be used for Pb, Cd, Cu, Ni, Zn and Cr which are primarily retained within the roots (USEPA, 2000). Sunflower, Indian mustard, tobacco, rye, spinach and corn have been studied for their ability to remove lead from water, with sunflower having the greatest ability. Indian mustard has a bioaccumulation coefficient of 563 for lead and has also proven to be effective in removing a wide concentration range of lead (4-500 mg L^{-1}) (Raskin and Ensley, 2000; USEPA, 2000). The advantages associated with rhizofiltration are the ability to use both terrestrial and aquatic plants for either *in situ* or *ex situ* applications. Another advantage is that contaminants do not have to be translocated to the shoots.

Thus, species other than hyper accumulators may be used. Terrestrial plants are preferred because they have a fibrous and much longer root system, increasing the amount of root area (Raskin and Ensley, 2000).

CONCLUSIONS AND PERSPECTIVES

After reviewing the above mentioned studies it may be concluded that monitoring and assessment of heavy metal concentrations in different vegetables from the market as well as production sites require more extensive studies for assessing the risk of health hazards to the human beings. Limited published data are available on heavy metal concentrations in the vegetables from the market sites in India. Comparison of heavy metal contamination due to atmospheric deposition at production and market sites is, however, not available in the literature till date (Sharma *et al.*, 2009).

The contamination of heavy metals to the environment, i.e., soil, water, plant and air is of great concern due to its potential impact on human and animal health. Cheaper and effective technologies are needed to protect the precious natural resources and biological lives. Substantial efforts have been made in identifying plant species and their mechanisms of uptake and hyper accumulation of heavy metals in the last decade.

However, much study is needed in this respect such as metal uptake studies at cellular level including efflux and influx of different metal ions by different cell organelles and membranes. Rhizosphere studies under the control and field conditions are also needed to examine the antagonistic and synergistic effects of different metal ions in soil solution and the polluted waters. In depth soil microbial studies are required to identify the micro-organisms highly associated with metal solubility or precipitations. Most of the heavy metals discussed have toxic potential but the detrimental impact become apparent only after decades of exposure. It is therefore, suggested that regular monitoring of heavy metals in plant tissues is essential in order to prevent excessive buildup of these metals in the human food chain.

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