



## Characterization of Heavy Metals in Vegetables Using Inductive Coupled Plasma Analyzer (ICPA)

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**ABSTRACT:** The heavy metals or trace elements play an important role in the metabolic pathways during the growth and development of plants, when available in required concentration. The heavy metal concentration of Cadmium (Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb) and Zinc (Zn) was analyzed using Inductive Coupled Plasma Analyzer (ICPA) (Perkin-Elmer ICP Optima 3300 RL, USA) in 21 vegetables collected from Vegetable Market of Anand town, Gujarat. The vegetables are Lady's Finger (*Abelmoschus esculentus*), Onion (*Allium sepa*), Cauliflower (*Brassica oleracea var. botrytis*), Beat (*Brassica oleracea*), Chilli (*Capsicum annum*), Tindora (*Coccinia indica*), Pattarveli (*Colocasia sp.*), Coriander (*Coriandrum sativum*), Cucumber (*Cucumis sativus*), Turmeric (*Curcuma longa*), Vetches/Gavar (*Cyamopsis soraloides*), Bean Pods (*Dolichos lablab*), Carrot (*Ductus carotus*), Ginger (*Gingiber officinalis*), Sweet Potato (*Ipomoea batatas*), Bottle Gourd (*Lagernaria vulgaris*), Tomato (*Lycopersicum esculentum*), Bitter Gourd (*Momordica charantia*), Drumstick (*Moringa oleifera*), Brinjal (*Solanum melongena*) and Parwar (*Trichosanthes dioicea*). The high concentration of Cd was found in Onion, Coriander and Cauliflower, while Co and Cu content was recorded high in Cauliflower and Bottle Gourd. On the other hand, high content of Fe was observed in Cauliflower and Cucumber. Vetches and Lady's Finger had shown high concentration of Ni. Cauliflower and Onion showed high amount of Pb. On the other hand, Cucumber and Cauliflower registered maximum content of Zn. The heavy metal concentration in vegetables was within the prescribed safety limits except Fe owing to iron-rich soil of the area. The distribution and characterization of heavy metals in vegetables was studied in detail and discussed in this paper. @JASEM

There are 35 metals that concerned us because of occupational or residential exposure; 23 of these are the heavy elements or "heavy metals". Distribution of heavy metals in plant body depends upon availability and concentration of heavy metals as well as particular plant species and its population (Punz and Seighardt 1973).

Many researchers have shown that some common vegetables are capable of accumulating high levels of metals from the soil (Garcia et al. 1981, Khan and Frankland 1983, Xiong 1998, Cobb et al. 2000). Certain species of *Brassica* (Cabbage) are hyperaccumulators of heavy metals into the edible tissues of plant (Xiong 1998). Many people could be at risk of adverse health effects from consuming common market vegetables cultivated in contaminated soil. Often the condition of the soil is unknown or undocumented; therefore, exposure to toxic levels can occur. Xu and Thornton (1985) suggested that there are health risks from consuming vegetables with elevated heavy metal concentrations. The populations most affected by heavy metal toxicity are pregnant women or very young children (Boon and Soltanpour 1992). Neurological disorders, CNS destruction, and cancers of various body organs are some of the reported effects of heavy metal

poisoning (ATSDR 1994a,b, ATSDR 1999a, ATSDR 1999b, ATSDR 2000). Low birth weight and severe mental retardation of newborn children have been reported in some cases where the pregnant mother ingested toxic amounts of a heavy metal through direct or indirect consumption of vegetables (Mahaffey et al. 1981).

Studies on Cd, Cu and Ni levels in vegetables from industrial and residential areas of Lagos City, Nigeria was carried out by Yusuf et al. (2002) which revealed that the levels of Cd, Cu and Ni in different edible vegetables along with its soils on which they were grown were higher in industrial areas than those of the residential areas due to pollution. Trace element and heavy metal concentrations in fruits and vegetables of the Gediz River region was intensively studied by Delibacak et al. (2002). Also edible portions of five varieties of green vegetables, viz. Amaranth, Chinese Cabbage, Cowpea leaves, Leafy Cabbage and Pumpkin leaves collected from several areas in Dar Es Salaam, Africa, were analyzed for Pb, Cd, Cr, Zn, Ni and Cu. There was a direct positive correlation between Zn and Pb levels in soils with the levels in vegetables. The relation was absent for other heavy metals (Othman et al. 2002).

In India, similar kind of study was undertaken by Somasundaram et al. (2003) on heavy metal content of plant samples of sewage-irrigated area of Coimbatore district. Leafy vegetables were found with very high levels of heavy metal contamination including Cd, Zn, Cu, Mn and Pb. A similar research was carried out in Delhi and its surrounding regions on 'Vegetables eating up vegetarians' found the presence of deadly heavy metals in vegetable samples collected from across the capital (The Hindu 2003).

Rana and Nirmal Kumar (1988) and Nirmal Kumar et al. (1989) have investigated elemental composition of certain aquatic plants by Energy Dispersive X-Ray Analysis (EDAX). Heavy metals like Al, Si, Mn, Fe were found accumulated in *Vallisneria spiralis*, *Hydrilla verticillata* and *Azolla pinnata*. Nirmal Kumar and Rita N. Kumar (1997) also carried out elemental composition of certain economic important plants by EDAX. Some studies on distribution and characterization of heavy metals in vegetable plants and its parts collected from organic farms and village agriculture fields around Anand province, Gujarat, was also carried out by Nirmal Kumar et al. (2004). The present investigation aims to study the distribution and characterization of heavy metals in common vegetables sold in vegetable market of Anand town, Milk City of Asia, Gujarat.

## MATERIALS AND METHODS

In the present study, 21 fresh vegetables sold in vegetable market of Anand town, Gujarat were collected and brought to the laboratory. The common vegetables available in market are Bean Pods, Beet, Bitter Gourd, Bottle Gourd, Brinjal, Carrot, Cauliflower, Coriander, Cucumber, Drumstick, Gavar, Tindora, Ginger, Chilli, Lady's Finger, Onion, Parwar, Pattarveli, Sweet Potato, Tomato and Turmeric. The edible parts of these vegetables like roots, stems, leaves, flowers and fruits were collected.

The samples were brought to the laboratory and washed under tap-water gently. The moisture and water droplets were removed with the help of blotting papers. 0.5 gm dry powder was weighed by electric monopan balance (Dhona 200D) and digested with Sulphuric acid (H<sub>2</sub>SO<sub>4</sub>), Nitric acid (HNO<sub>3</sub>) and Hydrogen Peroxide (H<sub>2</sub>O<sub>2</sub>) (2:6:6) as prescribed by Saison et al. (2004). The samples were analyzed in Inductive Coupled Plasma Analyzer (ICPA) (Perkin-Elmer ICP Optima 3300 RI, USA) at Sophisticated Instrumentation Center for Applied Research and Testing (SICART), Vallabh Vidyanagar, Gujarat. The concentration of heavy metals such as Cadmium

(Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb) and Zinc (Zn) were analyzed. The reading of each sample is calculated by taking the average readings of duplicate sets. All values are mentioned in mg/gr dry weight.

## RESULTS

Table 1 shows the concentration spectra of various heavy metals such as Cadmium (Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb) and Zinc (Zn) in different vegetables. In the present investigation, the value of Cadmium (Cd) ranges from 0.002 to 0.029 mg/gr in various vegetables. The maximum concentration (0.029 mg/gr) of Cd was recorded in reduced stem of Onion, while minimum concentration (0.002 mg/gr) was registered in fruits of Gavar. Acute doses (10-30 mg/kg/day) of Cadmium can cause severe gastrointestinal irritation, vomiting, diarrhea, and excessive salivation, and doses of 25 mg of Cd/kg body weight can cause death. Low-level chronic exposure to Cd can cause adverse health effects including gastrointestinal, hematological, musculoskeletal, renal, neurological, and reproductive effects. The main target organ for Cd following chronic oral exposure is the kidney (ATSDR 1999a). Intake of Cd can double if one smokes cigarettes because each cigarette contains about 2 mg Cd.

The Cobalt (Co) content varies from 0.002 to 0.319 mg/gr. The lowest concentration 0.002 mg/gr of Co was observed in fruits of Turmeric. On the other hand, Cauliflower showed highest concentration of Co (0.319 mg/gr). Deficiency of Co in diet results into pernicious anemia, severe fatigue, shortness of breath and hypothyroidism, while overdose may lead to angina, asthma, cardiomyopathy, polycythemia and dermatitis. The safety limit for human consumption of Co is 0.05 to 1 mg/day in humans (ATSDR 1994a). Thus the recorded range of Cobalt concentration in vegetables falls within the safety limit during present investigation.

The acceptable limit for human consumption of Copper (Cu) is 10 ppm (Nair et al. 1997). When Cu exceeds its safe level concentration, it causes hypertension, sporadic fever, uremias, coma etc. Present investigation reveals that Cu varies from 0.123 to 2.308 mg/gr, which falls below the safe limits for human health and hygiene. The highest concentration of Cu was found in Cauliflower (2.308 mg/gr), while lowest concentration 0.123 mg/gr was recorded in fruits of Parwar. As it falls within safety limits (10 ppm), the vegetables, which contain Cu, can be used for an edible purpose without any risk.

Table 1: shows concentration of heavy metals of selected vegetables collected from Anand Vegetable Market (mg/gr dry weight)

Sr. No.	Botanical Name	Common Name	Plant Part	Heavy metals						
				Cd	Co	Cu	Fe	Ni	Pb	Zn
1	<i>Abelmoschus esculentus</i>	Lady's Finger	Fruit	0.005	0.009	0.165	13.661	3.034	0.066	3.283
2	<i>Alium sepa</i>	Onion	Stem	0.029	0.016	0.832	39.980	0.742	0.280	4.265
			Leaf	0.008	0.009	0.781	14.972	1.365	0.236	3.637
			Bulb	0.009	0.003	0.365	11.598	2.031	0.143	4.613
3	<i>Brassica oleracea</i>	Beet	Root	0.005	0.020	0.323	18.744	0.501	0.149	3.321
4	<i>Brassica oleracea</i> var. <i>botrytis</i>	Cauliflower	Flower	0.018	0.319	2.308	131.225	0.944	0.256	8.992
5	<i>Capsicum annum</i>	Chilli	Fruit	0.007	0.011	0.838	9.537	2.032	0.073	2.773
6	<i>Coccinia indica</i>	Tindora	Fruit	0.009	0.007	0.533	8.548	2.569	0.131	3.680
7	<i>Colocasia sp.</i>	Pattarveli	Root	0.009	0.059	0.288	15.368	1.446	0.160	2.458
8	<i>Coriandrum sativum</i>	Coriander	Root	0.008	0.018	0.768	16.972	0.417	0.137	2.541
			Stem	0.018	0.041	1.156	19.061	0.474	0.152	3.927
9	<i>Cucumis sativus</i>	Cucumber	Fruit	0.010	0.030	0.592	24.130	2.151	0.122	12.676
10	<i>Curcuma longa</i>	Turmeric	Stem	0.007	0.002	0.208	10.445	0.442	0.094	2.373
11	<i>Cyamopsis soralioides</i>	Gavar (Vetches)	Fruit	0.002	0.005	0.240	6.337	4.493	0.103	3.707
12	<i>Dolichos lablab</i>	Bean Pods	Fruit	0.007	0.011	0.838	9.537	2.032	0.073	2.773
13	<i>Ductus carrotus</i>	Carrot	Root	0.006	0.011	0.573	13.043	0.345	0.078	2.155
14	<i>Gingiber officinalis</i>	Ginger	Stem	0.006	0.015	0.502	14.524	0.392	0.019	3.574
15	<i>Ipomoea batatas</i>	Sweet Potato	Root	0.006	0.026	0.601	6.559	0.344	0.034	1.655
16	<i>Lagernaria vulgaris</i>	Bottle Gourd	Fruit	0.016	0.065	0.971	13.421	0.906	0.170	3.125
17	<i>Lycopersicum esculentum</i>	Tomato	Fruit	0.012	0.018	0.560	11.564	1.259	0.059	3.278
18	<i>Momordica charantia</i>	Bitter Gourd	Fruit	0.008	0.005	0.270	11.327	0.221	0.136	2.740
19	<i>Moringa oleifera</i>	Drumstick	Fruit	0.011	0.003	0.567	7.422	1.643	0.111	3.305
20	<i>Solanum melongena</i>	Brinjal	Fruit	0.008	0.008	0.728	9.541	2.222	0.111	3.065
21	<i>Trichosanthes dioicea</i>	Parwar	Fruit	0.005	0.009	0.123	6.923	0.125	0.083	3.535

Iron is an essential element in production of Red Blood Cells (RBCs). The concentration of Iron (Fe) content was highest in Cauliflower (131.225 mg/gr), while it was found lowest (6.337 mg/gr) in fruits of Gavar. The Fe content ranges from 6.337 to 131.225 mg/gr. Low intake of Fe may cause anemia, tiredness and pallid physique, while high intake may results into hepatic megalay, cardiac infraction and nephric malfunction. The acceptable limit for human consumption of Iron is 8 to 11 mg/day for infants as well as adults (ATSDR 1994b). During present investigation, the value of Fe was found much higher, which is significant due to iron-rich soil of the area.

Nickel is found in soybeans, lentils, nuts, grains and vegetables. Fruits of Gavar showed high content of Nickel (4.493 mg/gr), while fruits of Parwar contain low value of Ni (0.125 mg/gr). The presence of Ni ranges from 0.125 to 4.493 mg/gr in various vegetables.

Deficiency of Nickel have been linked with hyperglycemia, depression, sinus congestion, fatigue,

reproductive failures and growth problems in humans, while excess intake leads to hypoglycemia, asthma, nausea, headache, and epidemiological symptoms like cancer of nasal cavity and lungs. The prescribed safety limit of Nickel is 3 to 7 mg/day in humans (ATSDR 1999a). Thus it falls within the safety limit in vegetables and can be consumed without any risk.

During the present study, Lead (Pb) content varies from 0.019 to 0.280 mg/gr, which falls within safety limit (1.5 ppm) for human consumption (Nair et al. 1997). Pb content was found high in Cauliflower (0.256 mg/gr), while stem of Ginger showed low concentration of Pb (0.019 mg/gr). Todd (1996) emphasized that most of the accumulated Lead is sequestered in the bones and teeth. This causes brittle bones and weakness in the wrists and fingers. Lead that is stored in bones can reenter the blood stream during periods of increased bone mineral recycling (i.e., pregnancy, lactation, menopause, advancing age, etc.). Mobilized lead can be redeposited in the soft tissues of the body and can cause

musculoskeletal, renal, ocular, immunological, neurological, reproductive, and developmental effects (ATSDR 1999b).

Among all metals, Zinc (Zn) is the least toxic and an essential element in the human diet as it is required to maintain the proper functions of the immune system. It is also important for normal brain activity and is fundamental in the growth and development of the foetus. Zinc deficiency in the diet may be more detrimental to human health than too much Zinc in the diet. Although the average daily intake of Zinc is 7-16.3 mg Zn/day, the recommended dietary allowance for it is 15 mg Zn/day for men and 12 mg Zn/day for women (ATSDR 1994a). On the contrary, the high concentration of Zinc in vegetables may cause vomiting, renal damage, cramps etc.

The acceptable limit for human consumption of Zn is 150 ppm (Nair et al. 1997). During present study, the concentration of Zn was found high in fruits of Cucumber (12.686 mg/gr), while low concentration of Zn was observed in fruits of Sweet Potato (1.655 mg/gr). The content of Zn ranges from 1.655 to 12.676 mg/gr, which falls within the safe limit. Thus the trend of concentration of various heavy metals in studied vegetables is as follows: Fe > Zn > Ni > Cu > Pb > Co > Cd

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