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TRACE METAL ACCUMULATION IN VEGETABLES GROWN IN INDUSTRIAL AND SEMI-URBAN AREAS OF SINGRAULI DISTRICT OF MADHYA PRADESH INDIA

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ABSTRACT: The study undertaken for trace metal accumulation by fly ash, coal and mines waste in Singrauli industrialized district of Madhya Pradesh, India, using atomic absorption spectrometry. Present studies were focused into three Industrial, semi-urban and rural areas. Mostly sources of trace metals to plants are the air or soil from which these elements are taken up by foliage or root. Soil grown vegetable samples were collected from these distinct areas and were analyzed for Pb, Ni, Co, Cu, Zn and Cd concentration and their accumulation pattern. Only rural area is free from most of the contaminant and treated as control intended for these trace metals. From each studies area composite samples of common growing and consuming vegetables samples were analyzed quantitatively. In this investigation six commonly consumable vegetables Potato *(Solanum Tuberosam*), Tomato (*Lycopersicon esculentum Mill*), Karela *(Momordica charantia)* Lady's finger (*Abelmoschus esculentus Linn.*), Brinjal (Solanum Melongena) Cabbage (Brassica oleracea) were studies for monitoring or observation of current status of following trace metals. Results indicated that an alarming situation in both studied areas was found. The remarkable differences were observed between the ranges of these elements in vegetables crops of rural with semi-urban areas and industrially growing areas. In industrial area Ni, Pb, Cu were reported in higher concentrations in *Lycopersicon esculentum, Momordica charantia*, *Solanum Melongena and Brassica oleracea* whereas in semi urban area the range of Cu higher in *Lycopersicon esculentum* and *Abelmoschus esculentus* on comparison with the rural areas. Based on air accumulation and concentration factor calculations, 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 vegetables. The air environments in industrial and semi-Urban areas were enriched with trace metals, but their concentrations were within the permissible levels. Accessibility of trace metals pretentious to environment and it has turn into a major threat to plant and common growing vegetables due to their bioaccumulation potential tendencies along with variable toxicity level.

INTRODUCTION: Vegetables are an important part of the human diet and essential source of our nutrition's for better health [1]. Rapid industrialization and urbanization increases the trace metal contamination in soils. The main sources of trace metals to plants are the air or soil from which metals are taken up by the root or foliage.

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Some trace metals are very essential as plant nutrition or promoter, they promoted the metabolism and growth of the plants, but plants growing in a polluted environment can accumulate trace elements at high concentrations, causing a risk to plant as well as human health [2-7].

Modern living style, civilization and prolonged discharge of industrial effluents and solid waste dump cause the air and ground water toxicity with undesired pollution to created health troubles [8] However, vegetables absorb these metals that area major concern to public health. Accumulation of contaminated elements in vegetables could pretense a direct threat to human health [7]. India is a developing country, rapid and unorganized urban and industrial developments have caused elevated ranges of metals in the urban environments [8].

Metals are non-biodegradable and persistent environmental contaminants, which may be deposited on the surfaces and then absorbed into the tissues of vegetables. The uptake of these metals and their concentration via plant roots depends on speciation of metal, soil features and type of plant species etc further metals gets solubilize and become available for plants and vegetables to created health risk or toxicity (Neurotoxicity, hepatotoxicity, nephrototoxicity) produced via absorption and accumulation of toxicants [9].

Atmospheric metals are also deposited on plant surfaces by rain, due, dust, irrigation. Trace metals are taken up via roots of plants and vegetables passes to edible leaves, fruits and seeds. It will also accumulate in animal milk and fatty tissues etc. The mobility and transpotation of metal and its availability on plant are important when evaluating the impact of soil contamination on plant metal uptake, as well as translocation and toxicity or ultra structural alterations [10]. A relationship exit between elemental deposition and elevated element concentrations in plants, especially in cities and in the vicinity of emitting factories [11-13]. Indirect impacts of pollutants via the soil are also great interference, because of large-scale sustained exposure of soil to both wet and dry depositions of trace elements.

However in India, there is limited published data available on trace metal concentrations in the vegetables. The investigation focused on the study area of Singrauli district which is the one of the most industrially developing zone of Madhya Pradesh. It is industrialized, spread over the States Uttar Pradesh also along with Madhya Pradesh.

Populations exit around 185,580 were calculated as per the census 2011 with 85/km^2 (220/sqm) covered density. Various energy generating industries like Singrauli Super Power Plant (SSPP), Vindhyanchal Super Thermal Power Plant (VSTPP), Northen Coal Limited (NCL), Kanoria Chemicals are regularly increases the quantity and types of pollutions via disposing of organic, inorganic, degradative and non-degradative waste materials in terms of trace metals in local environment which directly and indirectly affect the natural resources, soil growing crops, vegetables, fruits along with human health. Trace metal accumulation in plant systems has emerged only over the last three decades, and several research articles reported concentrations of a number of trace elements in the local crops and other plants [13-15].

The present study was aimed to find out the trace metal concentration in six common consumable and economically viable green and leafy vegetables species which were separately grown in industrial, semi-urban and rural areas of rapidly developing Singrauli district in relation with trace element.

MATERIALS AND METHODS:

Study Area:

The study area Singrauli district is developing industrialized region, often called a city of power, and has been selected for the case study since numerous sources emit trace metals including majority of major and minor industries such as coal mine, electricity generation power plants, Energy generating industries like Singrauli Super Power Plant (SSPP), Vindhyanchal Super Thermal Power Plant (VSTPP), Northen Coal Limited (NCL), Kanoria Chemicals and dense forests, located within the city.

In both the areas, industrial and semi-urban the vegetables and fruits are frequently cultivated by local farmers. The investigation was based on three different areas of singrauli district selected representing different environmental backdrops. The selected sites were industrial, Semi-Urban and Rural area. Samples were collected for a period of two years from 2011-2013. Side by side both Air and Soil samples were collected bimonthly and vegetable samples were collected seasonally and analyzed for trace metals ranges.

The collected air particulate matter treated with concentrated Nitric acid for elemental analysis [16]. From each representative area samples of vegetables were collected from different sampling sites. For trace metal analysis from each harvest a total of 20 plants were taken at random for analysis. The dried plant samples were digested with $HClO_4$

and Conc. HNO_3 for trace metal analysis by using Atomic Absorption photometer.

Collection of samples and Soil pH determination:

The studies were conducted on six commonly consumable vegetable species i. e. *Solanum tuberosam, Lycopersicon esculentum, Momordica charantia*, *Solanum Melongena*, *Abelmoschus esculentus* and *Brassica oleracea*. Vegetables were frequently and widely cultivated in open farms around established different industries, semi-urban and rural areas of Singrauli district, random sampling criteria were performed from 200 points all over the study areas. The samples were carefully collected, marked and stored accordingly. The pH of the bulked soil near the collected plant and vegetables sampling areas was determined using the electronic method [10].

The health of plants and vegetables with other essential history were recorded. Both Air Accumulation Factor (AAF) and Concentration factor (CF) were accounted which represent the origin toxicants in form of the trace metals in experimental samples of vegetables [17]. The water samples used in irrigation of vegetables according to different areas were also collected and evaluated for physico-chemical parameters status**.**

Washing and Grinding of samples:

After collection, the samples were brought to the laboratory and processed for further analysis. Samples of vegetable were properly separated and washed with doubled distilled water to remove the dust particles. Sampled were then equally chopped into small pieces using a sterilized knife. The vegetables samples were air dried and then dried in an oven at 35°C. Dried samples were grinded into a fine powder (80 mesh) using a mechanical electrical blender and stored in sterilized poly bags, until used for acid digestion with labeling. The washed water was also examined for the presence of trace metals.

Acid digestion and analysis of trace metals:

Trace metals in vegetable samples were extracted following acid digestion procedure in which 1g of the dry weight of each sample were taken in acid digestion and 10ml of 98% nitric acid was added in test tube. Further it was placed in water bath and allowed to boil for about 72h. Digestion was completed, with the results of pale yellow colour. A solution was makeup to 25ml with de-ionized water and stored in cool safe place. All prepared samples solution were analyzed for Cd using atomic absorption spectrophotometer (AAS, Perkin Elmer model 1100 B). A certified standard reference material was referred to ensure the accuracy along with analytical values were within the range of certified value. Blank and standards were run after five determinations to calibrate the instrument.

Statistical Analysis:

Statistical significance observed differences between samples was determined by Student's *t*-test and ANOVA test. Differences were considered to be significant at $p < 0.05$ and highly significant at $p < 0.001$, level of significance.

RESULTS AND DISCUSSION:

Trace metals ranges in soils and air:

The ranges with different concentrations of metals in soil are non significant mediators of toxicity but the availability of documentation and considerable effort has been made to demonstrate how metal toxicity is affected by the abiotic environment of the soil. Trace metal concentrations of Pb, Zn, Ni and Cu in industrial and semi-urban soils were statistically significant at 0.05 levels over rural area whereas the ranges were within the permissible limits for agricultural soils [18, 19] **Table-2.** The obtained results indicated that, in spite of the close proximity of cropping field to high exposing industrial sources, farming soil does not seem to have been notably contaminated by environmental deposition.

This may be outstanding to low deposition rate resulting from the dispersion of atmospheric pollutants and variations in physico-chemical characteristics of soil. Trace metals concentration were also accounted on the studies areas according to their accumulation pattern. It was noticed that all the air based contaminants and dusts particle indirectly entrapped via cultivated crops.

The leaves, stems, and shoot parts of the crops were easily observed the dusts and associated other contaminant which was further affect the metabolic process of plants. Metals degradation and assessment of health risks by the variable ranges of metals in ambient air along with dietary intake is a special interest today. Mostly air borne matter in industrial and semi-urban environments found to be highly enriched with trace metals. However, the concentration of the six metals in the air was found to be within the tolerance limits [20].

The Pb concentration in industrial area reported 1.46μg/m^3. Whereas the Zn, Ni and Cu concentrations were reported higher in semi-urban area compared with industrial area. The all six trace metals of industrial and semi-urban area have shown significant difference (>0.05) with rural area. It was may be due to the deposition of air pollutants at higher rates resulting from the dispersion of atmospheric pollutants which released from the industries as fly ash. In the same consequences the Cd, Co, Cu, Pb and Ni concentration were recorded 55, 58.9, 31.10, 47.8 and 29μg/m^3 in industrial studies area whereas the semi-urban areas on the reference of following trace metal were recorded 16.73, 20, 11.3, 15 and 16.8μg/m^3 respectively **Table 1**.

The both air and soil samples for the crops mostly shown as potential contributors of trace metals to the plants [21].

TABLE 1: TRACE METAL CONTENT IN SUSPENDED PARTICULATE MATTER IN AIR (μg/m3).

Study area ↓	Air					
Trace metals →	Pb	Cd	Zn	Ni	Co	Cu
Industrial	1.467* ± 0.41	1.431*± 0.23	2.453* ± 0.93	0.496** ± 0.15	0.243** ± 0.54	0.414** ± 0.99
Semi Urban	1.376* ± 0.52	1.541*± 0.16	4.985** ± 0.87	0.977** ± 0.34	0.632** ± 0.24	0.648** ± 0.14
Rural	0.689 ± 0.53	0.543 ± 0.13	1.691 ± 0.30	0.087 ± 0.01	0.244 ± 0.04	0.116 ± 0.02

* Significant at 0.05 level ** Significant at 0.001 level n = 12

TABLE 2: TRACE METAL CONTENT IN SUSPENDED PARTICULATE MATTER IN SOIL (mg/kg).

Study area ↓	Soil					
Trace metals →	Pb	Cd	Zn	Ni	Co	Cu
Industrial	47.8** ± 3.30	54.9** ± 2.34	49.7** ± 5.24	28.98** ± 2.50	58.87** ± 2.63	31.1** ± 3.28
Semi Urban	15.1** ± 2.4	16.73** ± 2.65	42.9** ± 6.3	16.8** ± 2.7	19.9** ± 3.7	11.3** ± 0.91
Rural	8.1 ± 0.82	8.3 ± 0.64	32.2 ± 1.75	8.7 ± 0.5	27. 3 ± 0.23	7.7 ± 0.45

* Significant at 0.05 level ** Significant at 0.001 level n = 12

Trace metals in vegetables:

The Pb, Cd, Zn, Ni, Co and Cu metal concentrations in commonly growing and consumable vegetables of *S. Tuberosam L. esculentum M. charantia A. esculentus S. melongena* and *B. oleracea* were examined during the present study (**Figure 1** and **Figure 2**).

Lead (Pb):

Many researchers have shown that some common vegetables are capable of accumulating high levels of metals from the soils [22, 23]. Pb concentration is variables in all the sampling stations. All the samples were found slightly variant from permitted level, so these samples concerned vegetable crops were not suitable for consumption. Pb 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 [24]. In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human [25]. The introduction of Pb into the food chain may affect human health and thus, studies concerning Pb accumulation in vegetables have increasing importance [24]. On the whole, all vegetables that were studied in this study were contaminated by Pb and they were toxic to consumer. Metals such as lead, mercury, cadmium and copper are cumulative poisons. These metals cause environmental hazards and are reported to be exceptionally toxic [26].

In general, Pb concentrations in vegetation have increased in recent decades owing to human activities. The Pb content of edible parts of vegetables growing in uncontaminated areas generally range from 0.05 to 3.0 μg/g dry weight. Present study for rural area reported Pb concentration in vegetables in range 0.76 to 1.45 μg/g in all investigated vegetable crops. Whereas in industrial and semi-urban areas the Pb concentration in vegetables in range of 1.76 to

4.26µg/g and 1.88 to 2.86 respectively **Table 3**. It is clearly shown that, the air or soil of urban environments was contributing the Pb by various sources which directly indirectly linked with urbanisation. The permissible limit of Pb in vegetables crops intended for human consumption i. e. 2.0-2.5 µg/g dry weight [27]. In this study the Pb concentration in vegetables cultivated in industrial and semi-urban areas reported above the permissible levels.

Hence, it is necessary to kept Pb levels as low as possible in the environments. Pb also occurs naturally in plants as a result of the processes of taking up the Pb normally from the soil. Pb forms and contents in vegetables vary greatly with the species and depend principally on the conditions of environmental, because contaminated soils can induce Pb accumulation by crops [28]. Pb accumulation by vegetable crops grown in soils with abnormally elevated levels of the metal poses a risk to human health.

Therefore, the capacity of these plants to accumulate Pb and its presence in edible parts should be evaluated. Increasing concern on the lack of suitable land for agriculture is prompting urban farmers to use contaminated land, such as waste disposal sites, to produce food crops. This situation is exacerbated by rapid population growth, urbanization and industrialization [29]. Thus, urban agriculture, practiced widely in developing countries, can be at great risk due to the proximity of these contaminant sources [30, 32].

Cadmium (Cd):

In this study rural area reported Cd concentration in vegetables in the range 0.36 to 1.56 µg/g in all crops whereas in industrial and semi-urban areas the Cd concentration in vegetables in range 1.67 to 3.69 µg/g thus the average concentration were 3.55 µg/g accounted **Figure 1**. It is clearly shown that air or soil of urban environments was contributing the Cd by various sources**.** Some other heavy metals such as copper (Cu), cadmium (Cd), zinc (Zn), manganese (Mn), cobolt (Co) act as micronutrients for the growth of animals and human beings when present in trace quantities, whereas others such as Cd, As, and Cr act as carcinogens.

Monitoring and assessment of these heavy metals concentrations in vegetables from the market sites have been carried out in some developed and developing countries [33. 34]. The amount of Cd accumulation in aerial parts of a plant is higher than in the parts below the ground (root). This finding is comparable with the findings of other earlier studies [35, 36]. They has been reported that Cd is a highly mobile metal, easily absorbed by the plants through root surface and moves to wood tissue and transfers to upper parts of plants. There is a direct relation between the levels of presence of Cd in the root zone end its absorption by plant [37, 38].

TABLE 3: CONCENTRATION OF TRACE METALS IN VEGETABLES.

Trace Metals ↓	Areas ↓	Vegetables					
		S. Tuberosam	***L. esculentum***	***M. charantia***	***A. esculentus***	***S. melongena***	***B. oleracea***
Pb	Industrial	1.76	4.24	1.34	4.26	3.42	2.86
	Semi-urban	1.88	2.86	1.89	1.96	1.90	1.88
	Rural	0.76	1.16	1.45	1.03	1.22	1.36
Ni	Industrial	1.26	1.49	3.64	2.24	2.84	2.79
	Semi-urban	1.14	1.26	2.63	2.10	1.63	1.88
	Rural	1.54	1.35	1.64	1.39	1.84	1.92
Co	Industrial	1.64	1.66	2.16	1.87	2.26	2.30
	Semi-urban	0.84	1.25	1.43	0.86	1.36	1.46
	Rural	0.26	0.46	0.39	0.40	0.53	0.67
Cu	Industrial	2.80	3.46	3.96	3.87	4.46	5.26
	Semi-urban	4.24	2.87	2.46	3.64	5.38	1.87
	Rural	2.60	2.74	2.25	2.51	2.15	2.65
Zn	Industrial	18.72	26.14	24.76	32.46	31.08	47.64
	Semi-urban	11.76	22.64	21.26	29.41	24.75	36.35
	Rural	16.92	11.76	9.23	21.13	27.64	21.44
Cd	Industrial	3.54	3.41	3.64	3.43	3.41	3.69
	Semi-urban	1.67	1.84	1.76	2.92	1.94	2.12
	Rural	0.36	0.92	0.39	0.87	0.64	1.54

* All the values of Zn concentration accounted in mg/gm.

Zinc (Zn):
The symptoms that an acute oral Zn dose may include: tachycardia, vascular shock, dyspeptic nausea, vomiting, diarrhea, pancreatic is and damage of hepatic parenchyma [39].

Vegetables that growing on heavy metal contaminated soils can accumulate high concentrations of Zn to cause serious health risk to consumers. Environmental pollution of Zn greatly influences the concentrations of this metal in plants. In ecosystems where Zn is an airborne pollutant, the tops of plants are likely to concentrate more Zn on the other hand; plants grown in Zn contaminated soils accumulated a great proportion of the metal in roots [40, 41].

Several investigations of water, soil and vegetables from urban areas have shown that these heavy metals are the main pollutants particularly of lands under irrigation with waste waters. In present study the Zn concentration were recorded in industrial and semi urban areas grown vegetables crops range from 11.76 to 47.64 µg/g whereas the concentration of Zn in rural areas grown vegetables were found in the range of 9.23 to 27.64 µg/g respectively **Figure 1**. The results indicated that all the studied six vegetable crops have similarity for the accumulation of Zn.

B. oleracea accumulated higher levels of Zn (47.64 µg/g) among six vegetables were within the permissible limits i.e. 10-50 µg/g for human consumption. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environments as well as from contaminated soils [42]. A number of studies have shown heavy metals as important contaminants of vegetables [43].

Heavy metal contamination of vegetables may also occur due to irrigation with contaminated water [44]. Emissions of heavy metals from the industries and vehicles may be deposited on the vegetable surfaces during their production, transport and marketing [44]. 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 [45, 46].

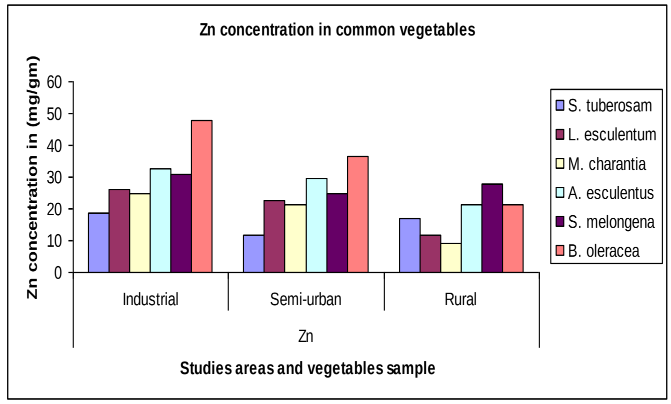

FIGURE 1: Zn CONCENTRATION IN VEGETABLES.

Nickel (Ni):
Vegetables have more nickel than animal products. The concentration of Ni in plants generally ranges from 1.35 to 3.64µg/g dry weight. Ni concentration in vegetables and fruits reported in the range 0.02 to 2.7µg/g [47]. The elevated concentrations of Ni in plant tissue reflect man made pollution.

The Ni content in vegetables from the industrial and semi-urban areas of studied district did not possess large variability between the study areas. In the present study the Ni concentration in industrial and semi-urban areas were reported in the range 1.26 to 3.64 µg/g and 1.14 to 2.63 µg/g respectively in all studied six crops, whereas in rural area it was reported in the range of 1.35 to 1.92 µg/g **Figure 2**. Concentrations of Ni in industrial and semi-urban areas were found at concentrations normally observed in vegetables grown in uncontaminated soils.

Cobalt and Copper:
The Co concentration in vegetables grown in industrial areas reported in the range of 1.64 to 2.30 µg/g in semi-urban areas the reported range 0.84-1.43 µg/g and in rural area the range of 0.26 to 0.67 µg/g **Figure 2**. The copper levels found in vegetables were within safe limits in all samples. The response of three vegetables to Cu toxicity were studies and found that Cu level was higher in both root and shoot, but root Cu concentration increased more sharply than shoot with increasing Cu levels in growth media [48, 51]. Accumulation of Cu recorded high range up to 30% in roots while a small fraction (10%) of absorbed Cu was

transported to shoot. During another important and same singrauli district focus study documented that the found heavy metals and their variables concentration in vegetables was significantly influenced by fly ash and other contaminants which is potential environmental hazard, discharge by industries and spread over the soil and air, uptake by the roots and via the adsorption phenomena of leaves of plants increased markedly [52-54].

Cu is essential trace element to plants and the amount of copper present in plants varies with the copper content of soil on which it is grown. The copper concentration in food stuffs reported in the range 1.75 to 9.26 µg/g.[55]. In present study the copper content in Semi-urban area reported in range 1.87 to 5.38 µg/g with an average 4.46 µg/g. whereas in the rural areas the range of Cu concentration reported as 2.60, 2.74, 2.25, 2.51, 2.15 and 2.65 µg/g on the analyzed plant sample respectively **Table 3**.

The concentration of copper in industrial zone growing plants samples shown range limit from 2.80 to 5.26 µg/g. The concentration of Cu in plants varied much with dependent nearby factors like proximity industries and use of fertilizers and Cu based fungicides. The maximum permissible limit for Cu in vegetables is 50 µg/g [27] and in the present study the concentration of Cu well within the limits in all the vegetables.

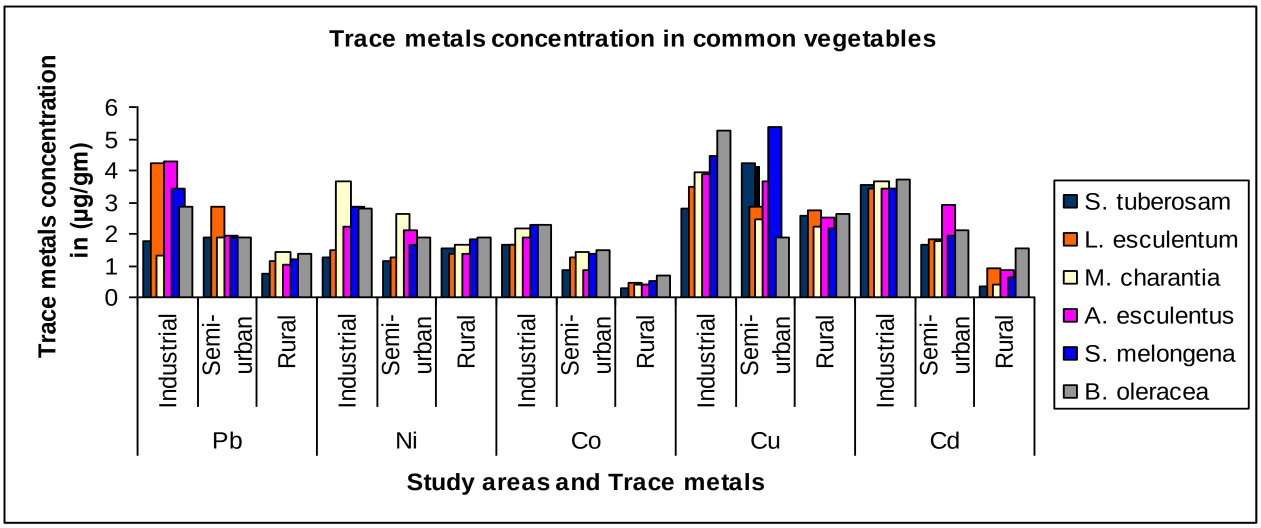

FIGURE 2: TRACE METALS CONCENTRATION IN VEGETABLES.

The trace metals Pb, Zn, Ni and Cu have shown variations in concentration among the vegetables and sampling sites. In the present study, the concentration of Zn, Ni and Cu trace elements in vegetables of Tomato, Lady's finger, Capsicum and Cabbage were high in industrially growing areas while remarkable differences were observed between the trace metal content of rural areas with semi-urban and industrial areas. In industrial area Ni, Zn was reported in higher concentrations in tomato and capsicum compared with control areas. In semi-urban area the concentration of Cu in tomato and lady's finger reported higher than the rural vegetables. It was known that the trace metal concentrations in harvested vegetables often show large variation from year to year and sampling sites to sites, even at the same location in the field. This is probably due to variable emission rates, atmospheric transport and deposition process, and plant uptake [6]. The increased value of trace metal was determined for Pb in vegetables grown in industrial areas. The four trace metals concentrations in industrial and semi-urban areas have shown a significant difference with rural area.

Air accumulation factor (AAF) and Concentration factors (CF):

The origin of trace metals in vegetables is accumulation due to atmospheric deposition or transfer from soil or both. The AAF and CF values were given in **Table 4** and **5**. In the case of Pb, Zn and Cd, both AAF and CF factors are high in all the six crops grown in industrial and semi-urban areas. The Ni and Cu have not shown any significant trend and the values are more or less similar in all the six crops. The Pb and Zn are contributing in considerable levels by both soil and air medium. However, the variation in AAF and CF values can be ascribed to a number of factors such as chemical speciation of trace metals, atmospheric and soil concentrations and variation in uptake etc. [27]

TABLE 4: AIR ACCUMULATION FACTOR WITH TRACE METALS IN VEGETABLES.

Vegetables		AAF					
Trace metals →	Pb	**Pb**	**Cd**	**Zn**	**Ni**	**Co**	**Cu**
Solanum Tuberosam	Ind.	1.795	0.186	0.524	0.287	0.253	0.196
	S.U.	0.921	0.141	0.452	0.175	0.123	1.087
Lycopersicon esculentum	Ind.	0.662	0.343	2.328	1.196	0.252	0.463
	S.U.	1.457	0.132	1.239	0.177	0.123	0.311
Momordica charantia	Ind.	1.747	0.253	1.290	0.342	0.251	0.298
	S.U.	1.711	0.129	1.181	0.193	0.163	0.121
Abelmoschus esculentus	Ind.	1.913	0.247	1.494	0.307	0.252	0.521
	S.U.	1.727	0.148	0.734	0.175	0.154	0.254
Solanum Melongena	Ind.	1.221	0.245	1.234	0.353	0.267	0.421
	S.U.	0.321	0.167	0.436	0.135	0.132	0.243
Brassica oleracea	Ind.	1.693	0.294	1.455	0.324	0.276	0.354
	S.U.	0.563	0.184	0.543	0.163	0.125	0.139

TABLE 5: CONCENTRATION FACTOR WITH TRACE METALS IN VEGETABLES.

Vegetables		CF					
Trace metals →		**Pb**	**Cd**	**Zn**	**Ni**	**Co**	**Cu**
Solanum Tuberosam	Ind.	0.513	0.456	0.540	0.477	0.253	0.168
	S.U.	1.030	1.120	0.836	0.889	0.162	4.117
Lycopersicon esculentum	Ind.	0.541	0.564	3.210	0.785	0.342	0.391
	S.U	1.423	1.323	3.101	1.415	0.134	1.215
Momordica charantia	Ind.	0.579	0.577	3.120	0.579	0.284	3.852
	S.U	1.512	1.453	3.707	0.510	0.173	0.470
Abelmoschus esculentus	Ind.	0.744	0.671	1.440	0.543	0.293	0.471
	S.U.	1.413	1.342	1.707	0.413	0.179	1.140
Solanum Melongena	Ind.	0.543	0.459	1.298	0.319	0.264	1.431
	S.U.	1.543	1.405	1.342	0.294	0.162	0.765
Brassica oleracea	Ind.	1.123	0.506	1.324	0.473	0.296	1.233
	S.U.	0.645	1.395	1.765	0.345	0.194	0.432

Correlation analysis:

Correlation analysis applied among sampling sites, vegetable plants and among trace elemental concentrations in vegetables. The data was presented **Table 6**. The physico-chemical parameters status of water samples used in irrigation of following vegetables crops according to different areas were shown variable data [55] **Table 7**.

TABLE6: CORRELATION ANALYSIS AMONG STUDY SITES, TRACE METALS AND VEGETABLES.

n = 10	Rural	Semi-urban	Industrial
Rural	1	0.821**	0.777*
Semi-urban		1	0.819**
Industrial			1

n = 10	Lead	Cadmiu	Zinc	Nickel	Cobalt	Copper
Lead	1					
Cadmium	0.203*	1				
Zinc	0.609*	0.073	1			
Nickel	0.038	0.065	0.121	1		
Cobalt	0.076	0.085	0.045	0.087	1	
Copper	0.176	0.043	0.235	0.419	0.421	1

n = 10	*S. Tuberosam*	*L. esculentum*	*M. charantia*	*A. esculentus*	*S. melongena.*	*B. oleracea*
	1					
S. Tuberosam	0.627*	1				
L. esculentum	0.726**	1				
M. charantia	0.724**	0.942**	1			
A. esculentus	0.816**	0.932**	0.926**	1		
S. melongena	0.826**	0.939**	0.954**	0.942**	1	
B. oleracea	0.845**	0.962**	0.969**	0.912**	0.923**	1

* Significant at 0.05 level, ** Significant at 0.01 level

Among six trace metals, strong correlation was found between Pb and Zn and no correlation with Ni and Cu. This is probably due to variation in uptake mechanism by plants. A strong correlation between all six vegetables species observed. It indicates that the chemical composition of growth media is the major factor influencing the chemical composition of plants. High significant correlation coefficients were found between the sampling sites of industrial and semi urban, semi–urban and rural. Correlation between industrial and rural areas also exists at 0.05 levels. This attributes various industrial and urban pollution sources may affect the trace metal composition in vegetables by soil and air pollution.

TABLE 7: MEAN VALUES OF WATER SAMPLES USED IN IRRIGATION IN TERMS OF PHYSICO-CHEMICAL PARAMETERS.

Station code	Sites		pH	EC	TDS	TH	Ca	Mg	TA	HC	Cl	Na	F	K	SO_4	NO_3
IW1/S1/S/13	Ind.		7.9	1285	1447	147	282	166	668	109	87	157	0.66	5	286	34
IW2/S2/S/13	SU		8.6	1222	986	195	185	37	280	188	56	74	0.58	6	194	28
IW3/S3/S/13	SU		7.9	1445	1295	168	242	107	297	164	64	96	0.45	7	146	42
IW4/S4/S/13	SU		7.4	525	684	175	175	58	265	125	66	95	0.95	9	184	25
IW5/S5/S/13	Ind.		8.8	1530	1442	174	243	115	643	175	264	14	1.63	12	88	46
IW6/S6/S/13	Ind		8.3	699	1245	153	187	47	356	185	136	97	0.26	23	58	28
IW7/S7/S/13	Ind.		8.2	676	1562	148	212	122	655	173	156	142	1.64	15	75	44
IW8/S8/S/13	SU		7.8	1333	1465	132	174	78	544	125	144	105	0.54	13	165	46
IW9/S9/S/13	SU		7.9	983	1243	145	127	127	324	134	165	132	0.84	15	176	15
IW10/S10/S/1	SU		8.2	1432	1346	154	227	139	614	156	284	158	0.57	14	273	27
IW11/S11/S/1	Ind.		8.4	1550	1406	177	248	125	675	116	254	143	1.35	17	224	24
IW12/S12/S/1	Ind.		6.8	835	523	164	177	113	515	134	160	89	0.67	15	243	32
WHO Standard		5	6.5	500	500	300	75	30	200	-	250	-	1	-	200	1
Highest desired limit																
Max. Permissible limit		10	8.5	2000	2000	600	200	100	600	-	1000	200	1.5	-	400	45

EC = Electrical Conductivity, TDS = Total Dissolved Solid, TA = Total Alkalinity, TH = Total Hardness
All the values expressed in mg/l except pH and Electrical Conductivity.

CONCLUSION: The results of our investigation substantiate the conclusions. Trace metals from thermal power effluents absorbed by surface of vegetables which creates toxicities with certain metabolic and structural alteration. Environmental problems in terms of land degradation, ground, and surface water contamination were also associated as results of toxicity of trace metals which enhance the toxicity of vegetable crops by the irrigation practices. Investigated vegetables species having variable range of trace metals. Present situation could however change in future depending on dietary pattern of community and volume of contaminants added to the ecosystem. Among six trace metals, the ranges of Zn, Ni and Cu in vegetables were found relatively low in industrial and semi-urban areas and their ranges were within the permissible limits.

Average Pb range in vegetables of industrial area reported higher in all crops and it is necessary to kept Pb levels in both air and soil environments as low as possible. Trace metal content of agricultural soils was within the standard limits for agriculture. However, rising levels of trace metals are observed in industrial and semi-urban soils compared to rural soils. The air borne particulates in industrial and semi-urban areas are enriched with trace metals particularly Pb, Zn, Ni and Cu and are being emitted by various industrial and transport sectors.

The AAF and CF factors for Pb and Zn are high in industrial and semi-urban areas and contributing those trace elements in to vegetables through air or soil or both. However vegetable species accumulate different metals, depending on plant available metal species/forms of trace metals rather than the total concentration in the soil.

Heavy metal depositions were associated with effluent from local industries, pesticide and fertilizer inputs also. Since the soils, stream waters and vegetables were found to be contaminated with heavy metals, it is recommended that vegetables should not be cultivated in farms in urban areas and fields irrigated by urban and industrial waste water or water contaminated by heavy metals. Further, it is also important to reclaim contaminated lands to avoid heavy metal pollution. Elemental residues have raised serious setbacks and risks, which will persevere also in future. There is an effort to decline to a minimum or eliminate dispersion of contaminants into the food string and therefore also into the livings.

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