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Risk Assessment of Heavy Metal Distribution and Contamination of Vegetables Irrigated with Storm Water in the Vicinity of Chandigarh, India

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Abstract
Bioaccumulation of heavy metal in vegetables resulting from the storm water irrigation and subsequently to the food chain is a cause of serious concern due to potential human health risk. This study was conducted to analyze the metal content of some vegetables and their toxicological implication. Samples of the irrigation water and edible portion of all the vegetables both irrigated with the sewage contaminated water and ground water (reference site) were collected and analyzed for heavy metals (As, Pb, Ni, Cd, Cr, Zn and Co). The results indicate that heavy metal concentrations were several fold higher in all the collected samples from wastewater irrigated site compared to the clean water irrigated ones. Statistical analyses of storm water samples for heavy metals followed the trend of Ni>Mn>Cd .Analysis of the vegetables collected at polluted sites showed that for Ni 57.1%, for Cd 35.7% and for Cr 28.5% of samples, concentration exceeded PFA (1954) limits. The study suggests that storm water irrigation led to accumulation of heavy metals in vegetables causing potential health risk to the consumers.
Keywords: Storm water, Heavy metals, Sewage, Vegetables, PFA

1. Introduction
Runoff pollution occurs every time rain or snowmelt flows across the ground and picks up contaminants. It occurs on farms or other agricultural sites, where the water carries away fertilizers, pesticides and sediment from cropland or pastureland. It occurs during forestry operations (particularly along timber roads) where water carries away sediment, nutrients and other materials associated with that sediment, from land which no longer has enough living vegetation to hold soil in place. Storm water carries away a wide variety of contaminants as it runs across rooftops, roads, parking lots, baseball, construction sites, golf courses, lawns and other surfaces in our cities and suburbs.

Long-term application of treated and untreated waste water resulted in significant buildup of heavy metals in soil (Khan *et al.*, 2008; Gosh *et al.*, 2012) and in vegetables and cereals and their subsequent transfer to food chain causing potential health risk to consumers (Singh *et al.*, 2010;Gupta *et al.*, 2011). Heavy metal concentration in plants grown in wastewater-irrigated soils were significantly higher than in plants grown in the reference soil (Khan *et al.*, 2008; Singh *et al.*, 2010; Gupta *et al.*, 2011). In urban areas of many (developing) countries, urban and periurban agriculture depends, at least to some extent, on wastewater as a source of irrigation. Metals are an indispensable part of our environment and play positive role in various biological processes such as signaling, homeostasis and enzyme catalysis. However, at higher concentration, they tend to have toxic effects. Heavy metals impede functioning of liver, brain and lungs showing characteristic symptoms since they are prone to bioaccumulation and biomagnification along food chain. Vegetables growing around heavy metal threatened areas are at higher risk of accumulating toxic levels of heavy metals. Through bio-magnification, consumption of root vegetables adversely affects the synthesis of haem in the blood of human beings (Gallacher et al., 1984). Usually, the root values of heavy metals are one to two orders of magnitude higher than the shoot values. Whatever the amount accumulated by leafy and root/ tuber vegetables, there is a fare chance of direct entry into human diet (Kisku et al., 2000).

Frequent changes in land use pattern to bring more area under urbanization, developmental activities in peripheral zone and deforestation are leading to land degradation and deteriorating environmental quality in the Union Territory of Chandigarh. These have resulted changes in the land use pattern and degradation of surface and subsurface water regimes. The waste generated in the city goes directly into the storm water drains which in turn flush the untreated waste into the nearby rivulets. The farmers of nearby villages are growing various types of vegetables to cater their own needs and to sell in the market to earn their livelihood. But they are unaware of the harmful effects of these vegetables grown by the application of wastewater. Therefore, in the present study, impact of effluents on heavy metal accumulation of storm water and their consequent impact on plants irrigated with effluent have been studied.

2. Study Area

Chandigarh is a Union Territory located at the foothills of the Siwaliks about 250 Km north of Delhi. The city also has the distinction of being the joint capital of Punjab and Haryana states even though it does not form part of any of the two States. Chandigarh lies between north latitudes 30^o 40' and 30^o 46' and east longitudes 76^o 42' and 76^o 51'. Chandigarh has an area of 114 Sq.Km. out of which 36 sq.km. is rural and remaining 78 sq.km, is urban and is divided into 56 dwelling sectors.

The North Choe (commonly known as N-Choe) is a seasonal, highly polluted rivulet which originates from Sector 3, Chandigarh. Layout of the study area and sample collection sites are shown Fig.1 & 2.The N-Choe flows through the densely populated residential areas of the city. It flows from northeast to southwest direction and traverses north central part of the city, before entering the adjoining township of Mohali which further carries it to Ghaggar river in Haryana. The choe where only rain water should flow, sewage discharge or polluted water is being discharged at various points in Chandigarh. Life of the residents living along the N Choe has become a nightmare with the stench, germs from the rotting vegetable waste and the vectors of protozoan parasites in forms of flies and mosquitoes and moreover this water is being utilized by farmers for growing vegetables in the agricultural fields along the stream.Therefore it is a matter of increasing concern to prevent the outbreak of water born diseases.

3. Material and Methods

Site selection: A thorough survey of the outskirts of Chandigarh city was carried out and villages Manauli, Chilla were identified where storm water was used for irrigation of vegetables and village Kaimbala were identified as reference site where ground water was used for irrigation.

3.1 Sample collection:

3.1.1 Collection of wastewater samples: 33 samples of wastewater were collected from N choe from upper, mid and downstream sites at about 20m interval during 2013. Good qualities, air tight plastic bottles with cover lock were used for sample collection and safe transfer to the laboratory for analysis. The standard procedures of sampling were adopted and preservatives were added as per nature of analysis during the collection of these samples. At the time of sampling, bottles were thoroughly rinsed two to three times with water to be sampled.

3.1.2 Collection of vegetable samples: 30 samples of vegetables were collected in the following ways:

- *15 samples of vegetables from the fields which are irrigated with contaminated water of N Choe.*
- *15 samples of vegetables from the fields which are irrigated with groundwater at a distance of 10 km from polluted site.*

Plant samples were collected in paper bags. Each sample was given a particular identification number.

3.2 Sample digestion for heavy metal analysis

3.2.1 Water Sample Digestion method:

Digestion of the samples was done using the open-beaker procedure. To ensure the removal of organic impurities from the samples and thus prevent interference in analysis, the samples were digested with concentrated nitric acid. Concentrated nitric acid (5 ml) was added to 50 ml of sample of water in a 100 ml beaker. This was heated on a hot plate to boil until its volume reduced to 20 ml. Another 5 ml of concentrated nitric acid was added and then heated for another 10 min and allowed to cool. About 5 ml of nitric acid was used to rinse the sides of the beaker, the solution was quantitatively transferred into a 50 ml volumetric flask and made up to the mark with distilled water. A blank solution was similarly prepared. Heavy metal analysis was done using ICP-MS.

3.2.2 Vegetable sample digestion method:

Vegetable samples were washed in running tap water then with distilled water and were carefully dried in oven at 7^{0}C for 24 hr. Preweighed samples were ground in a pestle and mortar followed by wet digestion with HNO3 and HClO4 (Tappi Test method, 1989) in the ratio 3:1. The samples were digested on a hot plate at a temperature corresponding to 100^{0}C for 3-4 hrs. Heating was done such that it did not boil. Heating was done till it dried up completely and whitish brown dry mass was obtained. It was then cooled and the precipitate/digest mixture was extracted in acid water mixture (HCl: distilled water in the ratio 3:1) and filtered through whatman filter paper No 42, volume was made up to 50 ml. The filtrate was analyzed for metal content using ICP-MS.

4. Results and discussion

The contamination of aquatic ecosystem with heavy metals is a major environmental problem. Analysis of surface water for heavy metals Pb,Cd,Cr,Cu,Ni,As,Zn,Mn revealed that elemental concentration has shown the trend of Ni > Mn > Cd (Table 1).Heavy metals are very harmful because of their non bio-degradable 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. Comparing the values of metals with the standard values given by FAO it was found that 72.7% samples were high in Ni, 36.3% samples were high in Mn and 12.1% samples were high in Cd. All the other metals were within the safe limits considering the FAO criteria for irrigation quality.

Heavy metals including Cd,Cu,Cr,Fe,Mn,Ni,Pb & Zn often originates from infrastructures like roads, guardrails and constructional materials, when precipitation lands on these and other impervious surfaces it picks up contaminants and finds their way to the storm water drain. High Ni concentration has also been observed in the study area The most common type of reaction to Ni exposure is a skin rash at the site of contact. Skin contact with metallic or soluble Ni compounds can produce allergic dermatitis.

Different metal showed the different enrichment factor for polluted site. Analysis of the vegetables collected at polluted sites showed that for Ni 57.1%, for Cd 35.7% and for Cr 28.5% of samples, concentration was found above the Prevention of Food Adulteration Act (PFA 1954) limits while analysis of the vegetables collected from reference site showed that 14.2% samples were observed with elevated concentration of Cd and 14.2% sample showed the high concentration of Cr (Table 2).Fig.3 clearly shows that vegetables irrigated with effluent containing storm water drain has the elevated level of metal content as compare to the vegetable samples taken from agricultural field of reference site.

It has also been observed that the heavy metal accumulation was higher in leafy vegetables as compared to other vegetables (Fig.4).Higher concentration of Cd was found in spinach (311.9 mg/kg), coriander (224.6 mg/kg), cauliflower (171.1 mg/kg), mint (1.995 mg/kg) exceeding the permissible limit of 1.5 mg/kg given by Prevention of Food Adulteration Act,PFA,1954 as compared to the other vegetables. The amount of Ni in the samples of spinach, coriander, beetroot , carrot ,garlic ,fenugreek was accounted for 84.2, 31.63, 18.27, 5.73,1.55,3.48 mg/kg respectively against the permissible limit of 1.5mg/kg (PFA,1954). Cr concentration in the leaves of spinach, garlic, mint and cabbage was 2.84, 13.91, 11.07 and 7.01 mg/kg respectively against the permissible limit of 2.0 mg/kg (PFA, 1954).Therefore the daily intake of such vegetables that accumulate more toxic elements should be avoided for consumption as metal uptake by plants may pose risks to human health when vegetables are grown on or near contaminated areas.

5. Conclusion

The water of N choe containing excessive amount of certain heavy metals should not be used to irrigate agricultural fields. The most important issue of concern includes the improper management of industrial and domestic effluents; therefore Sewage treatment plant (STP) should be installed in the vicinity of the N choe to prevent the outbreak of water borne diseases and to avoid the precarious situation in the area. It is equally necessary to educate the common people and make them understand the necessity of keeping the surface water clean by not letting the sewage water mix with storm water which urgently needs to be protected from the perils of contamination.

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Table.1. Results of the heavy metal analysis in the N choe

S.No.	Parameters	No. of samples	Analytical Results			
			Range	F.A.O. Irrigation Water Standards (mg/l)	No. of samples above permissible limit	Percentage of samples above permissible limit
1.	Pb(mg/l)	33	0.013-0.056	5	Nil	Nil
2.	Cd(mg/l)	33	0-0.6	0.01	4	12.1%
3.	Cr(mg/l)	33	0.001-0.046	0.1	Nil	Nil
4.	Cu(mg/l)	33	0.001-0.059	0.2	Nil	Nil
6.	Mn (mg/l)	33	0.04-0.467	0.2	12	36.3%
7.	Ni(mg/l)	33	0.002-5.786	0.2	24	72.7%
8.	As(mg/l)	33	0.001-0.005	-	Nil	Nil
9.	Zn(mg/l)	33	0.058-0.358	2	Nil	Nil

Table.2. Results of the heavy metal analysis of vegetable samples from polluted site and reference site

S.No.	Parameters	No. of samples	Analytical Results of vegetable samples from polluted site				Analytical Results of vegetable samples from reference site			
			Range (mg/kg)	PFA(1954) (mg/kg)	No. of samples above permissible limit	Percentage of samples above permissible limit	No. of samples	Range (mg/kg)	No. of samples above permissible limit	Percentage of samples above permissible limit
1.	As(mg/kg)	15	0.02 - 0.35	-	Nil	Nil	15	0.001-0.1	Nil	Nil
2.	Cd(mg/kg)	15	0 - 311.9	1.5	5	35.7%	15	0.01 -211.9	2	14.2%
3.	Cr(mg/kg)	15	0.51 -33.18	2	4	28.5%	15	0.21 - 3.84	2	14.2%
4.	Cu(mg/kg)	15	0.36 - 6.47	30	Nil	Nil	15	0.36 - 3.17	Nil	Nil
6.	Ni(mg/kg)	15	0 - 84.2	1.5	8	57.1%	15	0 - 3.63	Nil	Nil
7.	Mn(mg/kg)	15	0.89 -26.86	-	Nil	Nil	15	0.32 -11.22	Nil	Nil
8.	Pb(mg/kg)	15	0.43 - 1.98	2.5	Nil	Nil	15	0.3 - 2.25	Nil	Nil
9.	Zn(mg/kg)	15	3.51 - 16.0	50	Nil	Nil	15	0.3 - 9.7	Nil	Nil

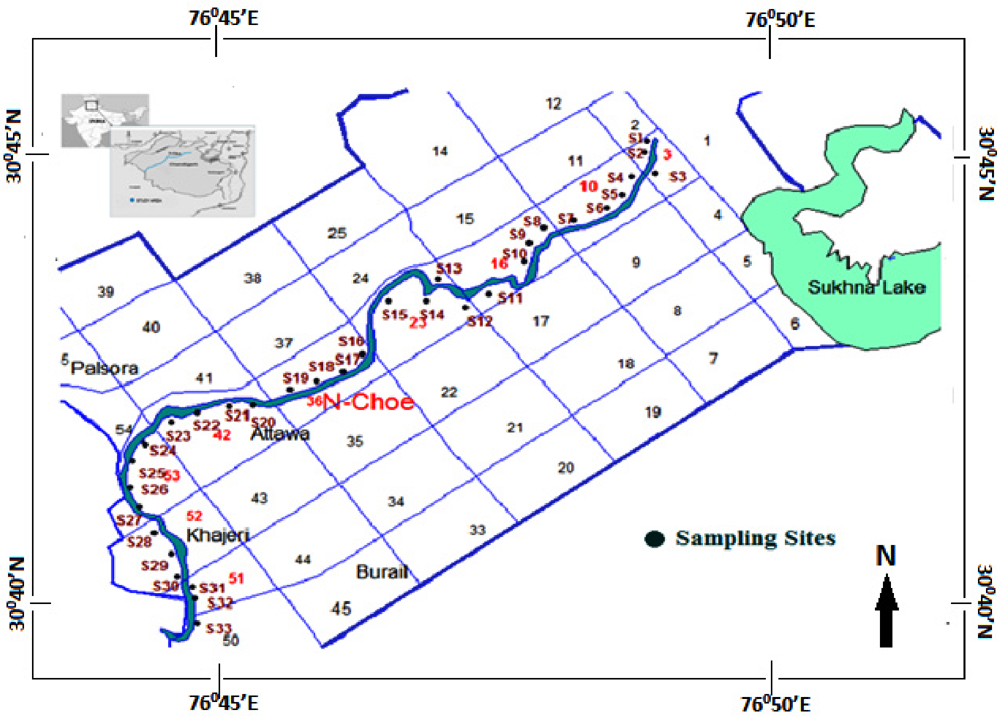


Fig.1.Map showing the sampling sites in the study area

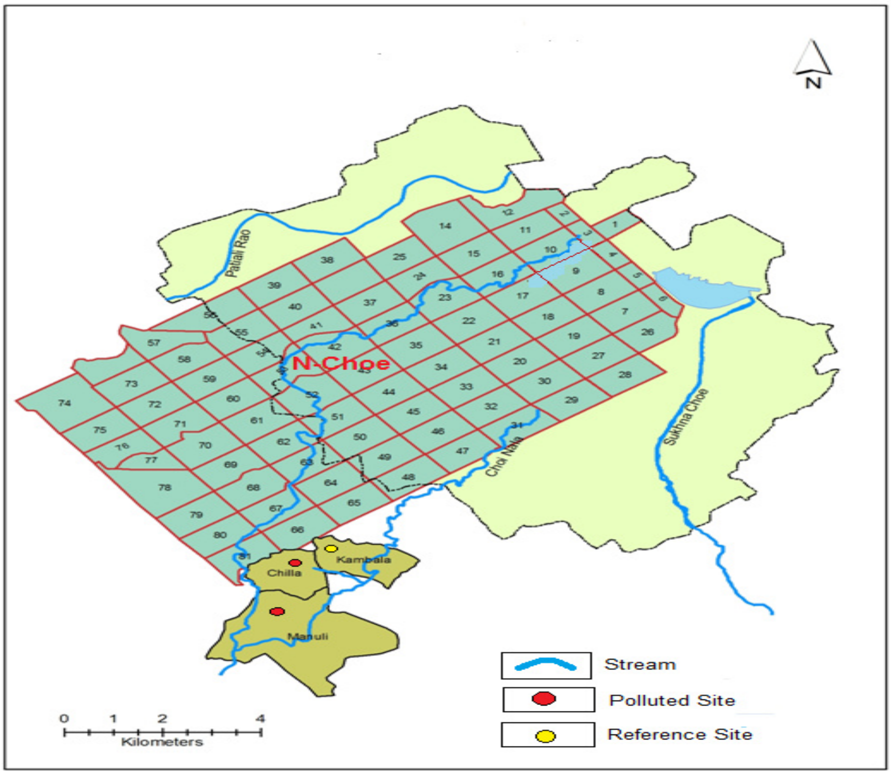


Fig.2 Map showing the vegetables sampling sites

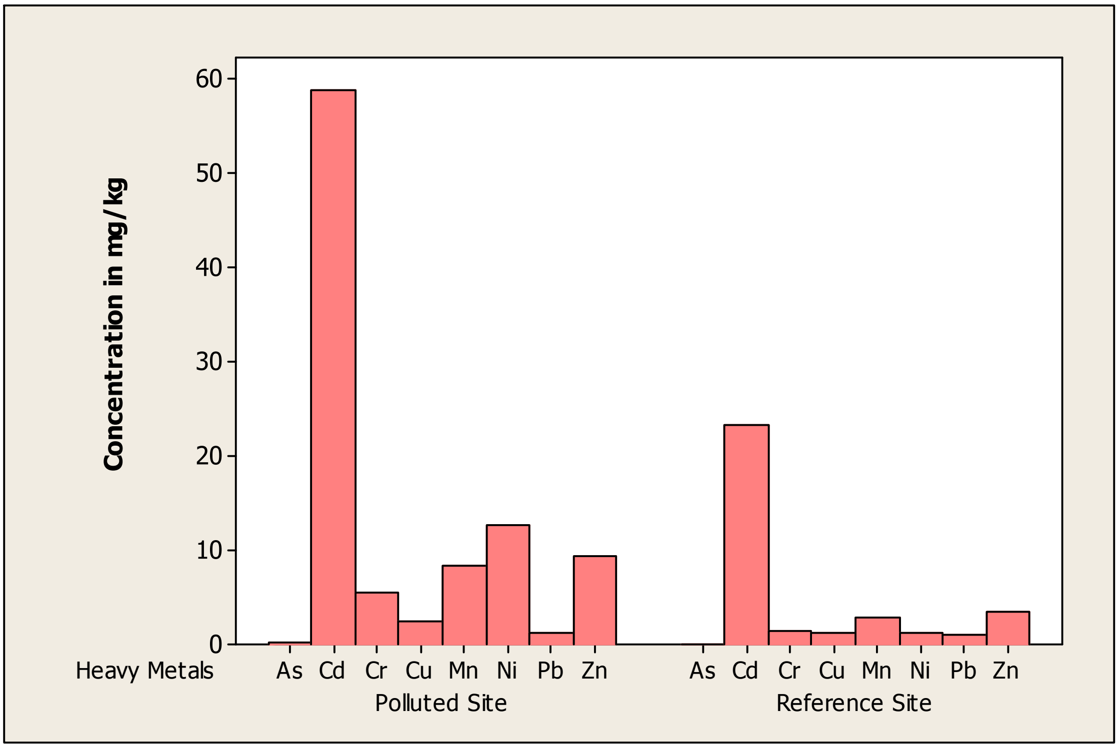
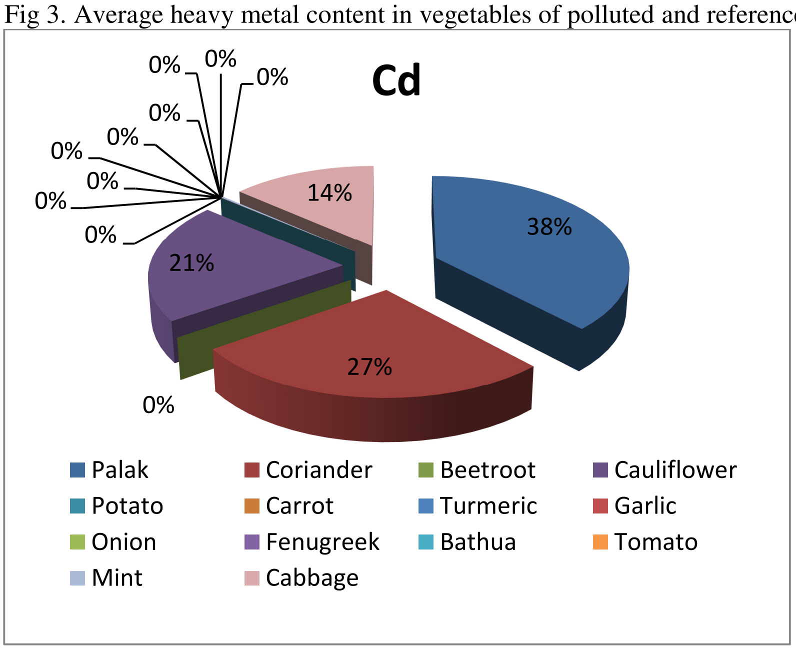
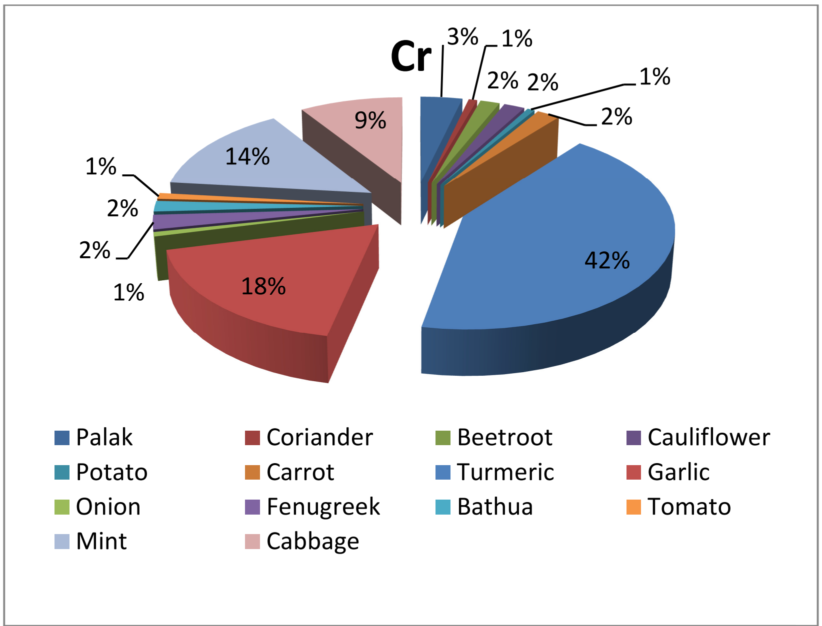


Fig 3. Average heavy metal content in vegetables of polluted and reference site

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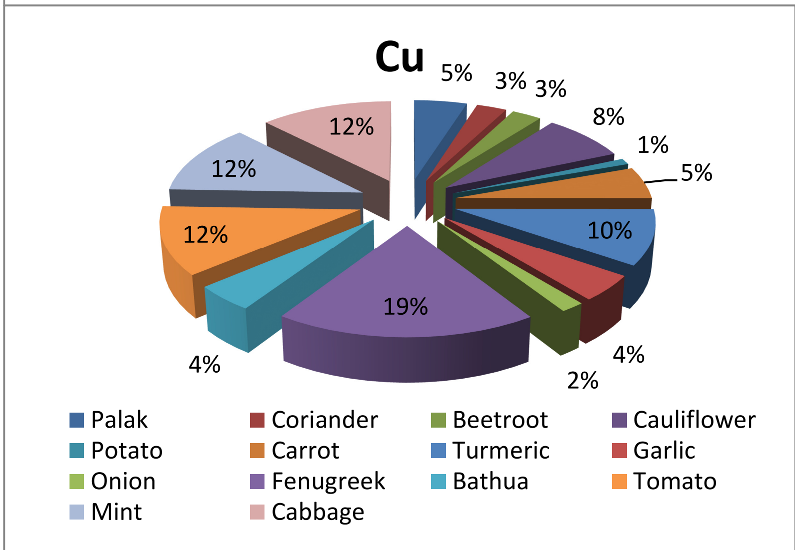
Bathua
Tomato
Mint
Cabbage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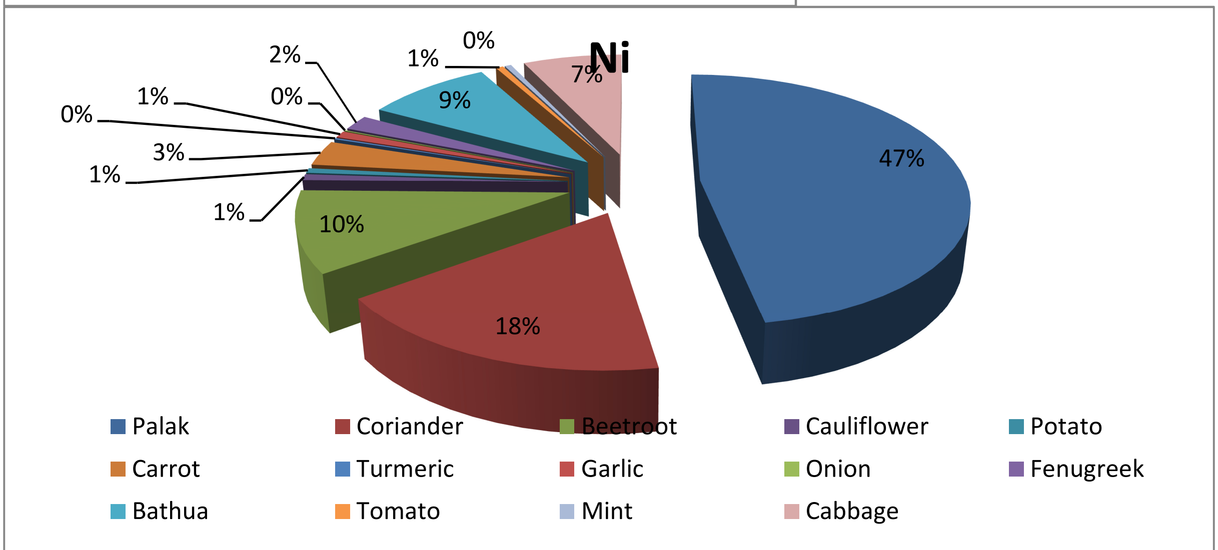
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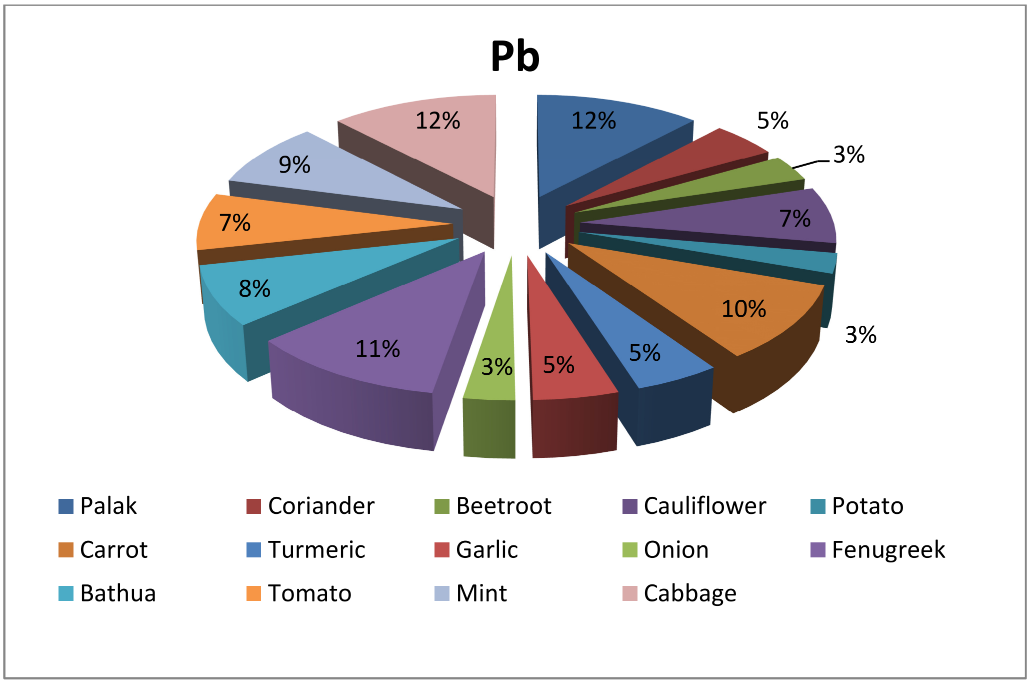

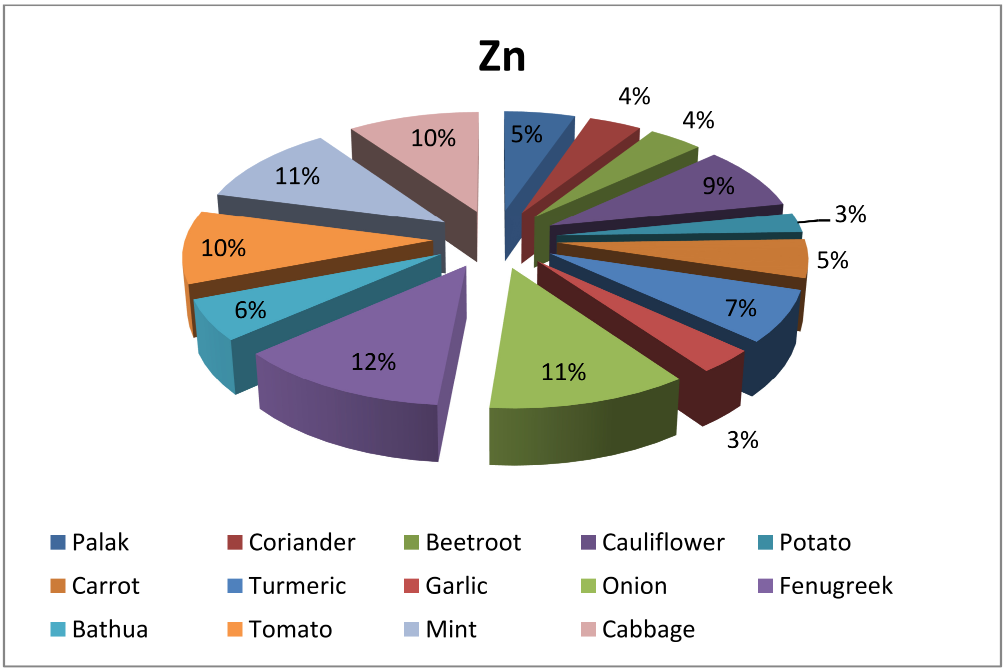

Fig.4 Enrichment percentage (%) of heavy metal in vegetables irrigated with contaminated drain

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