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Bioaccumulation of Heavy Metal Toxicity in the Vegetables of Mahalgaon, Nagpur, Maharashtra (India)

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ABSTRACT

Mahalgaon is a village in Kamptee Taluka, Nagpur district of Maharashtra state, India. Most of the village formers from this village are engaged in vegetable cultivation and the village serves as one of the main supplier of vegetables required in the Nagpur market. All the fields and farms of this region are irrigated by the Nag river water which is highly polluted by urban waste and heavy metals. The purpose of this study was to study the bioaccumulation of heavy metals i.e. Cu, Mn, Fe, Zn, Ni and Pb in Water, Soil and Vegetables irrigated by Nag River water and to evaluate the level of bioaccumulation of the metals by the different vegetables. For this study five farms were selected in the Mahalgaon region. Each farm was situated near the bank of Nag River. The sampling was carried out according to grab method as given in APHA for the sampling of water, soil and vegetables. The concentration of heavy metals (Cu, Mn, Fe, Zn, Ni, Pb) were analyzed using Atomic Absorption Spectrophotometer (AAS). It was found that in water the concentration of Iron and zinc was highest whereas conc. of Nickel and lead was lowest. The concentration of Fe and Zn in the soil samples was very high compared to the WHO/FAO maximum permissive limits while the concentrations of Cu and Mn were slightly above the permissible limits. The concentration of Pb and Ni were below the detection limits in soil. On the other hand in all the vegetables, the concentration of heavy metals was higher than the WHO/FAO permissible limits. the soil-plant transfer factor of different heavy metals shows the following order- TFZn> $TF_{Fe}>TF_{Cu}>TF_{Ni}>TF_{Mn}>TF_{Pb}$.

Key words: Bioaccumulation, Heavy Metals, Temasna, Nag River, Vegetables.

INTRODUCTION

Mahalgaon is a village in Kamptee Taluka, Nagpur district of Maharashtra state, India[1]. Nag River is the main river which flows through the city and passes through Mahalgaon village hence it is the easiest and cheapest source of water for irrigation to the villagers on the bank of this river. The river serves as the drainage for the city and is highly polluted by urban waste and heavy metals[2].

Most of the village formers are engaged in vegetable cultivation and the village serves as one of the main supplier of vegetables required in the Nagpur market. All the fields and farms are irrigated by the Nag river water.

Although trace quantities of certain heavy metals such as Chromium, Cobalt, Cupper, Manganese, Zinc etc. are essential micronutrients for higher animals and plant growth but their high concentration may cause health problem[3,4] hence lot of work has been carried out to assess heavy metal bioaccumulation in different vegetables and plants [5,6,7,8,9,10,11,12] which show that heavy metals are non-biodegradable and persistent environmental contaminants which are deposited on the surfaces and then absorbed into the tissues of vegetables. Plants take up heavy metals by absorbing them from contaminated soil.

By consumption of vegetables heavy metals enter the food chain[8] and if consumed in high concentration it may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of biochemical processes leading to cardiovascular, nervous, kidney and bone disease[8,13].

The purpose of this study was to study the bioaccumulation of heavy metals i.e. Cu, Mn, Fe, Zn, Ni and Pb in Water, Soil and Vegetables irrigated by Nag River water and to evaluate the level of bioaccumulation of the metals by the different vegetables. These are the most toxic heavy metals in water, soil and vegetables.

MATERIAL AND METHODOLOGY

Analytical reagent (AR) grade chemicals and distilled water were used throughout the study.

The sampling was carried out according to grab method as given in APHA for the sampling of water[14], soil and vegetables. Five farms were selected in the Mahalgaon region for study purpose. Each farm was situated near the bank of Nag River.

Water sampling

Water samples were collected from five sites along Nag River at Mahalgaon. All the sampling sites were adjacent to the farms which were selected for study purpose. Sampling was made in the summer 2013. The containers used for water sampling were plastic bottles which were thoroughly washed with nitric acid followed by double distilled water. 2ml nitric acid was added in 1 liter water sample for the digestion of heavy metals and it was stored at cold temperature till the further analysis.

The concentration of heavy metals (Cu, Mn, Fe, Zn, Ni, Pb) were analyzed using Atomic Absorption Spectrophotometer (AAS SL-243 ELICO).

Soil sampling

Soil samples were collected from five sites. Each farm was first subdivided into five parts (four cornors and one centre) and then soil was collected from all the five spots and mixed together to get a composite soil sample from one field. Likewise all the five samples were collected. Sampling was carried out by using plastic equipment instead of metal tool to avoid any cross contamination. The samples were collected in a self locking polythene bags and were sealed so as to avoid any kind of loss or leakage. The soil samples were air dried and then disaggregated with mortar and pestle and dried samples were finely powdered to 2mm thick sieve to make the sample homogeneous.

Vegetables

The vegetables selected for heavy metal analysis were Brinjal (Solanum Melongena), Flower, Bathua (Chenopodium Album), Chawli (Vigna Catjang), Spinach (Spinacia Oleraceae). All this are the common vegetables which are repeatedly consumed by peoples of this area. Grab method was used for collecting vegetable samples.

Table 1: Concentration (mg/l) of Heavy Metals in water samples.

Sites	Cu	Mn	Fe	Zn	Ni	Pb
1	0.63	0.91	4.67	4.62	0.51	0.23
2	0.65	0.92	4.65	4.6	0.53	0.25
3	0.61	0.9	4.66	4.63	0.51	0.24
4	0.63	0.91	4.69	4.62	0.5	0.22
5	0.63	0.91	4.68	4.63	0.5	0.21
Min	0.61	0.9	4.65	4.6	0.5	0.21
Max	0.65	0.92	4.69	4.63	0.53	0.25
Ave	0.63	0.91	4.67	4.62	0.51	0.23

Table 2: Concentration (mg/g) of Heavy Metals in Soil samples.

Site	Cu	Mn	Fe	Zn	Ni	Pb
1	0.42	0.69	11.08	2.85	0.11	0.083
2	0.4	0.67	11.09	2.86	0.09	0.084
3	0.43	0.68	11.09	2.88	0.13	0.081
4	0.44	0.7	11.06	2.84	0.1	0.085
5	0.41	0.71	11.08	2.82	0.12	0.082
Min	0.4	0.67	11.06	2.82	0.09	0.081
Max	0.44	0.71	11.09	2.88	0.12	0.085
Ave	0.42	0.69	11.08	2.85	0.11	0.083

The plant samples were put through a three step washing sequence, which involved agitating and rinsing first in 0.1% teepol for 15 seconds, followed by 0.1% HCl for 15 seconds and lastly three separate washes in deionised water. The clean vegetable samples were air dried, weighed and placed in a dehydrator at 70 °C for 48-72 hours depending on sample size. Dried samples were weighed and mechanically ground using a stainless steel grinder (<1 mm) for digestion.

Table 3: Concentration (mg/g) of Heavy Metals in Vegetables

	Vegtables	Cu	Mn	Fe	Zn	Ni	Pb
	Brinjal	0.002	0.005	2.35	1.06	0.005	0.001
	Flower	0.002	0.004	2.21	1.1	0.004	0.002
Site-I	Bathua	0.001	0.002	1.68	1.69	0.004	0.001
	Chawli	0.003	0.001	2.63	0.83	0.003	0.001
	Spinach	0.002	0.004	2.43	1.52	0.006	0.004
	Brinjal	0.001	0.002	1.93	0.98	0.003	0.002
	Flower	0.001	0.003	2.43	1.15	0.007	0.003
Site-II	Bathua	0.002	0.002	2.22	1.1	0.008	0.001
	Chawli	0.003	0.002	2.65	0.86	0.002	0.001
	Spinach	0.003	0.001	1.2	1.04	0.007	0.003
	Brinjal	0.002	0.004	1.34	1.46	0.005	0.001
	Flower	0.001	0.002	2.52	0.65	0.004	0.001
Site-III	Bathua	0.004	0.003	2.37	1.88	0.006	0.001
	Chawli	0.002	0.003	2.64	0.83	0.003	0.002
	Spinach	0.001	0.002	2.44	1.36	0.003	Nil
	Brinjal	0.002	0.001	3.04	1.11	0.006	0.004
	Flower	0.003	0.002	1.95	1.24	0.006	0.001
Site-IV	Bathua	0.004	0.003	2.07	1.04	0.004	0.003
	Chawli	0.002	0.004	2.63	0.82	0.002	0.001
	Spinach	0.002	0.003	2.43	1.46	0.005	0.002
	Brinjal	0.003	0.003	1.34	1.43	0.006	0.002
	Flower	0.003	0.006	1.36	0.93	0.005	0.002
Site-V	Bathua	0.001	0.003	1.82	1.43	0.002	0.002
	Chawli	0.001	0.003	2.67	0.85	0.003	0.001
	Spinach	0.003	0.002	1.78	1.26	0.005	0.001
	Brinjal	0.002	0.003	1.99	1.208	0.005	0.002
	Flower	0.002	0.0034	2.095	1.014	0.0052	0.0018
Average	Bathua	0.002	0.0026	2.032	1.428	0.0048	0.0016
	Chawli	0.0022	0.0026	2.63	0.838	0.0026	0.0012
	Spinach	0.0022	0.0024	2.056	1.328	0.0052	0.002

Table 4: Soil-plant Transfer factor (TF) of vegetables

Veg.	TF_{Cu}	TF_{Mn}	TF_{Fe}	TF_{Zn}	TF_{Ni}	TF_{Pb}
Brinjal	0.0048	0.0043	0.179	0.358	0.045	0.0241
Flower	0.0048	0.0049	0.189	0.356	0.047	0.0217
Bathua	0.0048	0.0038	0.183	0.501	0.043	0.0193
Chawli	0.0052	0.0038	0.237	0.294	0.024	0.0145
Spinach	0.0052	0.0035	0.185	0.466	0.047	0.0241

Table 5: Permissible limits of heavy metals given by IS/WHO/FAO[15]

Heavy Metals	Cu	Mn	Fe	Zn	Ni	Pb
Water (ml/l)	0.05-1.5	0.01-0.5	0.03-1.0	5.0-10.0	0.2	0.1-0.1
Soil (mg/g)	0.270	-	-	0.600	0.075	0.006
Crops (mg/g)	0.001	0.003	0.003	0.001	0.001	0.001

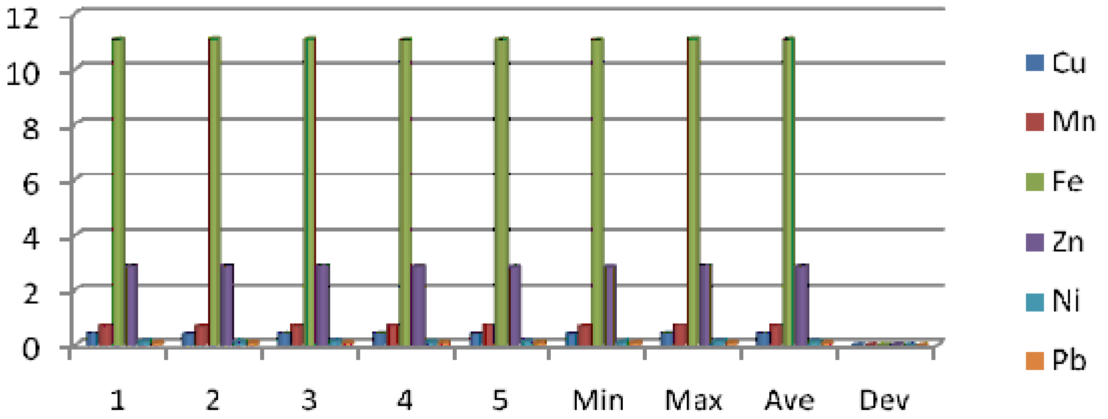

Fig.1: Concentration of Heavy metals in soil samples

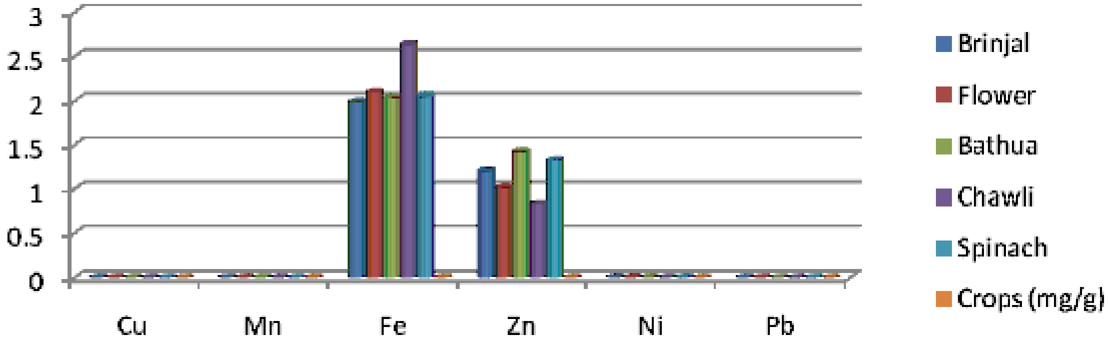

Fig. 2: Comparison of Heavy metal concentration of different vegetables with the permissible limit

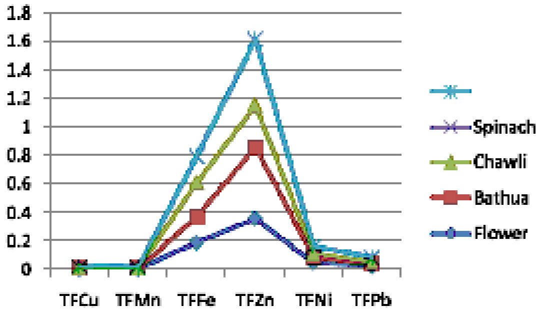

Fig. 3: Transfer factor of Heavy metals from oil to vegetables

A portion of the dry vegetable powder material was digested in a mixture of HNO_3 and perchloric acid ($HClO_4$). The extracts were analyzed for various elements using AAS.

RESULT AND DISCUSSION

The concentrations of the heavy metals (ml/l and mg/g) in water, soil and vegetables are given in tables 1, 2, 3 respectively.

In water the concentration of Iron and zinc was highest whereas concentration of Nickel and lead was lowest.

Table 2 shows that the city farm soil were moderately enriched in Cu, Mn and Ni, but strongly enriched with Fe and Zn may be due to anthropogenic contributions. The concentration of Cu, Mn, Fe, Zn, Ni, Pb in soil varied from 0.40-0.44; 0.67-0.71; 11.06-11.09; 2.82-2.88; 0.09-0.13; 0.081-0.085 mg/g respectively at different sites. Similar results are also reported by Tomar et. al, 2000. The order of accumulation of Metals in both soil and vegetables samples was Fe > Zn > Mn > Cu > Ni > Pb.

Transfer factors for heavy metals from soil to vegetables: Table 4 show the Transfer Factor (TF) of Cu, Mn, Fe, Zn, Ni and Pb from soil to plant, which is one of the key components of human exposure to metals through the food chain. Transfer factors were determined to quantify the relative difference in bioavailability of metals to plants or to identify efficiency of plant species to accumulate a given metal. These factors were based on the root uptake of metals and discount the foliar absorption of atmospheric metal deposits. The degree of accumulation shows that Zn is higher than Fe.

The soil-plant transfer factor of different heavy metals shows the following order- TFZn> TF_{Fe}>TF_{Cu}>TF_{Ni}>TF_{Mn}>TF_{Pb}.

When table 1, 2, 3 were compared with the table 5 to access the concentration of heavy metals with reference to their permissible limits in water, soil, vegetables it was found that Fe and Zn were in very high conc. Presence of these metals in higher concentration than permissible limits given by IS/WHO/FAO[15]. The concentration of Pb and Ni was below detectable limits and concentration of Cu and Mn was slightly above the permissible limits.

CONCLUSION

The concentration of Fe and Zn in the soil samples were very high compared to the WHO/ FAO maximum permissive limits while the concentrations of Cu and Mn were slightly above the permissible limits. The concentration of Pb and Ni were below the detection limits in soil. On the other hand in all the vegetables, the concentration of heavy metals was higher than the WHO/FAO permissible limits.

From the above study it was found that bioaccumulation of heavy metals in all the vegetables vary with the vegetable. The soil-plant transfer factor of different heavy metals shows the following order - TF_{Zn}> TF_{Fe}>TF_{Cu}>TF_{Ni}>TF_{Mn} >TF_{Pb}. The soil-plant transfer factor for Cu was highest in Chawli and spinach, TF of Mn was highest in Flower, TF of Fe was highest in Chawli, TF of Zn was highest in Bathua, TF of Ni was highest in Flower and spinach, TF of Pb was highest in Brinjal and Spinach.

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