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Toxic Metal Contamination of Staple Crops (Wheat and Millet) in Periurban Area of Western Rajasthan

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Abstract:- The objective of this study is to analyse the effect of sewage water pollution in food chain contamination in peri-urban area of Jodhpur city situated in Western Rajasthan. Twelve samples of Wheat and Millet crops in their natural environment were collected randomly from fields of Vinayakiya and Shikarbera sites which are located in vicinity of city sewage drains. Root, stem/leaves and grains of each plant sample were separated, processed and analysed by AAS for their toxic metal content. Soil samples were also taken and analysed in order to establish relationship between metal content in soil and its translocation in defferent parts of plant samples. On moving from soil, root, stem/leaves to edible part grains there is decrease in metal uptake. Bio-concentration factors and translocation ratio of different parts of wheat and millet samples were calculated and interpreted.

Keywords:- AAS, millet, toxic metals, waste water, wheat.

I. INTRODUCTION

Uptake and accumulation of heavy metals in crops bring about entry of toxic elements to the food chain, posing a potential threat to human health. Human involvement in the form of use of contaminated water in agriculture, excessive mining, manufacturing and industrial activities leads to heavy metal pollution [1,2]. Improper waste disposal activities and excess use of pesticides were among the most significant sources of heavy metal pollution in environment [3,4].

Heavy metals such as Cr, Cd, Pb, As and Hg are often cited as primary contaminants of concern. These metals transferred from soil into plant tissue and bio accumulate there and brought about significant reductions in both plant growth and grain yield of wheat[5,6]. Such metals are toxic to chlorophyll synthesis, photosynthetic activity and antioxidant enzymes[7,8,9]. Uptake and distribution of heavy metals are also affected by different tillage systems, continuous grass and agricultural crop rotation[10,11].

Large differences in accumulation of heavy metals by cereals and legume crops have been reported[12,13]. Some plants have capacity to control metal absorption at soil root interface.. More accumulation of metals was found in dicotyledonous crop plants than monocotyledonous plants[14].

Wheat (*Triticum aestivum*) and Millet (*Pennisetum glaucum*) are staple crops in Rajasthan. There is a lack of study on these crop plants fully grown on the agricultural soil. Increased use of raw city effluent for irrigation, metal accumulation and trans location in soil and plant necessitated this study to be carried out under local field conditions to determine heavy metal accumulation in wheat and millet grown in soil irrigated with raw effluent from city drains. This has important implication in the understanding of heavy metal contamination through food chain.

II. EXPERIMENTAL

1. Sampling Area:- The survey was conducted at selected location in peri-urban area of Jodhpur, Rajasthan where raw city effluent is used for irrigation of cereals, fodder and vegetables for a long time. The sites for wheat and millet samples were Vinayakiya and Shikarbera respectively.

2. Sample Collection and Preparation:- Samples of wheat and millet were taken randomly from different fields of Vinayakia and Shikar Bera regions. These sites are in vicinity of Vinayakiya Nallah and Degari Nallah (Drains) and most of the times waste water is used for irrigation purposes.

The whole wheat and millet plants were uprooted together with the soil around the root zone area to a depth of between 0 - 30 cm. In laboratory the plants were washed with running water, platted dry with a clean paper towel and then cut into various parts i.e., leaves, stems, roots and grains and then dried at 65°C for 48 hours, grounded with an agate mill and homogenized.

Soil samples were collected from the fields from which plants were taken. Soil samples were air dried ground and passed to 2 mm sieve and stored in plastic container and analyzed for heavy metals.

About 0.5 – 5g of homogenized samples was digested under pressure in Teflon vessels with 4 ml of nitric acid and 1.5 ml of hydrogen peroxide. Samples with a low aqueous content were ashed at 450°C in a furnace. On completion of digestion and after adequate cooling, solutions were filtered and made up to 50 ml with 1% nitric acid. Pb, Cr, Cd, Cu & Zn contents were analyzed by Flame Atomic Absorption Spectrometry (FAAS nov AA 400, Analytik jena). All reagents were supra pure and high purity water was employed through out. A sample of standard reference material, a blank and a determination in duplicate were included for assurance of analytical accuracy.

Concentration of various metals was examined in both wheat and millet plant samples. Their bio-concentration factors and translocation factors were determined. Analysis was done by comparing the data.

III. RESULT AND DISCUSSION

The average concentrations in agricultural soils are given in table 1. It ranged between 14.37 to 26.53 mg/kg for Pb, 3.247-9.438 mg/kg for Cd, 13.278-22.520 mg/kg for Cr, 14-289-32.273 mg/kg for Cu and 10.325-16.981 mg/kg for Zn. Heavy metal concentrations in different parts of wheat and millet plants are presented in table 2-7. Concentrations of studied heavy metals were found higher in the roots in comparison with the above ground material and grains in all cases. Average values of Pb in wheat and millet roots were 17.09 and 15.52 mg/kg respectively. Among root, stem / leaf and grain, the lowest values of Pb were also observed for the grains (0.85and 1.47 mg/kg respectively). The uptake and accumulation of lead in wheat were higher than in millet. More over concentration of Pb in the wheat grains approaches the Chinese National Food Guideline limits (1.0 mg/kg) as well as Indian Standards where as concentration of lead in millet crossed the two. Therefore it is worth noticing Pb contamination in the wheat and millet grains.

Average Cd values in wheat and millet roots were 3.41 ad 2.44mg/kg d.w. respectively. Cd concentration of roots showed some differences in both cereals[15]. Average cadmium concentration in both the grains was 0.04 and 0.18 mg/kg d.w. respectively. Thus accumulation of cadmium was higher in millet grains than in wheat grains but root and stem accumulated higher cadmium in case of wheat crops than in millet crops. The increment of total soil content of cadmium could enhance Cd accumulation. Mean content of Cr was higher in wheat roots (5.28 mg/kg) than in millet roots (3.73 mg/kg) possibly due to higher accumulating capacity of heavy metals in wheat plants which was slightly higher than that in rice roots analyzed by Liu[15]. Among the different parts of wheat and millet crops, the lowest value of Cr was observed for the grains 0.2 and 1.15 mg/kg respectively. This was in accordance with the findings of Liu et al.[15] who reported the lowest value of Cr in the rice grain among root, straw and grain.

The average copper contents were 14.15 mg/kg in roots, 10.84 mg/kg in leaves and 6.11mg/kg in grains of wheat plants and 14.48 mg/kg, 8.5 mg/kg and 5.89 mg/kg in roots, stem and leaves; and grains of millet plants respectively. A gradual increase of the content could be observed in the wheat and millet plants, from grain above ground material to root. The significant differences were found between the copper content of plants and soils in which they were irrigated. Though the copper level in soil was higher than Indian standards but its uptake was very less and leaves the millet and wheat plants safe as far as amount of copper is concerned. The copper concentration in roots were similar in both wheat and millet plants (14.15 and 14.48 mg/kg respectively). Conversely the copper content was considerably lower in millet leaves and grains than in wheat leaves/stem and grains. Thus almost all plant parts are safe to consume as far as copper content is concerned.

Average zinc values were 10.321, 7.937 and 2.325 mg/kg for root, stem/leaves; and grains of wheat samples respectively. In millet plant samples the values were 7.57, 4.991 ad 1.527 mg/kg for root, stem/leaves, and grains respectively. Compared with wheat the Zn content was slightly lower in millet plants. In addition concentration of lead, cadmium, chromium and copper in edible grains of wheat plants were well below the Chinese National Food Guideline limit as well as Indian Standards. Similarly edible grains of millet are safe to consume as far as concentration of chromium and copper is concerned. Thus the wheat grains were not contaminated with Pb, Cd, Cr and Cu.

In general terms, the contents of five toxic elements were higher in roots than in the aerial parts for both crops (wheat and millet) cultivated in agricultural soil indicating that the roots act as barriers for metal translocation and protect the edible parts from toxic heavy metal contamination. Mean heavy metal concentration of differetn plant parts of two crops has been mentioned in table 8.

The **bio-concentration factor** (BCF) was calculated as the ratio of the content of heavy metals in wheat or millet plant part to that in soil in which they were grown. Figure 8-9 show the BCF values for Pb, Cd, Cu, Zn, Cr in wheat and millet plants. When BCF $\leq$ 1, it indicates that the plant can only absorb but not accumulate heavy metals, when BCF > 1it shows that plant can accumulate metals. Average BCF values for Pb in winter wheat was 0.7655, 0.6472 and 0.0380 for roots, stem/leaves and grains respectively. BCF values of Pb in root and stem was higher in wheat than millet plants (0.695 for root, 0.326 for stem and leaves) whereas Pb BCF values for grains were higher in millet plants. The rhizosphere changes of various crops effects Pb bio-availability. Pb content of soil is about 3 times higher than in the studied agricultural soil. This indicates the uptake of Pb is not only related to the plant species, but to the total concentration in the soil.

Mean BCF values of Cd in wheat was 0.552for roots, 0.2819 for stem/leaves and 0.006 for grains; and 0.395 for roots, 0.095 for stem/leaves and 0.064 for grains of millet plants grown in study sites. Again root and stem/leaves of wheat plant accumulated higher content of cadmium than millet plants whereas grains have lower BCF values thus safer to consume as far as the amount of cadmium is considered.

Zarcinas[16] also reported that Cd uptake was strongly correlated with organic matter. Winter wheat and rice accumulated high quantities of cadmium when grown in non-polluted areas as in a medium containing this metal[17]. Higher plants synthesize sulphur rich peptides phyto chelatins (PCS) in response to cadmium it has been reported that PC – heavy metal complexes accumulate in the vacuole. The symplastic radial cadmium transport to the xylem and further transport to the shoot might be influenced by the retention of Cd in the root cell vacuoles[18].

BCF values for Cr in wheat and millet samples were in order root > stem/leaves > grains. Similar was the case for Cu and Zn metals in both kinds of plants. Over all it has been found that except for Cu, BCF values of all metals were higher in millet grains than in wheat grain. The BCF values of Cu were comparable in grains of both plants. Some difference for Zn uptake was observed in various irrigation regions. The mechanism has not been deducted yet.

In conclusion wheat plants showed greatest accumulation of Zn, Pb, and Cd in the roots. Though there is difference in various irrigation regions. Never the less copper and chromium was hardly taken up by winter wheat and millet roots, the heavy metal uptake by wheat and millet roots were in following order : Zn > Pb > Cd Cu > Cr and Zn > Pb > Cu > Cd > Cr respectively. The heavy metal pollutants as well as physiological properties of plants are responsible. All BCF values are given in table 9-10.

The **translocation ratio** (Heavy metal in stem/leaf or grains/heavy metals in root) from root to stem and leaf or grains was calculated for each heavy metal and is given in table 11. Figure 10-11 show translocation ratios of Pb, Cd, Cu, Cr and Zn in wheat and millet plats and all values were below 1. Translocation ratio of stem and leaf was more than that of grain for each heavy metal in both wheat and millet plant samples. More over the translocation factor for stem and leaf to grain (HM grain/ HM stem and leaf) was found smaller than that of root to stem/leaf of wheat and millet plants except for Cr and Cu. This finding is in food agreement with the results obtained in wheat grown in soil amended with industrial sludge by Bose and Battacharya.[19] Selection of cereal varieties with respect to restricted metal absorption may add to safer crop production on heavy metal contaminated soils[20]. For five toxic metals, absorption of wheat and millet plants had the relation: Root > Straws >> grains. It is important to not that five toxic metals were transported weakly in plants. In addition the result revealed that wheat transported cadmium very weakly into the stem and leaf, whereas Pb and Zn were transported most easily into the stem and leaf among studied heavy metals. Compared with the millet plants, wheat transported Cr very weakly from root to grain but Cu ad Zn were easily transported from root to stem/leaf and grains in both wheat and millet plants. Five heavy metals examined properties and consequently each metal has peculiar accumulation and translocation capacity.

By examining mean heavy metal concentrations of various metals in wheat and millet samples, it was found that grains of both the plants are safe to consume as far as concentration of Cu and Zn is considered. Concentrations of Pb, Cd and Cr in wheat plants were lower than the safe limits of Indian Standards. But mean Pb and Cd levels exceeded the safe limits prescribed by the Indian Standards in millet samples. Thus the millet plants were contaminated lead and cadmium toxicity and thus hazardous to health. Average content of chromium was found two folds the Indian Standard limit so it can be said that wheat plants were polluted as far as chromium is concerned and thus hazardous to human health on consumption.

IV. TABLES AND FIGURES

Table 1 Mean Concentration in Agricultural Soil (mg/kg) of Study Sites

Metals	Concentration
Pb	22.325
Cd	6.172
Cr	18.239
Cu	24.732
Zn	12.325

Table 2: Concentration (mg/kg) of Various Heavy Metals in Roots of Wheat Plants

Sample No.	Pb	Cd	Cr	Cu	Zn
1	21.72	2.98	3.73	16.22	9.38
2	17.63	3.06	6.99	10.15	11.43
3	16.81	2.59	5.57	14.54	8.72
4	20.59	4.12	3.18	15.71	12.80
5	18.90	3.56	6.23	12.63	13.01
6	14.48	4.02	7.80	12.30	9.17
7	18.07	3.41	8.06	12.85	7.18
8	16.16	3.88	8.37	15.25	10.59
9	14.97	3.19	4.60	17.15	8.66
10	13.24	2.45	2.35	17.46	8.54
11	14.39	2.74	3.62	10.98	12.13
12	18.12	4.93	2.89	14.18	12.24
Range	**13.24 - 21.72**	**2.45 - 4.93**	**2.35 - 8.37**	**10.15 - 17.46**	**7.18 - 13.01**
Mean ± SD	**17.09 ± 2.59**	**3.41 ± 0.73**	**5.28 ± 2.17**	**14.12 ± 2.36**	**10.32 ± 1.96**

Table 3: Concentration (mg/kg) of Various Heavy Metals in Wheat Stem/leaves

Sample No.	Pb	Cd	Cr	Cu	Zn
1	15.96	1.83	1.79	14.86	11.24
2	12.56	1.42	1.88	7.91	5.29
3	18.10	1.37	1.69	15.73	5.08
4	13.69	2.01	1.65	8.24	7.52
5	16.52	1.88	1.75	12.93	6.43
6	11.25	1.62	1.62	9.02	6.37
7	14.89	1.78	1.81	7.57	7.30
8	13.02	1.44	1.97	10.38	7.18
9	15.97	1.52	1.59	12.64	10.29
10	11.67	1.89	1.52	8.11	8.81
11	12.49	1.96	1.98	9.20	8.06
12	17.24	2.16	1.88	13.49	12.15
Range	**11.25 - 18.1**	**1.37 - 2.16**	**1.52 - 1.98**	**7.57 - 15.73**	**5.08 - 12.15**
Mean ± SD	**14.45 ± 2.3**	**1.74 ± 0.26**	**1.76 ± 0.15**	**10.84 ± 2.93**	**7.98 ± 2.26**

Table 4: Concentration (mg/kg) of Various Heavy Metals in Wheat Grains

Sample No.	Pb	Cd	Cr	Cu	Zn
1	0.73	0.011	0.199	3.10	3.23
2	0.45	0.023	0.232	8.41	4.24
3	1.43	0.021	0.193	4.14	1.08
4	0.29	0.017	0.237	3.23	3.42
5	1.82	0.043	0.218	5.52	2.31
6	0.87	0.057	0.181	7.27	2.59
7	0.63	0.013	0.261	6.46	1.77
8	0.91	0.061	0.283	8.35	3.08
9	2.18	0.019	0.192	8.21	2.45
10	0.39	0.083	0.118	6.38	1.33
11	0.31	0.041	0.173	7.20	1.14
12	0.19	0.099	0.171	5.11	1.26
Range	**0.19 - 2.18**	**0.011 - 0.099**	**0.118 - 0.283**	**3.1 - 8.41**	**1.08 - 4.24**
Mean ± SD	**0.85 ± 0.64**	**0.04 ± 0.03**	**0.2 ± 0.04**	**6.12 ± 1.91**	**2.325 ± 1.0326**

Table 5: Concentration (mg/kg) of Various Heavy Metals in Millet Roots

Sample No.	Pb	Cd	Cr	Cu	Zn
1	18.01	2.67	2.96	15.72	8.42
2	16.59	1.39	3.81	16.32	8.92
3	13.52	2.39	4.49	14.51	6.51
4	18.52	2.57	1.95	15.98	6.93
5	12.11	1.99	4.11	12.98	6.32
6	14.89	3.24	5.23	13.58	7.58
7	15.90	2.92	3.69	12.83	8.42
8	17.12	3.14	3.39	14.09	7.66
9	13.29	2.20	5.08	15.48	7.98
10	15.23	1.88	2.58	13.29	6.98
Range	**12.11 - 18.52**	**1.39 - 3.24**	**1.95 - 5.23**	**12.83 - 16.32**	**6.321 - 8.925**
Mean ± SD	**15.52 ± 2.11**	**2.44 ± 0.59**	**3.73 ± 1.05**	**14.48 ± 1.31**	**7.57 ± 0.87**

Table 6: Concentration (mg/kg) of Various Heavy Metals in Millet Stem/Leaves

Sample No.	Pb	Cd	Cr	Cu	Zn
1	7.62	1.03	1.44	7.73	4.16
2	6.35	0.98	1.67	9.15	6.23
3	6.89	1.32	1.93	7.32	5.58
4	8.78	1.18	1.17	9.24	4.95
5	8.51	1.25	1.79	9.46	3.72
6	8.23	1.37	2.32	8.58	3.95
7	7.12	1.12	1.23	8.87	6.09
8	7.89	1.09	2.25	8.69	5.89
9	5.62	1.19	2.09	7.90	5.26
10	5.82	1.21	1.58	8.11	4.08
Range	**5.62 - 8.78**	**0.98 - 1.37**	**1.17 - 2.32**	**7.32 - 9.46**	**3.72 - 6.23**
Mean ± SD	**7.28 ± 1.11**	**1.17 ± 0.12**	**1.75 ± 0.4**	**8.51 ± 0.71**	**4.99 ± 0.95**

Table 7: Concentration (mg/kg) of Various Heavy Metals in Millet Grains

Sample No.	Pb	Cd	Cr	Cu	Zn
1	0.321	0.091	0.877	3.103	1.783
2	0.893	0.312	0.813	4.712	1.697
3	0.138	0.231	0.932	3.246	1.833
4	2.933	0.359	1.102	2.935	0.789
5	0.421	0.178	1.231	8.664	0.723
6	3.139	0.083	1.379	3.359	0.932
7	2.957	0.129	1.987	9.878	2.321
8	0.382	0.237	1.423	6.597	2.792
9	1.351	0.089	0.932	4.480	0.871
10	2.158	0.098	0.871	11.901	2.533
Range	**0.138 - 3.139**	**0.083 - 0.359**	**0.813 - 1.987**	**2.935 - 11.901**	**0.723 - 2.792**
Mean ± SD	**1.47 ± 1.22**	**0.18 ± 0.1**	**1.15 ± 0.36**	**5.89 ± 3.22**	**1.62 ± 0.80**

Table 8: Mean Heavy Metal Concentration in Different Parts of Wheat and Millet Plant Samples.

	Plant Part	Pb	Cd	Cr	Cu	Zn
Soil		22.33	6.17	18.24	24.73	12.33
Wheat	Root	17.09	3.41	5.28	14.12	10.32
	Stem/Leaves	14.45	1.74	1.76	10.84	7.97
	Grains	0.85	0.04	0.20	6.11	2.33
Millet	Root	15.52	2.44	3.73	14.48	7.57
	Stem/Leaves	7.28	1.17	1.75	8.50	4.99
	Grains	1.47	0.18	1.15	5.89	1.62

Table 9: Bio-concentration Factors of Wheat Samples

Plant Part	Pb	Cd	Cr	Cu	Zn
Root	0.7655	0.5520	0.2890	0.5720	0.8370
Stem/Leaves	0.6472	0.2819	0.0964	0.4380	0.6468
Grains	0.0380	0.0060	0.0109	0.2470	0.1886

Table 10: Bio-concentration Factors of Millet Samples

Plant Part	Pb	Cd	Cr	Cu	Zn
Root	0.6950	0.3950	0.2056	0.5850	0.6140
Stem/Leaves	0.3260	0.1890	0.0959	0.3440	0.4049
Grains	0.0650	0.0290	0.0641	0.2380	0.1230

Table 11: Translocation Ratios of Various Plants Parts

	Plant Part	Pb	Cd	Cr	Cu	Zn
Wheat	Root	0.8455	0.5100	0.3333	0.7660	0.7734
	Stem/Leaves	0.0497	0.0117	0.0378	0.4318	0.2252
	Grains	0.0588	0.0222	0.1136	0.5636	0.2916
Millet	Root	0.4690	0.4790	0.4690	0.5764	0.6590
	Stem/Leaves	0.0947	0.0737	0.3083	0.4067	0.2017
	Grains	0.2019	0.1538	0.6571	0.6920	0.3060

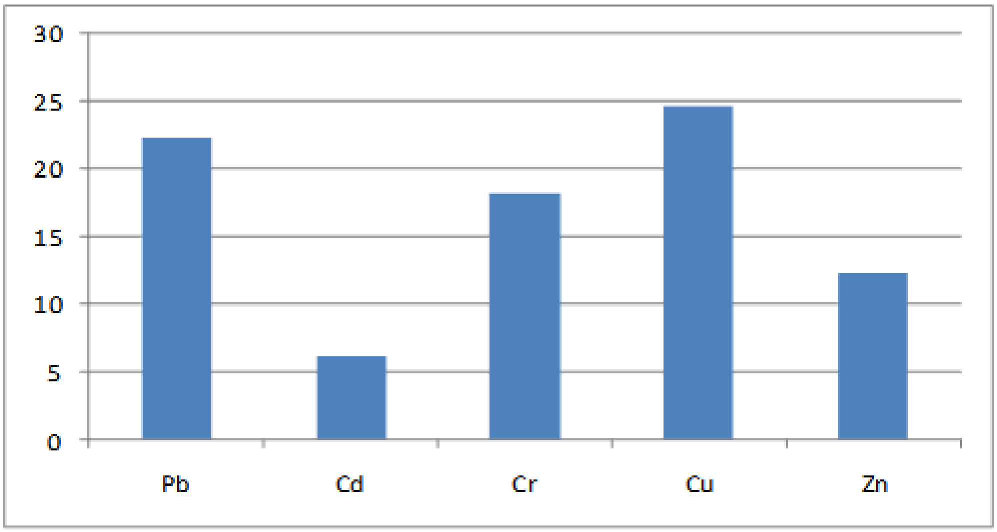

Figure 1. Mean Concentrations in Agricultural Soil (mg/kg) of Study Sites

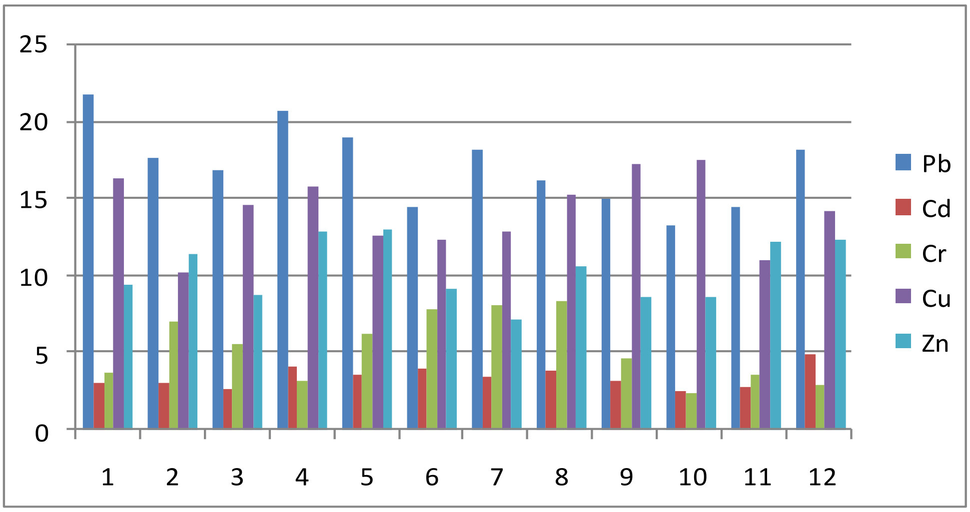

Figure - 2: Concentration (mg/kg) of Various Heavy Metals in Wheat Roots

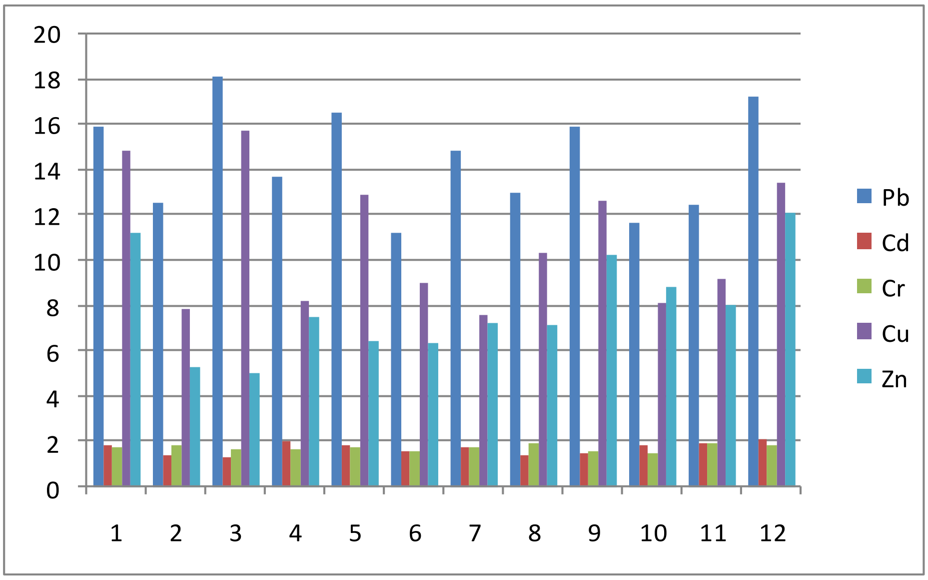

Figure - 3: Concentration (mg/kg) of Various Heavy Metals in Wheat Stem/leaves

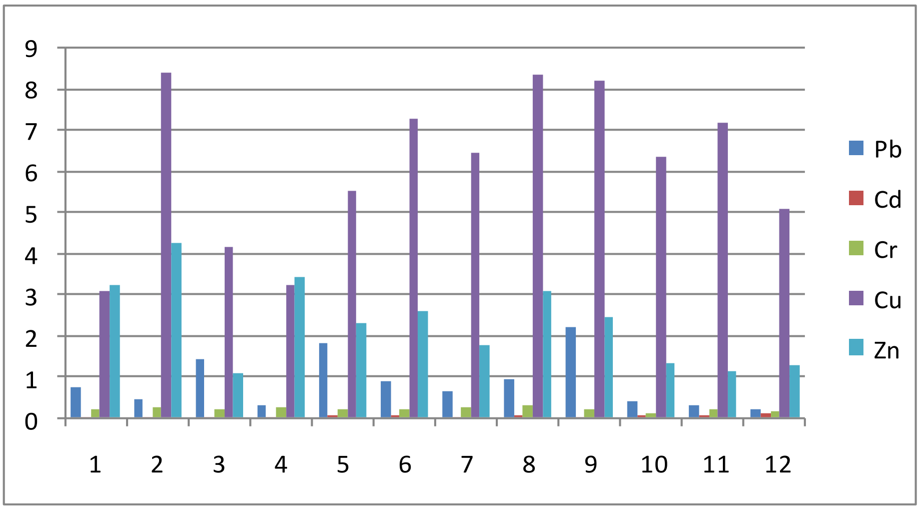

Figure - 4: Concentration (mg/kg) of Various Heavy Metals in Wheat Grains

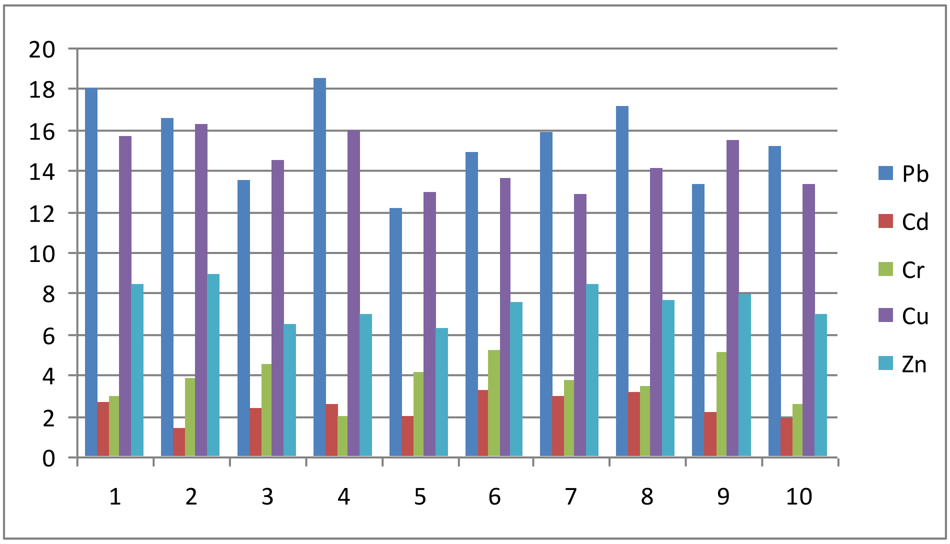

Figure - 5: Concentration (mg/kg) of Various Heavy Metals in Millet Roots

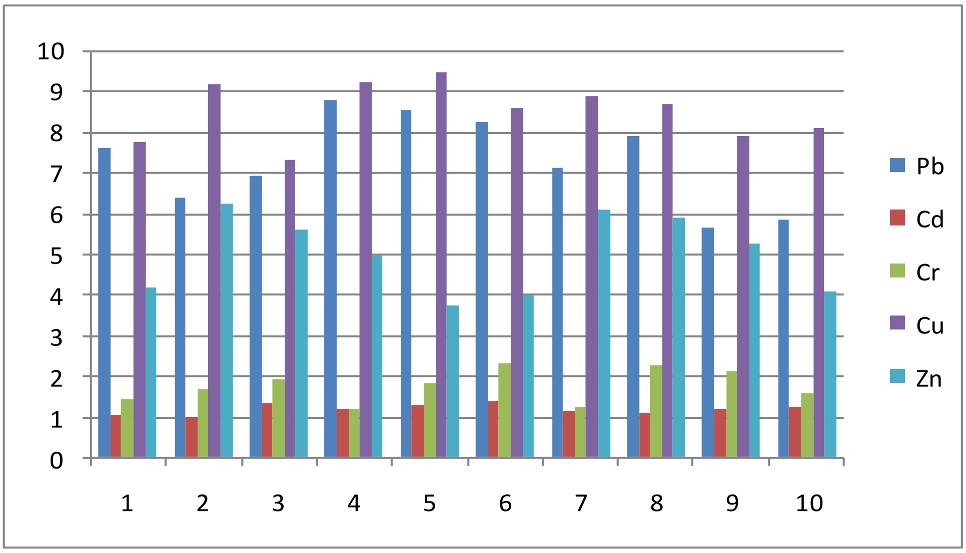

Figure - 6: Concentration (mg/kg) of Various Heavy Metals in Millet Stem/Leaves

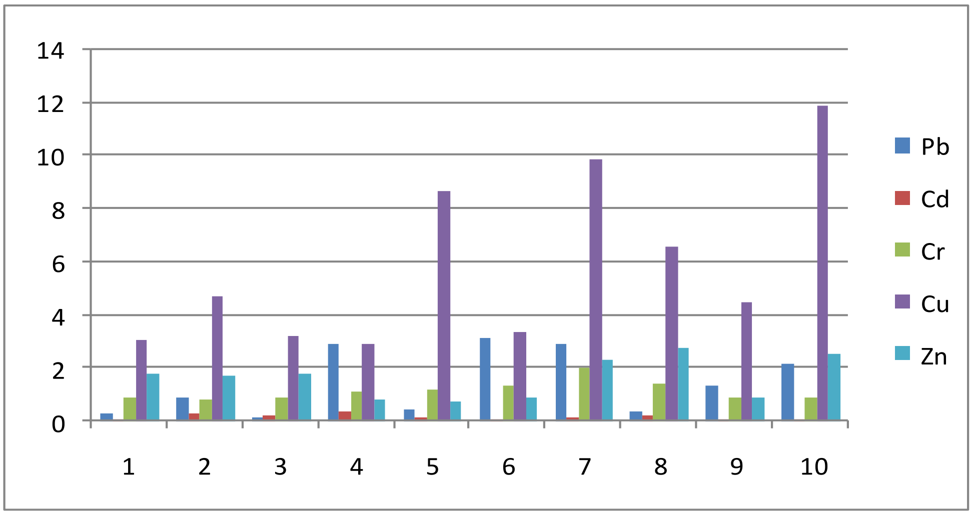

Figure - 7: Concentration (mg/kg) of Various Heavy Metals in Millet grains

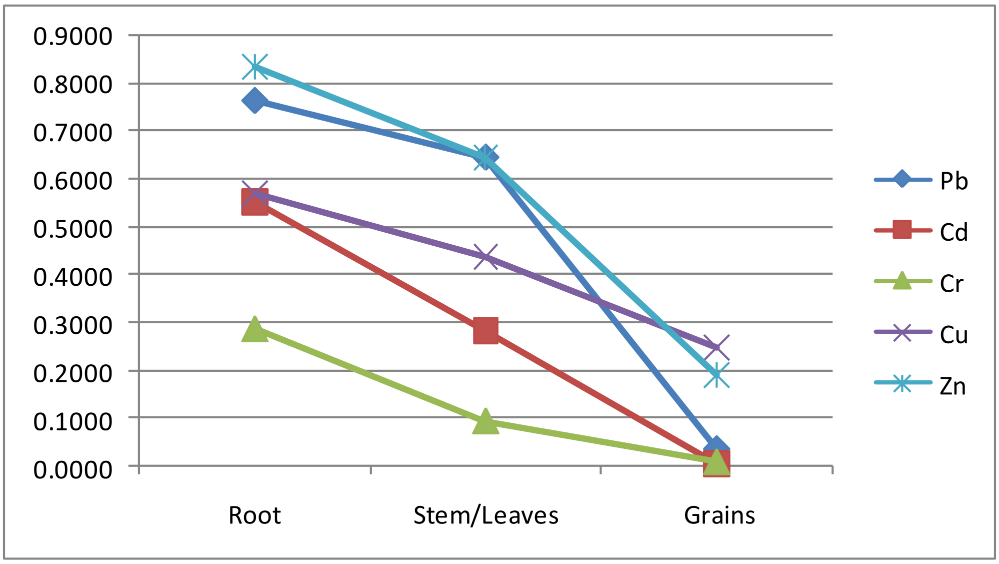

Figure - 8: Bio-Concentration Factors of Wheat Samples

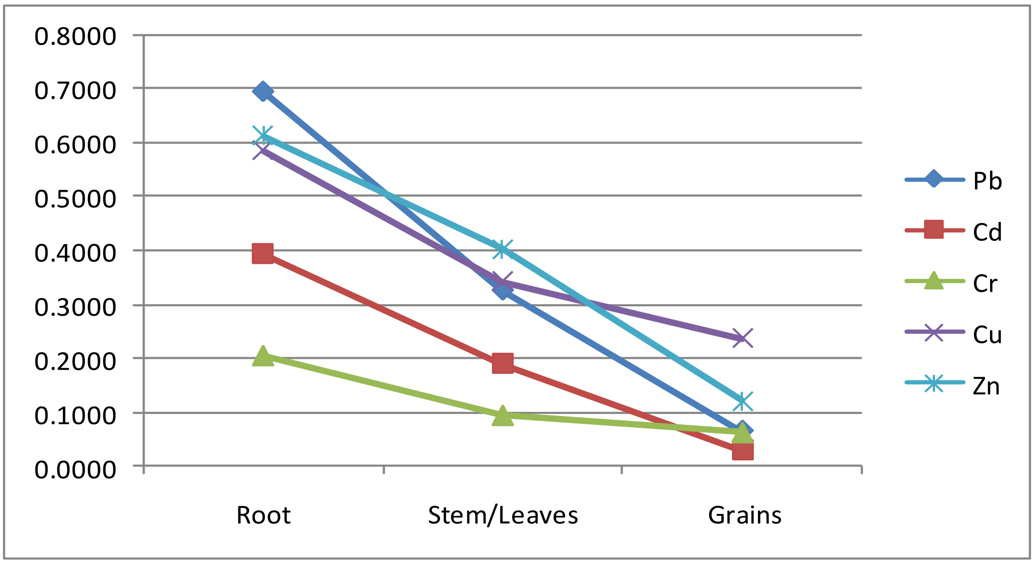

Figure - 9: Bio-Concentration Factors of Millet Samples

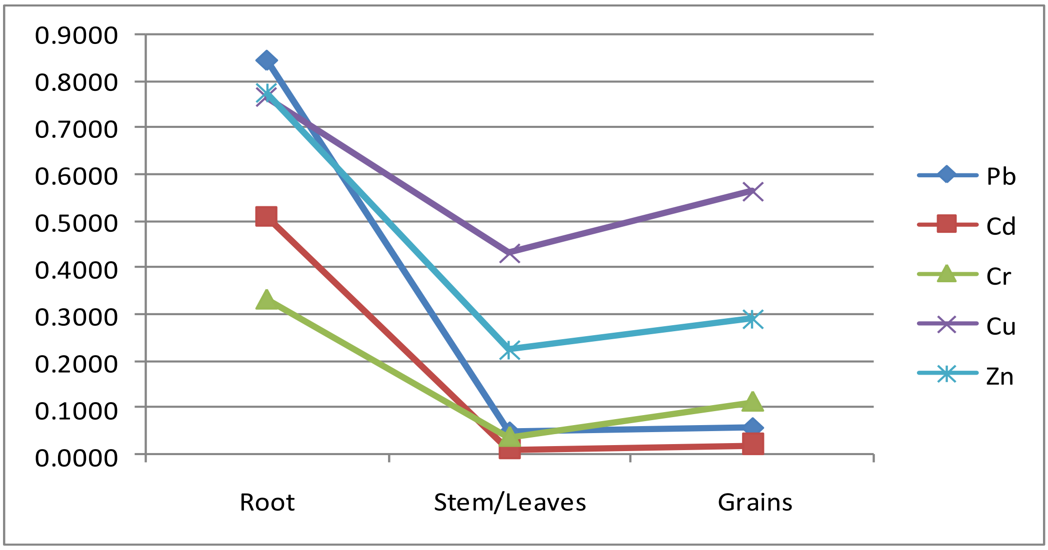

Figure - 10: Translocation Ratios of Various Parts of Wheat Plants

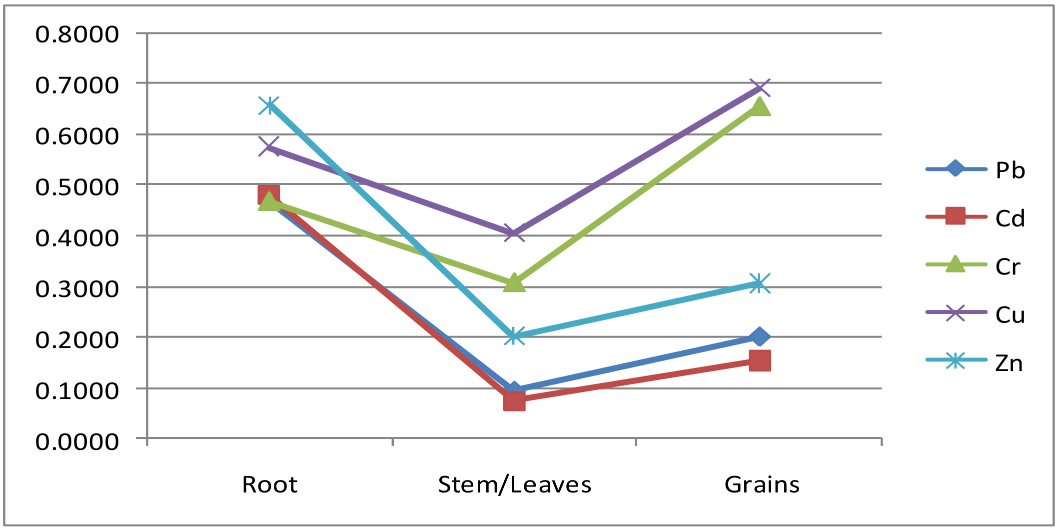

Figure - 11: Translocation Ratios of Various Parts of Millet Plants

V. CONCLUSION

Most of heavy metals studied were found to accumulate mainly in the roots of wheat and millet plants while other part including grains contained low levels but in significantly considerable amounts. Less accumulation of heavy metals in grains does not mean that they are completely safe for consumption. Important steps must be taken by local people and administration to prevent mischievous peasents from using untreated waste water from such drains for irrigation purpose. There is also a need to deveope economic methods of treating waste water. State government should take necessary steps immediately in this direction to ensure pure water supply in agricultural fields otherwise the results will be much hazardous in the near future.

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