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RELATIONSHIP BETWEEN HEAVY METAL AND TRANSFER FACTOR FROM SOIL TO VEGETABLE COLLECTED FROM WASTE WATER IRRIGATED AREA OF REWA (M.P.) INDIA

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Abstract— **The study examined the concentration of heavy metals in water, soil and vegetables growing wildly on cement-polluted soil of Rewa city, India. Accumulation of HMs in vegetables occurs by various sources but soil is considered the major one. In this study, soil to vegetable transfer factor (TF) for various HMs were also calculated and data showed that TF values differed significantly between soil and vegetable, the difference in TF values among different vegetables may be attributed to differences in element uptake by different vegetables. However TF values obtained for all vegetables were below (1) at all sites. TF were computed to quantify relative differences in bioavailability of metals to vegetables to identify the efficiency of a vegetables species to accumulate a HM(s). These factors were based on roots uptake of metals and discount the foliar absorption of atmospheric metal deposits. However TF does not present the risk associated with the metal in any form.**

Key words— **Heavy metal, soil contamination, Transfer Factor (TF), Health Risk (Hazardous), Waste Water.**

I. INTRODUCTION

The clean and safe environment is the basic requirement of human existence. Rapid urbanization and industrialization releases enormous volumes of wastewater, which is increasingly utilized as avaluable resource for irrigation in urban and peri-urban agriculture. It drives significant economic activity, supports countless livelihoods particularly those of poor farmers, and substantially changes the water quality of natural water bodies (Marshall *et al.,* 2007). Wastewater from industries may contain various heavy metals including Fe, Zn, Cu, Pb, Cd, Mn, Ni, Cr, Cd, depending upon the type of activities it is associated with. Continuous irrigation of agricultural land with industrial wastewater may cause heavy metal accumulation in the soil and vegetables (Chaney *et al.,* 2000; Sharma *et al.,* 2007; Marshall *et al.,* 2007). Soil to plant transfer of heavy metals is the major path way of human exposure to metal contamination. Food is the major intake source of toxic metals by human beings. Vegetables take up heavy metals and accumulate them in their edible and non-edible parts at quantities high enough to cause clinical problems to both animals and human beings.

Transfer of Heavy Metals from Soil to Vegetables

Transfer factor expressed the bioavailability of a metal at a particular position on a species of plants (vegetables). This is however, dependant on different factors such as the soil p^H and the nature of plant itself. As the vegetables are the source of human consumption so the soil-to-plant transfer quotient is the main source of human exposure. A convenient way for quantifying the relative differences of bioavailability of metals to plants is the transfer coeficient. The higher transfer coefficient of heavy metal indicates the stronger accumulation of the respective metal by that vegetable. Transfer coeficient of 0.1 indicates that plant is excluding the element from its tissues (Thornton and Farago, 1997). The greater the transfer coefficient value than 0.50, the greater the chances of vegetables for metal contamination by anthropogenic activities will be and so the need for environmental monitoring of the area will be required (Sponza and Karaoglu, 2002). Thus accumulation of heavy metals in consumable vegetables has been well linked with soil heavy metal and irrigation water from long back; atmospheric deposition has now been identified as one of the principal source of heavy metals entering into plants and soil especially around urban-industrial areas (Pandey *et al.,* 2009). Atmospheric heavy metals may deposit by rain and dust, and contributed to elevated metal concentrations in surface layer of soil (Sharma *et al.,* 2008). Atmospheric metals may be absorbed directly on leafy surface, or entered through stomatal openings and accumulated within plant tissue. Metal accumulation in different plant parts depends on chemical form of metals, their translocation potential, and individual species with their stage of maturity (Salt *et al*., 1995). Heavy metal contamination in agricultural soil and vegetables through industrial wastewater and atmospheric source are of great concern because of metal translocation in soil-plant system and ultimately to the food chain (Khan *et al.,* 2008; Rattan *et al.,* 2005). Thus accumulation of heavy metals in the edible parts of vegetables represents a direct pathway for their incorporation into the human food chain (Florijin *et al.,* 1993); and therefore has drawn the attention of researchers to health risk assessment of population exposed to contaminated foodstuffs. The aim of this research work was to determine the level of some heavy metals from soil that is transferred to the plants collected from waste water as well as clean water irrigated area of Rewa (M.P.), India and to correlate potential health effect of the people those who consumes those vegetables.

II. MATERIALS AND METHODS

A. Experimental Sites

Rewa is a city in the northern-eastern parts of the state of Madhya Pradesh, India. It is the administrative centre of Rewa District and Rewa Division. The cities lie about 420 km. (261 mi) north east of the state capital Bhopal, Madhya Pradesh and

130 km. (81 mi) south of the city of Allahabad, Uttar Pradesh. It is situated at 24.53^0 North latitude and 81.3^0 East longitudes and covers an area of 6,240 km^2 (2,410 sq mi). It has an elevation of 304 m. (997 ft) above mean sea level. The average rainfall is 980 mm (39 inches) per year. The average temperature is around 25^{0}C (77^0 F) and the humidity is quite high. Experimental sites of different irrigation sources J.P. Cement Plants Bela, Naubasta (waste water irrigated sites) &, Bhiti village (clean water irrigated site) were selected. Cultivated land of these two industrial areas (Bela & Naubasta) received waste water discharge from industries, manufacturing cement while third site of rural area (Bhiti) received clean (ground) water from deep bore well. Thus all sites of different irrigation sources were selected and the sampling of water, soils and vegetables of the surrounding areas were carried out in May month, to estimate heavy metals contamination from soil to vegetables (TF).

Sampling and laboratory analyses

B. Collection and digestion of water samples

At each site, both waste water and clean water samples collected randomly from different location. As soon as the samples were brought to the laboratory, they were acidified with HNO_3 (Merck), filtered and stored in dark at ambient temperature (4^{0}C) before analysis. Both waste water and clean water samples were digested according to APHA, (2005); the irrigation water sample, 50 ml. was transferred into beaker and 10 ml. of concentrated nitric acid (HNO_3) was added. The beaker with the content was placed on a hot plate and evaporated down to about 20 ml at 80^{0}C .The beaker was cool and another 5 ml. concentrated HNO_3 was also added. The beaker was covered with watch class and returned to the hot plate. The heating was continued, and then small portion of HNO_3 was added until the solution appeared transparent. The beaker wall and watch glass were washed with distilled water and the solution was filtered through whatman NO. 42 filter paper and the total volume were maintained to 50 mL with distilled water.

C. Collection and digestion of soil samples

Waste Water Irrigated soil samples were collected from the cultivated fields near the J.P. Cement Plant (Bela and Naubasta) along a distance of 100m from the Plants. Soil samples taken from each sites were separately labelled and transferred into air tight polythene bags and brought into laboratory. Before its transported to the research laboratory, care was taken, to the extent possible, to ensure that there were no other sources of contamination at the site of investigation such as motor vehicle emission, dumpsite garbage, sewage water, grey water, domestic waste, slurry, or compost to mask the effect of waste water irrigation. Soils were sieved through a 2 mm sieve to remove coarse particles and stored at ambient temperature prior to analysis. Soil samples were digested according to Allen *et al.*, (1986). To 5g of each of the air dried and sieved soil samples was thoroughly grinded, 1.0g of each of the ground soil samples were placed in 100 ml beaker. 15 ml of HNO, H_2SO_4 and HCl mixture (5:1:1) of tri-acid were added and the content heated gently at low heat on hot plate for 2 hrs at 80^{0}C until a transparent solution was obtained. After cooling, the digested sample was filtered using whatman NO. 42 filter paper. It was then transferred to a 50 mL volumetric flask by adding distilled water.

D. Collection and digestion of vegetable samples

Vegetable samples were taken in the agricultural fields around the commune where they were known to be affected by waste water and where they were not (control). Samples of seven different kinds of vegetables; leafy vegetables included

Table 1. Description of vegetable samples analyzed

Common Name	Designation	Scientific Name	Edible Parts
Spinach	SP	*Betavulgaris L. CV.*	Leaf
Cabbage	CA	*Brassica oleracea L. Var. Capatuta*	Leaf
Cauliflower	CF	*Brassica oleracea L. Var. botrytis*	Inflorescence
Lady's Finger	LF	*Abelmoschus esculentus L.*	Fruit
Brinjal	BR	*Solanum melongena L.*	Fruit
Tomato	TO	*Lycopersicon esculentum L.*	Fruit
Radish	RA	*Raphanus sativus L.*	Root

Spinach (SP) (*Betavulgaris L. CV.* All green), and Cabbage (CA) (*Brassica olerācea L. Var. Capatuta*). Inflorescence vegetable included Cauliflower (CF)(*Brassica oleracea L. Var. botrytis*), Fruit vegetables included Lady's Finger (LF) (*Abelmoschus esculentus L.*), Brinjal (BR)(*Solanum melongena L.*), Tomato (TO) (*Lycopersicon esculentum L.*) and Root vegetable included Radish (RA) (*Raphanus sativus L.*) were taken from the same experimental sites where waters and soils samples were taken . The detailed of the vegetable samples collected from the experimental sites are given in Table 1. Vegetable sample were collected randomly by hand using vinyl gloves carefully packed into polyethylene bags and the whole plant body was brought to the laboratory from each experimental site in order to estimate heavy metals. Cleaning (soil removal) of vegetable plant samples was performed by shaking and also by means of a dry pre-cleaned vinyl brush. Only edible parts of different vegetables were randomly taken from each experimental site. Freshly collected mature vegetable samples from each experimental site were brought to the laboratory and washed primarily with running tap water, then in distilled water and finally rinsed carefully in demonized water to remove any attached dust pollen particles (Burton and Patterson, 1979). Vegetable samples were also digested according to Allen *et al.*, (1986) as described above.

E. Analysis of samples

Concentrations of Fe, Zn, Cu, Pb, Cd, Mn and Cr in the filtrate of digested soil, water and different kind of vegetables samples were estimated by using an Atomic Absorption Spectrophotometer (AAS, Perkin Elmer analyst 400). The instrument was fitted with specific lamp of particular metal. The instrument was calibrated using manually prepared standard solution of respective heavy metals as well as drift blanks. Standard stock solutions of 1000 ppm for all the metals were obtained from Sisco Research Laboratories Pvt. Ltd., India. These solutions were diluted for desired concentrations to calibrate the instrument. Acetylene gas was used as the fuel and air as the support. An oxidising flame was used in all cases.

F. Quality Control Analysis

Quality control measures were taken to assess contamination and reliability of data. For this Blank samples (zero metal concentration) were analyzed after seven samples. Concentrations were calculated on a dry weight basis. All analysis was replicated three times. The accuracy and precision of metal analysis were checked against NIST (National institute of standard and Technology)-SRM (Standard Reference Material) 1570 for every heavy metal.

BIOCONCENTRATION CALCULATION

A. Transfer Factor (TF)

Metal concentrations in the extract of soils and vegetables were calculated on the basis of dry weight (mg/kg). TF was calculated as follows (Cui *et al.*, 2004):

$$TF = \frac{C_{(Vegetable)}}{C_{(Soil)}} \qquad (1)$$

Where,

$C_{(Vegetable)}$ represent the heavy metal concentration (mg/kg) in extract of edible parts of vegetables & $C_{(Soil)}$ represent the heavy metal concentration (mg/kg) in soils from where the vegetable was grown.

B. Statistical analysis

Statistical analysis of data was done by SPSS 17. For water, soil, vegetable and site, two-way ANOVA was used. Pearson's Correlations between the vegetable and the soil were also worked out. Statistical significance of means was computed using Pair Samples t-test, with a significance level of $P < 0.001$ (Steel and Torrie, 1980).

III. RESULTS AND DISCUSSIONS

A. Level of heavy metals in water, soil & vegetables

The present study had generated data on heavy metals (Fe, Zn, Cu, Pb, Cd, Mn and Cr) in water, soil and different kind of vegetables (edible parts) from waste water irrigated sites of Rewa, India and associated risk assessment for consumer's exposure to heavy metals. Pb, Cd, Mn and Cr concentration in waste waters; Cd concentration in waste water irrigated soils and Pb, Cd and Cr concentration in all tested vegetables (from WWI sites) were above the national and international permissible limits. These accumulated heavy metals from Waste Water Irrigated area of Rewa (J.P.Cement Plant of Bela &Naubasta) had affected soil and water for a long time. People living in the contaminated area are at greater risk for health issues than individuals in the reference area. Children are at somewhat higher risk than adults. Heavy metal concentrations were several fold higher in all the collected samples from waste water irrigated sites compared to clean water irrigated ones.

B. Transfer Factor of heavy metals from soil to vegetables

In all sites of WWI &, CWI, TF of the heavy metals from soil to vegetables are presented in Fig 1, 2 & 3. These factors were based on roots uptake of the metals and discount the foliar absorption of atmospheric metal deposits (Lokeshwari and chandrappa 2006; Awode *et al.,* 2008). The TF values between waste and clean water irrigated soils were not significantly different. The values of TF obtained from each sites were below (1). The TF values of Fe, Zn, Cu, Pb, Cd, Mn and Cr for various vegetables varied greatly between plant species and location. From the results, the highest TF value was observed for Cu in Spinach (0.634) at WWI-Bela site while lowest was in Cd in Cauliflower (0.015) at CWI-Bhiti village. The higher value of TF suggests poor retention of metals in soil and/or more translocation in vegetables. Because metal with high TF are easily transferred from soil to the edible parts of vegetables than ones with low TF. The higher uptake of heavy metals in leafy vegetables may be due to higher transpiration rate to maintain the growth and moisture content of these plants (Gildon and Tinker (1981). The present result agrees with the investigation made by (Zhuang et al. 2009) in the food crops in the vicinity of Dabaoshan mine, South China where the Bioaccumulation factors for heavy metals were significantly higher for leafy than non-leafy vegetables. Similarly high transfer factor value for Cu in Spinach from WWI site of Beijing, China, reported by Yong-Guan *et al.*, (2004). Due to the high conc. of exchangeable Cu in vegetable soils, the Cu in edible parts of Spinach probably came from the root uptake from soils. The lowest values of the Cu in Cauliflower may be the absence of Cd concentration in soil of CWI-site. Thus a major pathway for Cd to enter the above- ground edible parts of Cauliflower, from vegetable soils, may be through application of fertilisers by farmers.

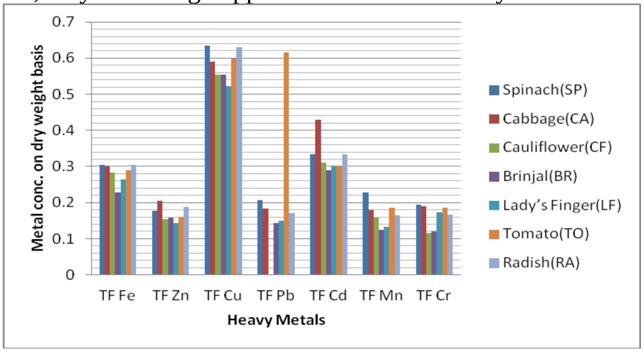

Fig.1. Transfer Factor of heavy metals for vegetables of WWI site of Bela

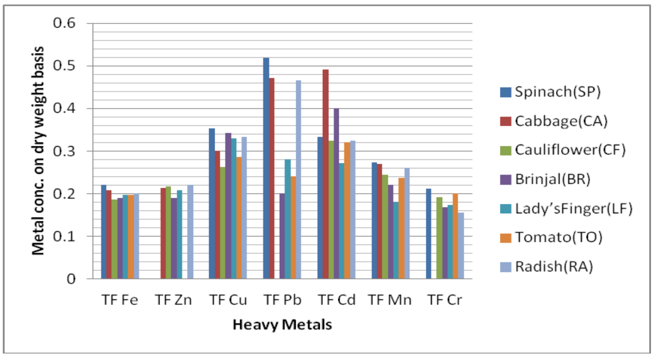

Fig.2. Transfer Factor of heavy metals for vegetables of WWI site of Naubasta

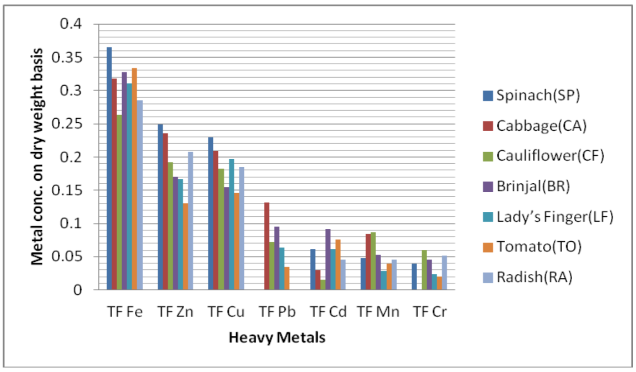

Fig.2. Transfer Factor of heavy metals for vegetables of CWI site of Bhiti

C. *Pearson's Correlation Coefficient for Transfer Factor*

The Pearson's correlation coefficient of heavy metals in soils and different kind of vegetables are summarised in table 2.

VEG	TF_{Fe}	TF_{Zn}	TF_{Cu}	TF_{Pb}	TF_{Cd}	TF_{Mn}	TF_{Cr}
FOR WWI SITE OF BELA							
SP	-0.389	0.395*	-0.232*	-0.711**	0.837**	-0.502**	0.972**
CA	-0.502**	-0.011 ^{NS}	0.370*	0.204*	0.947**	-0.226 *	0.942**
CF	-0.130*	-0.643**	-0.005 ^{NS}	0.409*	0.182*	-0.021 ^{NS}	0.850**
BR	-0.499*	-0.577**	-0.190*	0.362*	-0.207*	-0.660**	0.842**
LF	-0.217*	-0.208*	-0.144*	-1.35*	-0.001 ^{NS}	-0.498*	0.590**
TO	-0.225*	-0.0522 ^{NS}	-0.412*	-0.570**	0.002 ^{NS}	0.758**	0.883**
RA	-0.358*	-0.211*	-0.070 ^{NS}	0.010 ^{NS}	-0.009 ^{NS}	0.334*	-0.996**
FOR WWI SITE OF NAUBASTA							
SP	-0.382*	-0.447*	0.999**	-0.988**	-0.246*	0.996**	0.315*
CA	-0.710**	-0.201*	0.946**	0.332*	1.00**	0.936**	-0.760**
CF	-0.529**	0.535**	0.285*	-0.511**	-0.974**	0.972**	0.858**
BR	-0.437*	-0.971**	0.971**	-0.837**	-0.710**	0.789**	0.542**
LF	-0.326*	0.992**	0.169*	-0.989**	0.946**	-0.061 ^{NS}	0.356*
TO	0.793**	-0. 689**	-0. 214*	-0. 888**	0. 683**	-0. 991**	-0.751**
RA	-0.094 ^{NS}	-0.979**	-0.572**	-0.954**	0.893**	-0.239*	-0.629**
FOR CWI SITE OF BHITI							
SP	0.683**	-0.912**	-0.939**	-0.210*	-0.818**	0.971**	0.539**
CA	0.479*	0.845**	-0.569**	-0.236*	-0.972**	-0.318*	0.421*
CF	-1.48**	-0.963**	0.980**	0.451*	-0.689**	0.656**	0.168*
BR	0.970**	-0.421*	0.738**	0.516**	-0.044 ^{NS}	0.046 ^{NS}	-0.139*
LF	-0.169*	0.437*	-0.371*	0.016 ^{NS}	0.283*	0.721**	0.377*
TO	-0.277*	-0. 999**	0. 923**	0. 844**	0. 283*	0. 989**	-0.986**
RA	0.429*	0.956**	0.449*	-0.065 ^{NS}	-0.689**	0.257*	-0.884**

Computation of Pearson's correlation coefficient of heavy metals between soils and vegetables showed that for some vegetables; there were positive but not significantly correlation found while for other vegetables it was positively and significantly correlated. Positive correlation suggested that the metal in different kind of vegetables were translocated efficiently from the soil through root system (Agbenin *et al.*, 2009). However most vegetables showed negatively and significantly while other showed negative but not significantly correlation (Table 2). Negative correlation indicated that higher concentration of heavy metals present in soils but in comparison much lower concentration were found to be in vegetables of that soils. This was due to poor retention capabilities of different edible parts of vegetables. TF values decreases with increasing respective metal concentration in soils, indicating an inverse relationship between transfer factor and metal concentration such inverse relationship were also reported by Wang *et al.*, (2006).

IV. CONCLUSIONS/RECOMMENDATION

This study indicated that long term and indiscriminate application of waste water or letting of waste water directly to agricultural field without prior treatment which contain heavy metals in association with sludge particles may cause accumulation of toxic metals in surface and sub surface soils. And build up of heavy metals in soil profile may prove not only to plants and animals but also to consumers of harvested crops and vegetables. The vegetable samples were taken in the month of May when the temperature was high and also, the study area had received minimum rainfall in the recent years. This may also have contributed to the higher concentration of metals in the soil. It may be expected that during the summer season the relatively high decomposition rate of organic matter is likely to release have metals in soil solution for possible uptake by vegetables. Soil to vegetable transfer is one of the key components of human exposure to metals through food chain. In this study, the soil to vegetable transfer factor (TF) for various heavy metals and for most common vegetables consumed by human being were calculated and data showed that the TF values differed significantly between soil and vegetable concentrations the difference in TF values among different vegetables may be attributed to differences in element uptake by different vegetables.**Present studies on uptake of heavy metals through vegetables and the correlation between the heavy metals content in soil and vegetables are necessary to further understand the problem and to plan remedial measures with public participation.

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