

# Human health risk assessment of heavy metals via dietary intake of vegetables grown in wastewater irrigated area of Rewa, India

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**Abstract-** In India, farmers are blindly using untreated industrial waste water for crops and vegetable production especially in peri-urban areas. Nowadays, increasing attention has focused on heavy metal concentrations of vegetables all over the world. Heavy metals have positive and negative roles in human life. Intake of vegetables is an important path of heavy metal toxicity to human being. The use of industrial waste water for irrigation exposes humans at various health risks. This is because heavy metals are not easily biodegradable and consequently can be accumulated in human vital organs. This situation cause varying degree of illness based on acute and chronic exposures. The present study was conducted to assess the risk to human health by heavy metals (Fe, Zn, Cu, Pb, Cd, Mn and Cr) through the intake of locally grown vegetables in Rewa city (M.P.) India, where, soils contaminated with heavy metals were mainly due to waste water irrigation from Cement Plants (Bela and Naubasta) and may be possible atmospheric deposition. The higher standard deviation reveals higher variation as in the heavy metal distributions from the point source of emission to the adjacent areas. In present study a value of intake of heavy metals in human diet was calculated to estimate the risk to human health. From the results the hazardous quotient (HQ) of all studied heavy metals indicated that all vegetables were safe with no risk to human health except for Pb (>1.0 to near 1.0) contamination in Spinach, Cauliflower and Radish had potential for human health risk due to consumption of these vegetables grown in the area having long term uses of untreated waste water for irrigation. Children are at somewhat higher risk than adults. However, DIR (<1.0) & HI (within 1.0 to near 5.0) for all studied vegetables was found to be safe i.e. free of risks, it is therefore indicated that there is a relative absence of health risks associated with the ingestion of contaminated vegetables.

**Index Terms-** Average Daily Dose, Daily Intake Rate, Hazardous Quotient, Health Risk (Hazardous) Index, Heavy Metals

## I. INTRODUCTION

Heavy metals contamination is a major problem of our environment and they are also one of the major contaminating agents of our food supply. This problem is receiving more and more attention all over the world, in general and in developing countries in particular. The tradition of growing vegetables within and at the edge of industrial area of the cities is very old. It is revealed that most of these cultivated lands are contaminated with heavy metals contributed through industrial waste water irrigation. These contaminated soils have resulted in the growth of contaminated vegetables. Heavy metals in soil reduce the yield of vegetables because of disturbing the metabolic processes of plants (Abdulla and Igbal, 1991). The probability risk assessment technique has been adopted by a number of researchers (Solomon *et al.*, 1996; Giesy *et al.*, 1999; Cardwell *et al.*, 1999; Hall *et al.*, 1999, 2000; Wang *et al.*, 2002) to fully utilize available exposure and toxicity data. However, these methods are only applied to quantify the magnitude of health risks of carcinogenic pollutants, but not for quantifying non cancer risks. Current non cancer risk assessment methods do not provide quantitative estimates on the probability of experiencing non cancer effects from contaminant exposures. These are typically based on the hazard quotient (HQ), which is a ratio of determined dose of a pollutant to the dose level (a Reference Dose or  $RfD_0$ ). If the ratio is less than 1, there will not be any obvious risk. Conversely, an exposed population of concern will experience health risks if the dose is equal to or greater than the  $RfD_0$ . The method for the determination of THQ was provided in the U.S. EPA Region III risk-based concentration table (US EPA, 2000a). It was further assumed that the ingested dose is equal to the absorbed pollutant dose as stated in the U.S. EPA guidance (US EPA, 1989). Although the HQ-based risk assessment method does not provide a quantitative estimate on the probability of an exposed population experiencing a reverse health effect, it indeed provides an indication of the risk level due to pollutant exposure. This risk estimation method has recently been used by Chien *et al.*, (2002) and proved to be valid and useful. This non cancer risk assessment method was also applied in this study. The U.S. EPA is developing approaches for quantitative estimates of health risks for non carcinogenic effects. Similar techniques used in cancer risks (i.e., dose-response data and linear low dose extrapolation) are being applied for these purposes, but are not yet widely use (US EPA, 2000b). The suburban area of Rewa City, India, are polluted by various heavy metals (Tiwari *et al.*, 2011), but information on the health risks of these metals is quite limited. The main objective of this study is to estimate the health risks of heavy metals, such as Fe, Zn, Cu, Pb, Cd, Mn, and Cr, via consumption of vegetables to the general public in Rewa(M.P.), India, near industrial areas using the hazard quotient (HQ) estimates.

## II. MATERIALS AND METHODS

### General description of the 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° North latitude and 81.3° East longitudes and covers an area of 6,240 km<sup>2</sup> (2,410 sq mi) (sources: WGS 84 coordinate reference system). It has an elevation of 304 m. (997 ft) above mean sea level. Time zone offset: IST, UTC+5:30 hours. Rewa has a humid subtropical climate with cold, misty winter, a hot summers and a humid monsoon season. The climate of Rewa city sometimes changes to extremes. In summer, the temperature is vary from the lowest of 30°C (86°F) to the maximum of more than 40°C (104°F). Usually first monsoon shower comes in between end of June to early July. The average rainfall is 980 mm (39 inches) per year. The average temperature is around 25°C (77°F) and the humidity is quite high. Experimental sites of different irrigation sources J.P. Cement Plants Bela (WWI-Bela), Naubasta (WWI- Naubasta) (waste water irrigated sites) & Bhiti (control) 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 varying irrigation sources were selected and the sampling of water, soils and vegetables of the surrounding areas were carried out to estimate intake of heavy metals by local inhabitants.

### Water, soil and vegetables sampling and analyses

Water and soil samples collected randomly from different location. Samples of seven different kinds of vegetables; leafy vegetables included Spinach (SP) (*Betavulgaris L. CV. All green*), and Cabbage (CA) (*Brassica oleracea 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. Only edible parts of different vegetables were randomly taken from each site. The detailed of the vegetable samples collected from the experimental sites are given in Table 1. All samples were labeled and brought to the laboratory for analysis. 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 oxidizing flame was used in all cases.

Table 1. Description of vegetable samples analyzed

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

### 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.

### Health risk calculation

#### Daily Intake Rate (DIR)

For the Daily Intake Rate (DIR), the average metal content in each vegetable was calculated and multiplied by the respective consumption rate. Daily Intake Rate (DIR) was determined by the following equation (Arora *et al.*, 2008; Sajjad *et al.*, 2009):

$$DIR = C_{(Metal\ conc.)} \times C_{(Factor)} \times D_{(Vegetable\ intake)} \quad (1)$$

Where,

$C_{(Metal\ conc.)}$  = Heavy metal concentration in vegetables (mg/kg);  $C_{(Factor)}$  = conversion factor (0.085);  $D_{(Vegetable\ intake)}$  = Daily Intake of Vegetable (kg person<sup>-1</sup>day<sup>-1</sup> FW).

The conversion factor of 0.085 is set to convert fresh vegetable weight to dry weight based on Eqn. (Rattan *et al.*, 2005; USDA, 2007).

$$IR_{dw} = IR_{ww} \left[ \frac{100-W}{100} \right] \tag{2}$$

Where,  $IR_{dw}$  = dry-weight intake rate;  $IR_{ww}$  = wet-weight intake rate &  $W$  = percent water content.

**Average Daily Dose (ADD: mg kg<sup>-1</sup> day)**

The average daily vegetable intake rate (ADD) was calculated by conducting a survey where 100 people having average body weight of 60 kg were asked for their daily intake of particular vegetable from the experimental area (Wang *et al.*, 2005; Sajjad Khan *et al.*, 2009).

Where,

the average daily intake for adults and children were set to 0.345Kg and 0.232 kg person<sup>-1</sup>day<sup>-1</sup> (expressed as fresh weight), respectively while the average adult and child body weights were set to 60 and 32.7 kg, respectively in this study ;based on Eqn.( EPA 1989d, 2010e):

$$ADD = \frac{C \times IR \times FI \times EF \times ED}{BW \times AT} \tag{3}$$

Where,

$C$  = Contaminant concentration in vegetable (mg kg<sup>-1</sup>);  $IR$  = Ingestion rate per unit time or event (kg day<sup>-1</sup>);  $FI$  = Fraction ingested from contaminated source (unit less);  $EF$  = Exposure frequency (days/year);  $ED$  = Exposure duration (70 years; lifetime; by convention) is the length of time that a receptor is exposed via a specific exposure pathway;  $BW$  = Body weight;  $AT$  =Pathway specific period of exposure for no carcinogenic effects (i.e.,  $ED \times 365$ days/year), and 70 year lifetime for carcinogenic effects (i.e., 70 years  $\times 365$  days/year).Upper tolerable daily intake limit (safe limits) for both adults and children through the consumption of vegetables were presented in Table 2.

Table 2.Upper tolerable daily intake limit for both adults and children

Upper tolerable daily intake (mg day <sup>-1</sup> )	
Heavy Metals	Integrated Risk Information System (US EPA 2009)
Fe	45E-00
Zn	40E-00
Cu	10E-00
Pb	2.40E-01
Cd	6.40E-02
Mn	11E-00
Cr	1.05 E-02

**Hazardous Quotient (HQ)**

Hazardous Quotient (HQ) for the locals (consumers) through the consumption of contaminated vegetables was assessed by the ratio of Daily Intake Rate (DIR) to the oral reference dose ( $R_fD_o$ ) for each metal (USEPA 2013). If the value of HQ is less than 1, then the exposed local population (consumers) is said to be safe, if HQ is equal to or higher than 1, is considered as not safe for human health, therefore potential health risk occurred, and related interventions and protective measurements should be taken (US-EPA, 2013). An estimate of risk to human health (HQ) through consumption of vegetables grown in metal contaminated soil was calculated by the following equation:

$$HQ = \frac{DIR}{R_fD_o} \tag{4}$$

Where,

$R_fD_o$  is the oral reference dose.  $R_fD_o$  is an estimate of a daily oral exposure for the human population, which does not cause deleterious effects during a lifetime (US-EPA, 2009). Table 3 showed the values of oral reference doses ( $R_fD_o$ ) for some heavy metals by IRIS, 2013; DEFRA, 2005 and FAO/WHO, 2013.

Table 3: Oral reference doses (R<sub>f</sub>D<sub>O</sub>) mg kg<sup>-1</sup> day<sup>-1</sup> for heavy metals

Heavy Metals	R <sub>f</sub> D <sub>O</sub> (mg kg <sup>-1</sup> day <sup>-1</sup> )	
	Integrated Risk Information System (US EPA 2013)	FAO/WHO (Codex Alimentarius Commission, 2013)
Fe		7.00 E-01
Zn	-	3.00E-01
Cu	-	4.00E-02
Pb	1.00E-03	4.00E-03
Cd	-	1.00E-03
Mn	-	1.4E-02
Cr	1.5E-00	1.5E-00

### Hazardous Index (HI)

To estimate the risk to human health through more than one HM, the hazard index (HI) has been developed (US EPA, 1989). The hazard index is the sum of the hazard quotients for all HMs, which was calculated by the Eqn. (Guerra *et al.*, 2010).

$$HI = \sum HQ = HQ_{Fe} + HQ_{Zn} + HQ_{Cu} + HQ_{Pb} + HQ_{Cd} + HQ_{Mn} + HQ_{Cr} \quad (5)$$

It assumes that the magnitude of the adverse effect will be proportional to the sum of multiple metal exposures. It also assumes similar working mechanisms that linearly affect the target organ.

### Statistical analysis

The recorded data were subjected to two-way analysis of variance (ANOVA) to assess the influence of different variables on the concentrations of heavy metals in the vegetables tested. Statistical significance of means was computed using Pair Samples t-test, with a significance level of P < 0.001 (Steel and Torrie, 1980). Statistical analysis of data was done by SPSS 17.

## III. RESULTS AND DISCUSSION

### 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.

## HUMAN HEALTH RISK ASSESSMENT

### Estimation of Daily Intake Rate

Daily vegetable consumption was obtained through a formal survey conducted in the urban areas of Rewa to estimate the average consumption of fresh vegetables including Spinach, Cabbage, Lady's Finger, Cauliflower, Brinjal, Tomato and Radish and also may be other vegetables per person per day for both adults and children (Table 4). This Fresh Weight of different kind of vegetables then converted into Dry Weight of vegetables by multiplying with Conversion Factor (0.085). The degree of toxicity of heavy metal to human being depends upon their daily intake (Singh, Sharma, Agrawal and Marshall 2010). DIR as a function of body weight and intake. The DIR estimated for both Bela & Naubasta sites shown in table 4 but did not show for control site because it showed negligible values. In both sites of Bela & Naubasta, the estimated Daily Intakes of heavy metals for both adults and children through the consumption of vegetables in this study was less than tolerable daily intake limit set by the US-EPA, IRIS (2013) (see Table 2 & 4). Radwan and Salama (2006) & Khan *et al.*, (2008) had also observed no risk due to consumption of vegetables grown under waste water irrigated areas. Singh (2010); Sharma (2010); and Zheng *et al.*, 2007 (except for Cd), Khan *et al.*, (2008); and Guerra *et al.*, (2010) also found lower values than tolerable daily intake limits. On the other hand Sridhara Chary *et al.*, (2008) recorded higher DIR values for heavy metals than tolerable daily intake limits. In present study the highest DIR value in vegetables were for Fe (3.48E-02) for children at

Bela site while lowest was for Cd (4.15E-04) for adults at Naubasta site. The highest daily intake of Fe was estimated as 0.034 mg/kg per day which represents approximately 4.97% of  $R_fD_o$  value of 0.700 mg/kg per day for 0.232 kg for children. This higher DIR of Fe was lower than 0.329 mg/kg per day, reported by Santos *et al.*, 2004 and 0.248 mg/kg per day, reported by Biego *et al.*, 1998. While the lowest DIR of Cd was estimated to 0.000415 mg/kg per day which represent approximately 41.5% of  $R_fD_o$  value of 0.001g/kg per day for a 0.345Kg for adults. However The DIR of Fe and Cd were lower than tolerable daily intake (Table 2). This lower DIR of Cd was lower than that reported in literature, which ranged between 0.008 mg/kg and 0.052 mg/kg per day by Santos *et al.*, (2004) & Tripathi *et al.*, (1997).

Table 4: DIR for individual heavy metals caused by the consumption of vegetables

VEGETABLES		INDIVIDUALS DIR (mg person <sup>-1</sup> day <sup>-1</sup> )													
		Fe		Zn		Cu		Pb		Cd		Mn		Cr	
		Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children
FOR BELA SITE	SP	3.02 E-02	3.48 E-02	1.5 E-02	1.75 E-02	9.71 E-03	1.16 E-02	2.17 E-03	2.50 E-03	5.29 E-04	6.09 E-04	7.91 E-03	9.09 E-03	2.15 E-03	2.47 E-03
	CA	2.70 E-02	3.17 E-02	1.75 E-02	2.01 E-02	9.04 E-03	1.04 E-02	1.94 E-03	2.23 E-03	6.81 E-04	7.83 E-04	6.24 E-03	7.18 E-03	2.10 E-03	2.42 E-03
	CF	2.59 E-02	2.98 E-02	1.32 E-02	1.52 E-02	8.50 E-03	9.78 E-03	1.72 E-03	1.98 E-03	4.93 E-04	5.66 E-04	5.51 E-03	6.33 E-03	1.29 E-03	1.48 E-03
	BR	2.09 E-02	2.41 E-02	1.36 E-02	1.57 E-02	8.48 E-03	9.75 E-03	1.51 E-03	1.74 E-03	4.61 E-04	5.30 E-04	4.31 E-03	4.95 E-03	1.33 E-03	1.53 E-03
	LF	2.41 E-02	2.77 E-02	1.23 E-02	1.41 E-02	8.01 E-03	9.20 E-03	1.58 E-03	1.82 E-03	4.77 E-04	5.48 E-04	4.57 E-03	5.26 E-03	1.91 E-03	2.20 E-03
	TO	2.65 E-02	3.05 E-02	1.38 E-02	1.59 E-02	9.16 E-03	1.05 E-02	1.70 E-03	1.95 E-03	5.19 E-04	5.54 E-04	6.44 E-03	7.41 E-03	2.04 E-03	2.35 E-03
	RA	2.78 E-02	3.20 E-02	1.60 E-02	1.84 E-02	9.67 E-03	1.11 E-02	1.80 E-03	2.08 E-03	5.29 E-04	6.09 E-04	5.70 E-03	6.55 E-03	1.84 E-03	2.10 E-03
	SP	2.14 E-02	2.47 E-02	1.91 E-02	2.19 E-02	7.54 E-03	8.67 E-03	3.93 E-03	4.52 E-03	3.97 E-04	4.52 E-04	8.30 E-03	9.55 E-03	2.75 E-03	3.16 E-03
FOR NAUBASTA SITE	CA	2.02 E-02	2.32 E-02	1.77 E-02	2.03 E-02	6.42 E-03	7.38 E-03	3.57 E-03	4.11 E-03	5.77 E-04	6.63 E-04	8.22 E-03	9.44 E-03	2.47 E-03	2.84 E-03
	CF	1.81 E-02	2.08 E-02	1.78 E-02	2.05 E-02	5.60 E-03	6.44 E-03	2.82 E-03	3.20 E-03	3.82 E-04	4.44 E-04	7.41 E-03	8.52 E-03	2.49 E-03	2.86 E-03
	BR	1.84 E-02	2.12 E-02	1.56 E-02	1.80 E-02	7.32 E-03	8.42 E-03	1.52 E-03	1.74 E-03	4.72 E-04	5.42 E-04	6.70 E-03	7.71 E-03	2.19 E-03	2.52 E-03
	LF	1.91 E-02	2.20 E-02	1.71 E-02	1.97 E-02	7.05 E-03	8.10 E-03	2.13 E-03	2.45 E-03	3.20 E-04	3.67 E-04	5.51 E-03	6.34 E-03	2.27 E-03	2.61 E-03
	TO	1.91 E-02	2.20 E-02	1.85 E-02	2.12 E-02	6.14 E-03	7.06 E-03	1.82 E-03	2.09 E-03	3.77 E-04	4.34 E-04	7.21 E-03	8.29 E-03	2.62 E-03	4.48 E-03
	RA	1.96 E-02	2.25 E-02	1.82 E-02	2.10 E-02	7.13 E-03	8.20 E-03	3.54 E-03	4.07 E-03	3.82 E-04	4.40 E-04	7.94 E-03	9.13 E-03	2.03 E-03	2.39 E-03

**Estimation of Hazard Quotient (HQ)**

HQ values were calculated on the basis of the oral reference dose. Oral reference doses ( $R_fD_o$ ) for heavy metals are presented in table 3 (US-EPA, IRIS and FAO/WHO 2013). From the result, in all sites, the HQ values of all heavy metals, in all vegetables were all below the one (1) (except for Pb in Spinach, Cabbage and Radish at Naubasta site) for both adults and children (Table 5). When HQ exceed one (1), there is concern for health effect (Huang *et al.*, 2008). HQ was more than 1 for Pb in Spinach 1.12 E-00 (for adults) and 1.29E-00 (for children); In Cabbage 1.02 E-00 (for adults) and 1.17 E-00 (for children) and In Radish 1.01 E-00 (for adults) and 1.16 E-00 (for children) at Naubasta site (Table 5). Sridhara Chary *et al.*, (2008) also found HQ in Spinach as high as 5.3 E-00. This high HQ for Pb observed in Spinach, Cabbage and Radish had greatest potential to pose health risk to the consumer. The results indicated that those living around the Cement Plant of Naubasta area of Rewa were probably exposed to some potential health risk through the intake of Pb via consuming locally grown Spinach, Cabbage and Radish but for remains vegetables it was found to be nearly free of risk. Even though there was no apparent risk when each metal was analysed individually, the potential risk could be multiplied when considering all heavy metals. Although HQ was higher for Pb in SP, CA and RA neither population suffered from ingestion of vegetables contaminated with heavy metals. Higher HQ for Pb were also

reported by Zheng *et al.*, (2007) in vegetables collected from waste water irrigated area of Huludao Zinc Plant in Huludao city, China; & In vegetables from Pb and Sb smelter in Nanning, China reported by Cui *et al.*, 2004. In the present study, all heavy metals (except for Pb at Naubasta site) were least responsible for causing risk to the local population as the value of HQ was below 1 for all the vegetables from waste water irrigated area of Rewa (M.P.), India.

Table 5: HQ for individual heavy metals caused by the consumption of vegetables

VEGETABLES		INDIVIDUALS HQ													
		Fe		Zn		Cu		Pb		Cd		Mn		Cr	
		Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children	Adults	Children
FOR BELA SITE	SP	0.432 E-01	0.497 E-01	0.507 E-01	0.583 E-01	0.242 E-00	0.279 E-00	0.622 E-00	0.715 E-00	0.529 E-00	0.609 E-00	0.565 E-00	0.649 E-00	0.143 E-02	0.164 E-02
	CA	0.394 E-01	0.452 E-01	0.585 E-01	0.672 E-01	0.226 E-00	0.260 E-00	0.554 E-00	0.637 E-00	0.681 E-00	0.783 E-00	0.446 E-00	0.513 E-00	0.140 E-02	0.161 E-02
	CF	0.370 E-01	0.426 E-01	0.441 E-01	0.507 E-01	0.212 E-00	0.244 E-00	0.493 E-00	0.566 E-00	0.493 E-00	0.566 E-00	0.393 E-00	0.452 E-00	0.860 E-03	0.989 E-03
	BR	0.427 E-01	0.344 E-01	0.456 E-01	0.524 E-01	0.212 E-00	0.243 E-00	0.433 E-00	0.497 E-00	0.416 E-00	0.530 E-00	0.308 E-00	0.354 E-00	0.891 E-03	0.102 E-02
	LF	0.344 E-01	0.396 E-01	0.410 E-01	0.471 E-01	0.200 E-00	0.230 E-00	0.454 E-00	0.522 E-00	0.477 E-00	0.548 E-00	0.327 E-00	0.376 E-00	0.127 E-02	0.146 E-02
	TO	0.379 E-01	0.436 E-01	0.981 E-01	0.531 E-01	0.229 E-00	0.263 E-00	0.487 E-00	0.559 E-00	0.519 E-00	0.554 E-00	0.460 E-00	0.529 E-00	0.136 E-02	0.156 E-02
	RA	0.398 E-01	0.457 E-01	0.536 E-01	0.616 E-01	0.241 E-00	0.278 E-00	0.517 E-00	0.594 E-00	0.529 E-00	0.609 E-00	0.407 E-00	0.468 E-00	0.122 E-02	0.140 E-02
FOR NAUBASTA SITE	SP	0.307 E-01	0.353 E-01	0.637 E-01	0.732 E-01	0.188 E-00	0.216 E-00	1.12 E-00	1.29 E-00	0.393 E-00	0.452 E-00	0.593 E-00	0.682 E-00	0.183 E-02	0.211 E-02
	CA	0.289 E-01	0.332 E-01	0.590 E-01	0.678 E-01	0.160 E-00	0.184 E-00	1.02 E-00	1.17 E-00	0.382 E-00	0.663 E-00	0.587 E-00	0.674 E-00	0.164 E-02	0.189 E-02
	CF	0.258 E-01	0.297 E-01	0.596 E-01	0.685 E-01	0.140 E-00	0.161 E-00	0.807 E-00	0.928 E-00	0.382 E-00	0.440 E-00	0.529 E-00	0.608 E-00	0.166 E-02	0.190 E-02
	BR	0.264 E-01	0.303 E-01	0.522 E-01	0.600 E-01	0.183 E-00	0.210 E-00	0.434 E-00	0.499 E-00	0.472 E-00	0.542 E-00	0.479 E-00	0.550 E-00	0.146 E-02	0.168 E-02
	LF	0.274 E-01	0.315 E-01	0.572 E-01	0.657 E-01	0.176 E-00	0.202 E-00	0.610 E-00	0.701 E-00	0.320 E-00	0.367 E-00	0.394 E-00	0.453 E-00	0.151 E-02	0.174 E-02
	TO	0.273 E-01	0.314 E-01	0.617 E-01	0.709 E-01	0.153 E-00	0.176 E-00	0.521 E-00	0.599 E-00	0.377 E-00	0.434 E-00	0.515 E-00	0.592 E-00	0.174 E-02	0.298 E-02
	RA	0.280 E-01	0.322 E-01	0.609 E-01	0.700 E-01	0.178 E-00	0.205 E-00	1.01 E-00	1.16 E-00	0.382 E-00	0.440 E-00	0.567 E-00	0.652 E-00	0.135 E-02	0.155 E-02

**Estimation of Hazard Index (HI)**

An Index of Risk called Hazard Index (HI) for residents of ingesting these metals by consuming vegetables grown around waste water irrigated areas were calculated by summation of HQ of all heavy metals for each vegetable (Fig. 1 & 2). In present study the highest HI of heavy metals was found in Cabbage (2.80E-00; 20%) for children at WWI-Naubasta site whereas lowest was in Brinjal and Lady's Finger (1.50 E-00; 12%) for adults at WWI-Bela site whereas negligible (<0.00 E-00) values were found for CWI site. Although HI was higher in Cabbage for children, neither population suffered from ingestion of Cabbage contaminated with heavy metals. HI values of Heavy metals for all vegetables were between 1 to 5 (one to five) by US-EPA, IRIS, indicated that there was no risk from the intake of these vegetables. Huang *et al.*, (2008) and Wang *et al.*, (2005) were also recorded minimum contribution of heavy metals to aggregated risk via consumption of vegetables in Kunshan and Tianjin, China.

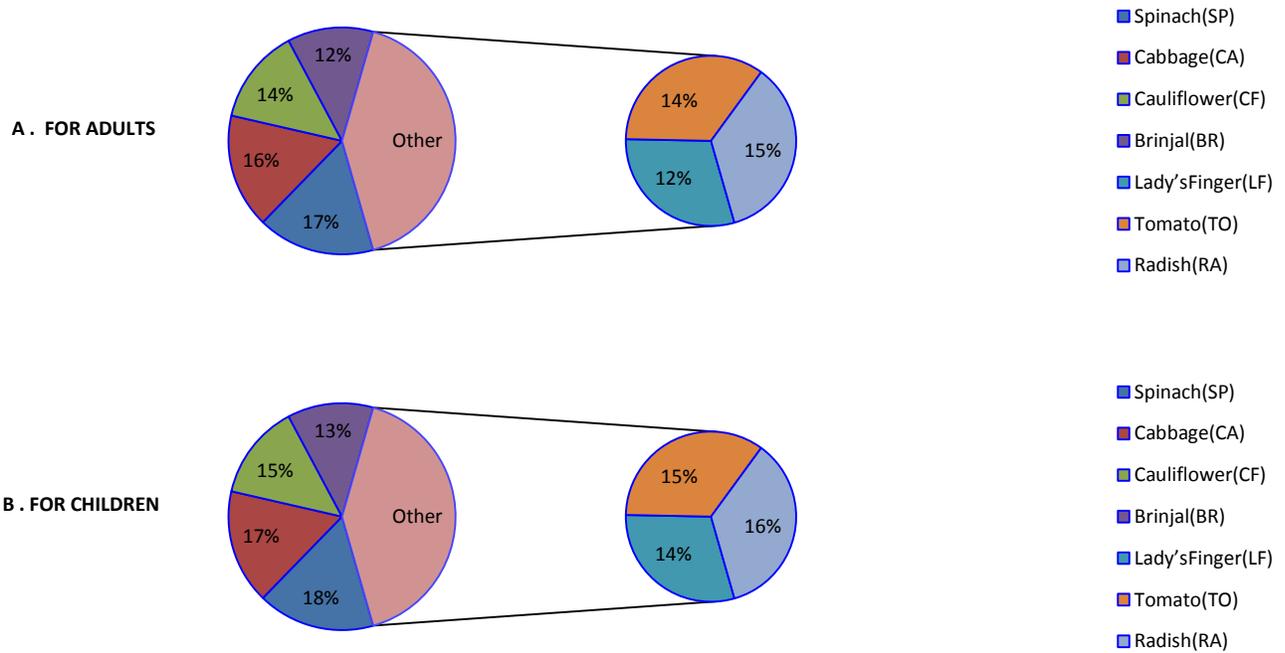


Fig.1: Hazard Index (HI) for individuals through consumption of different vegetables collected from Bela

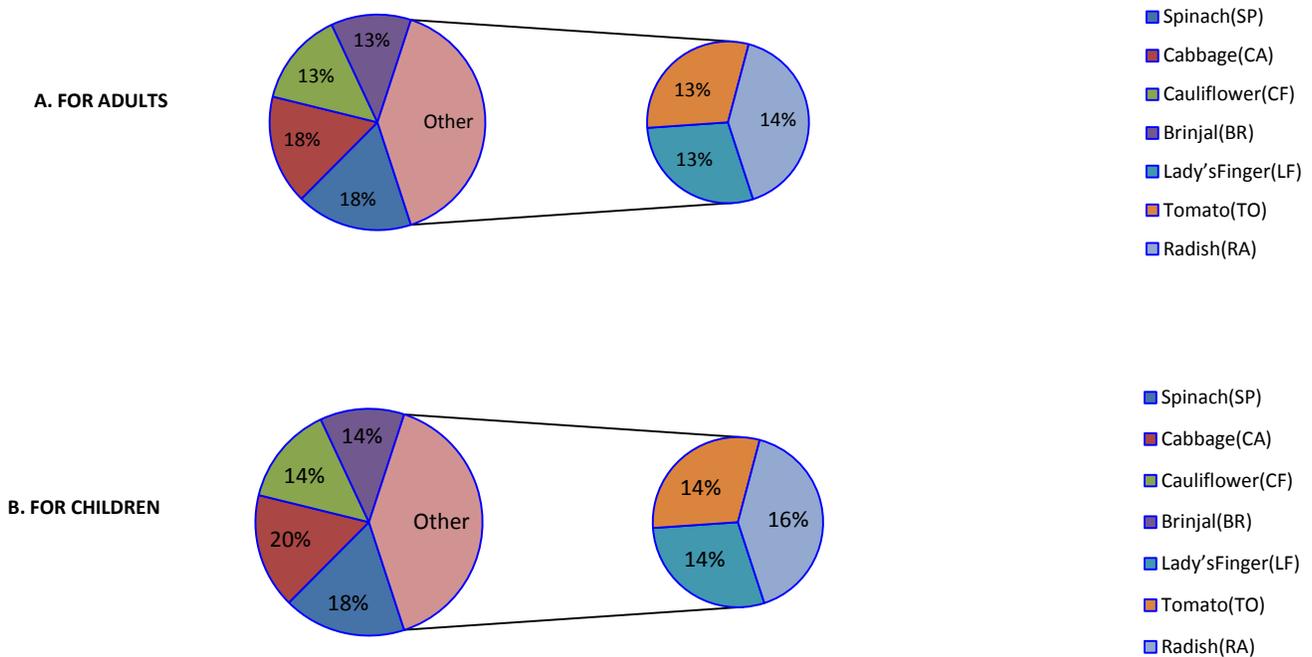


Fig.2: Hazard Index (HI) for individuals through consumption of different vegetables collected from Naubasta

#### IV. CONCLUSION

The present study was carried out around sub urban area of Rewa city, a small sized city of india, where irrigation of vegetables with waste water was a very common practice. Knowledge on the contamination of vegetables with heavy metals from waste water irrigation (WWI) sites of Rewa is not yet established. The present study had generated data on heavy metals 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. The finding of this study regarding DIR, HQ and HI showed that the consumption of vegetables grown in waste water irrigated soils was nearly free of risks (except for Pb in Spinach, Cabbage and Radish at Naubasta site). Consumption of these vegetables with elevated levels of heavy metals may lead to high level of body accumulation causing related health disorders. But the situation could however change in the future depending on the dietary pattern of the community and the volume of contaminants added to the ecosystems. Thus regular monitoring of heavy metal contamination in the vegetables grown at waste water irrigated area is necessary and consumption of contaminated vegetables should be avoided in order to reduce the health risk caused by taking the contaminated vegetables. The waste water treatment technology should involve steps to remove heavy metals causing risk to human health.

#### Recommendations

- Ⓡ Taking the health risks in diet as a result of high level of heavy metals in vegetables, the maximum allowable levels of these metals in vegetables should not exceed levels that reflect good agriculture practices. Farmers should be educated on the problems associated with excessive usage of fertilizers and other chemicals, as well as irrigating the vegetables with waste water and the need to grow vegetables with safe levels of heavy metals. The data generated must be used as baseline wastewater quality framework to serve as a basis for monitoring irrigation water quality in urban areas of Rewa to ensure safety.
- Ⓡ The high HQ of Pb suggested that the consumption of Spinach grown in waste water irrigated site of Naubasta is not free of risks. Responsible agencies should carry out public health education within the consumption area to sensitise the general public on the potential effects of indiscriminate disposal of waste and the potential health hazards associated with the consumption of vegetables cultivated with wastewater. Measures must be taken to reduce heavy metal pollution and nutrient loading of irrigation water and soils to protect the safety of both farmers and consumers.

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