Wastewater From Natural Drainage of Rural Areas is a Healthier Irrigation Practice

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Abstract - The present study was carried out for safety assessment of wastewater irrigation from Bairagiya nala which is a natural drainage in rural areas of Allahabad. It involves investigation of different heavy metals like Fe, Mn, Cu, Zn, Pb and Ni in soil and vegetables irrigated with wastewater from natural drainage. The soil along the sides of the wastewater channel shows higher productivity and concentration of heavy metals than the crops away to it but lies within the safe limits of WHO/ FAO. The order of metal concentration was found to be Fe > Zn > Mn > Ni > Cu > Pb in wastewater used for irrigation and for wastewater irrigated soil the order of mean concentration of metals was Fe>Mn>Zn>Cu>Pb>Ni. The study reveals that there is significant relation between the concentrations of the metals in soil to the concentration of metals in water used for irrigation, but no significant relationship for its transfer to the vegetables. The low concentration of metals in the soil may be ascribed to its continuous removal by vegetables grown in the study areas. Spinach accumulates the maximum heavy metals among the six vegetables (coriander, radish, carrot, mint and cabbage). The study concludes that the natural drainage is being utilized for draining the domestic wastewater in rural areas and same used for irrigation have no hazard to soil and human health if not linked to any industrial discharge.

Keywords: Wastewater Irrigation, Natural Drainage, Heavy Metal, Daily Intake of Metal, Contamination, Health safety, Bairagiya nala, Allahabad.

I. INTRODUCTION

Effluent irrigation has been reported in for throughout the globe from centuries (Tripathi et al., 2011). It provides farmers with a nutrient enriched water supply and society with a reliable and inexpensive system for wastewater treatment and disposal (Feigin et al., 1991). Utilization of wastewater unrestraint the fresh water consumption and promotion of wastewater irrigation facilitate in reducing anthropogenic impacts (Hamilton et al. 2005). According Bixio 2005, to the water stress index i.e. the ratio of a country's total water withdrawal to its total renewable freshwater resources, more than half of the countries are under water stress. The other major environmental benefit from reusing wastewater is reduction in the amount of water need to be extracted for agricultural irrigation. This practice of reusing wastewater poses several threats to the environment via contamination by nutrients, heavy metals, and salts. Moreover long-term application of wastewater increase the load of nitrates in wastewater may increase the risk of groundwater contamination (Stagnitti et al 1998) and accumulation of trace elements such as Cd, Cu, Zn, Cr, Ni, Pb and Mn in surface soil of crop fields can reach the toxic level (Mapanda et al. 2005) which affect food quality.

A number of studies show an elevated level of heavy metals in vegetables grown in areas having long-term uses of treated or untreated wastewater (Sharma et al. 2006; Sharma et al. 2007; Singh et al. 2004). Heavy metals persisting in the environment are non-biodegradable and have the potential to accumulate in different body organs (Radwan and Salama 2006). Food crops are one of the most important component from which the heavy metals enter the food chain (Wang et al. 2004). Prolonged consumption of unsafe concentrations of heavy metals through food stuffs may lead to chronic accumulation of heavy metals in the Kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous Kidney and bone diseases (Jarup 2003). The present study was conducted to assess the heavy metals concentration in the Bairagiya nala, a natural drainage passing through rural areas of Allahabad and its accumulation in soil and vegetables irrigated with this drain.

II. STUDY AREA

The study was carried out around Bairagiya nala, north side of the River Ganga and 30 kilometers east of Allahabad city of Uttar Pradesh, State of India from December 2012-June 2013. Bairagiya nala flows from Phulpur (25°32'31.90"N 82°02'24.05"E) to Rasulpur (25°18'58.48"N 82°05'00.43"E). Six sampling sites in downstream and one control site were considered for the study shown in the map (fig. 1). Bairagiya nala is a natural drainage which drains the runoff and wastewater from different villages in downstream till it joins the river Ganga. It originates from a village pond of Phulpur and not linked to any industrial discharge in its course. The common vegetables grown in the area are considered for study is Spinach (Spinacia olerasea L.), Coriander (Coriandrum sativum L.), Radish (Raphanus sativus L.), Carrot (Daucus carrota L.), Cabbage (Brassica oleracea) and Mint (Mentha viridis L.). Most of the vegetables cultivated in these sites are supplied to the wholesale vegetable markets in Allahabad city and rest of enter the local markets. Kajipur Fatuha (25°25'19.38"N 82°

3'23.53"E) a vegetable cultivating agricultural land 3.2 km from sampling site 4 with no history of wastewater use was chosen as the control site (Yadav et al. 2014).

III. METHODOLOGY

Experiment Design vegetables are collected randomly in triplicate from each sites of agricultural land irrigated with wastewater in downstream of the Bairagiya nala, along with the control site during the months from December 2012-June 2013. For metal analysis only the edible parts of vegetable samples were used (Table 1). All samples were collected and put in clean polythene bags according to their type and brought to the laboratory for preparation and treatment as soon as possible. In each plant sample 6-8 vegetable plants of the same species were collected at random from the fields of the sampling sites by hand using vinyl gloves carefully packed into polyethylene bags and the whole plants body was brought to the laboratory. The cleaning (removal of soil) of vegetable plant samples was performed by shaking and also by means of a dry pre-cleaned vinyl brush. Then the whole vegetable plants bodies were divided into different parts and non-edible portions were removed.

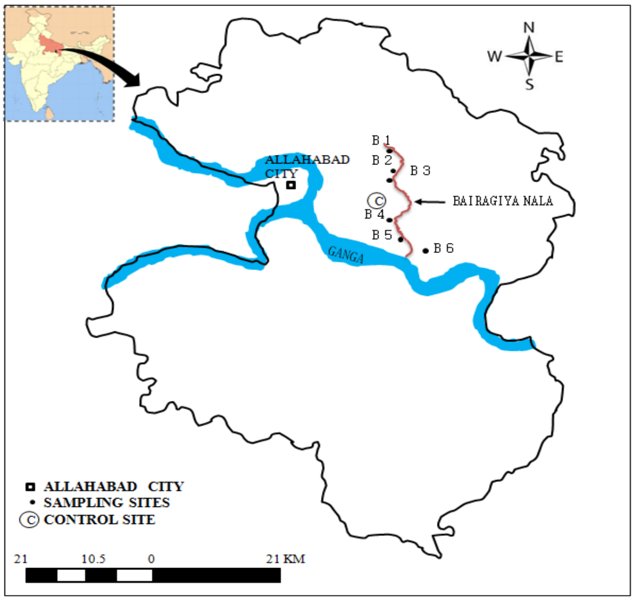

Figure 1: Map of Allahabad District showing sampling sites along the Bairagiya Nala (Yadav et al. 2014)

Table 1: Vegetable samples collected from experimental sites.

Common Name	Botanical Name	Family	Edible parts
Spinach	Spinacia olerasia L.	Chenopodiaceae	Leaf
Coriander	Coriandrum sativum L.	Umbelliferae	Leaf
Radish	Raphanus sativus L.	Brassicaceae	Root
Carrot	Daucus carrota L.	Apiaceae	Root
Mint	Mentha viridis L.	Labiatae	Leaf
Cabbage	Brassica oleracea L.	Brassicaceae	Leaf

The edible parts of the vegetable samples were washed with tap water and subsequently dipped in 0.01N HCl acid, for 5 minutes followed by scrupulous washing in distilled water to remove airborne pollutants. Then the samples were cut into 2-cm pieces and dried in a hot air oven at 70-800C till the constant weight was achieved. The dried samples were grounded in a stainless still blender and then passed through a 2-mm size sieve. Soil samples from the surface soil to a depth of 12cm around each plant root zone were collected simultaneously from the field with the plants. The soil samples were air dried at room temperature finally powdered, and sieved through a 2-mm nylon mesh to remove large debris. Then the 500 gm samples of soil dried at 1050C for 2 hour to remove all the moisture content and homogenized for analysis. The dried samples were wet digested according to standard protocols. For water quality analysis, three replicate polythene bottles (acid washed) of capacity 100 ml were immersed one by one at an interval of 15 seconds into the water of Bairagiya drain that was being used for irrigation purpose, and immediately after filling, 1ml of concentrated HNO3 was added to the water and the bottles were brought back to the laboratory and digestion was completed within a week.

For heavy metal analysis performed according APHA (1985), fifty milliliters of contaminated water samples was digested with 10 ml of concentrated HNO3 at 800C until the solution became transparent. The solution was filtered through Whatman no. 42 filter paper and the filtrate was diluted to 50 ml with distilled and dehumanized water. Method of Allen et al., (1986) used for wet digestion where one gram each of soil and vegetable samples were digested (wet acid digestion) with 15 ml of concentrated HNO3, H2SO4, and HClO4 in 5:1:1 ratio at 80 0C until a transparent solution was obtained. The digested samples of water, soil, and vegetables were filtered through Whatman no. 42 filter paper and the filtrates were diluted to 50 ml with distilled water. All samples were stored at ambient temperature before analysis. Trace elements concentrations in water, soil, and in vegetable samples were estimated by an atomic absorption spectrophotometer (Perkin Elmer AAnalyst 300). Blank samples were analyzed after six samples to minimize the error. Concentrations were calculated on a dry weight basis. The precision and analytical accuracy were checked by analysis of standard reference material, NIST-SRM 2709 for soil, NIST-SRM 1570 for water, and NBS-SRM 1573 for plant samples used by Yadav et al. (2014). The results were found to be within 2% of certified values for every heavy metal. Statistical summary and correlation analysis was performed using Microsoft Excel (version 2007).

IV. RESULT & DISCUSSION

1. Heavy metal concentrations in irrigation water

The heavy metal content found by Yadav et al. 2014 in Bairagiya nala is under the specified limits of FAO for irrigation purposes and also below the limits of drinking water quality for livestock. Fe have highest concentration out of six elements examined in the wastewater used for irrigation in the study area, this is due to fact that availability of iron in soil is more which comes in this natural drainage through runoff. Pb was lowest (0.0041 mg/l, SD: 0.00044) and mean concentration of other metals are; Cu (0.00737 mg/l, SD: 0.00025), Mn (0.48584 mg/l, SD: 0.00047), Zn (0.09239 mg/l, SD: 0.00051) and Ni (0.01692 mg/l, SD: 0.00379). The mean metal concentrations of wastewater irrigation in Bairagiya nala region are less than from different parts of India where wastewater irrigation is a practice. The recorded concentration of heavy metal in the Bairagiya nala is very low as compared with suburban areas of Varanasi, Uttar Pradesh (Sharma et al. 2007, 2006), Titagarh, West Bengal (Gupta et al. 2008), Ramgarh Lake, Gorakhpur, Uttar Pradesh (Singh et al. 2011) Nagpur, Maharashtra (Singh et al. 2012) and in urban area of Naini Allahabad Uttar Pradesh (Yadav et al. 2013). The low concentration of heavy metals in the Bairagiya nala is due to the fact it is not linked to any industrial discharge or sewerage system of any big city or town while other studies mentioned above are done on the drains which are either linked to any industrial discharge of sewerage system.

Table 2: Heavy metal concentrations (mg/l) in wastewater of Bairagiya nala (n=36)

Metals	Mean	Minimum	Maximum	Stn.dev	Recommended maximum concentration a	Livestock Drinking Water
Cu	0.00737	0.00706	0.0078	0.00025	0.2	0.5
Fe	0.48584	0.4835	0.4885	0.00160	5	NA
Mn	0.02402	0.0232	0.0245	0.00047	0.2	0.05b
Zn	0.09239	0.09186	0.0932	0.00051	2	24
Pb	0.00416	0.00366	0.0048	0.00044	5	0.1c
Ni	0.01692	0.011	0.023	0.00379	0.2	NA

Source: (Yadav et al. 2014)

a The maximum concentration is based on a water application rate which is consistent with good irrigation practices (10 000 m3 per hectare per year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 m3 per hectare per year. The values given are for water used on a continuous basis at one site.

b Insufficient data for livestock. Value for human drinking water used.

c Lead is accumulative and problems may begin at a threshold value of 0.05 mg/l.

2. Heavy metal concentrations in Soil

The concentration of heavy metals (mg/Kg dry soil) in agricultural soils of study area in (Table 3) is under the limits of standards of FAO and other regulatory bodies. Fe has the highest mean concentration recorded in soil fallowed by Mn Cu, Zn, Pb, and Ni.

Table 3: Concentration of heavy metals in soil (mg/Kg dry soil) irrigated with wastewater of Bairagiya nala in rural area, Allahabad (n=36).

Metals	Mean	Minimum	Maximum	Stn.dev	Recommended maximum concentration [a]	Limits of MoEF[b]
Cu	1.0716	0.83	1.36	0.1904	140	200
Fe	14.0033	11.02	16.12	2.2583	NA	NA
Mn	9.9416	5.97	14.88	3.8456	NA	1800
Zn	1.62	1.26	1.93	0.2422	300	150
Pb	0.0386	0.032	0.043	0.0039	300	200
Ni	0.011	0.004	0.014	0.0041	75	100

Source: (Yadav et al. 2014)

a. WHO (2007).
b. The Environmental Management Act (Soil Quality Standards) Regulations, 2007.

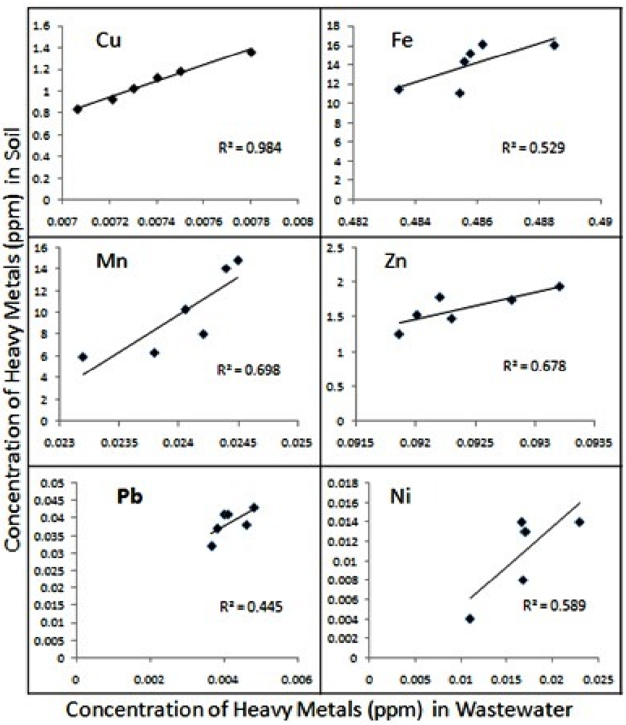

Figure 2: Relationships between heavy metal concentrations in wastewater and soil (Yadav et al. 2014)

The extent of metals observed in agricultural soil of the fields lower than those reported by Kabata-Pendias and Pendias (1992) Temmerman et al. (1984), Gupta et al. (2008), Singh et al. (2012) and by Sharma et al. (2007) Thandi et al. (2004) and Mapanda et al. (2005) in agricultural soil irrigated with wastewater. As the metal concentration in the wastewater of the Bairagiya nala is very less, its mobility to the soil irrigated with is also less as there is very strong positive correlation between concentration of heavy metals in wastewater and transportation of these heavy metals from the wastewater to soil through irrigation. Cu ($r2 = 0.984$; $P<0.01$) recorded the highest degree of correlation followed by Mn ($r2 = 0.698$; $P<0.01$) while other heavy metals show moderate positive correlation (r2, 0.36 to 0.67) between the concentration in wastewater and soil of the study area (Fig. 2).

3. Heavy metal concentration in vegetables.

The heavy metal concentrations in edible parts of vegetables grown in rural areas from Phoolpur to Rasulpur Allahabad irrigated by Bairagiya nala are shown in Table 4 and Fig 4. Concentrations of heavy metals in vegetables were within the safe limit of WHO and Indian standard (Awashthi, 2000). The mean Cu content in vegetables (0.76-0.92mg/Kg) was very low to the result reported in Titagarh west Bengal, India (15.66-34.49 mg/Kg) (Gupta et al. 2008), (61.20 mg/Kg) from Zhengzhou city, China (Liu et al. 2006), (10.95-28.58 mg/Kg) by Sharma et al. (2007). Maximum Cu concentration (1.42 mg/Kg) was found in cabbage whereas the mean value for spinach, coriander, radish, carrot and mint were 0.84, 0.72, 0.78, 0.63 and 0.67 mg/Kg respectively. Which were lower than the mean value 32.74 and 36.41 mg/Kg, respectively, reported by Sharma et al. (2008) for carrot and Mint, 15.5 and 8.51 mg/Kg from Samata village, Jessor, Bangladesh obtained by Alam et al. (2003) for leafy and non-leafy vegetables while higher for carrot and coriander 0.573 and 0.768 mg/Kg reported by Kumar et al 2007.

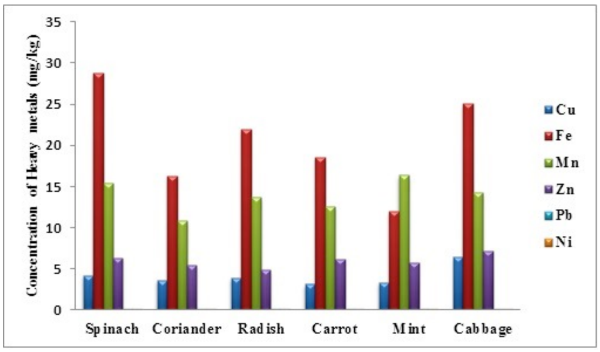

Figure 3: Mean heavy metal concentration in different vegetables.

The mean Fe concentrations varied from (2.39 - 5.76 mg/Kg) which was in very low with concentrations (111-378 mg/Kg) observed in vegetables by Arora et al. (2008). Maximum uptake of Fe was in Spinach (5.76 mg/Kg) followed by cabbage, radish, carrot and mint mentioned in table 4. The lower concentrations of Fe in vegetables were also found very similar to the values (2.11-336.9 mg/Kg) reported by Kisku et al. (2000) for irrigated with mixed industrial effluents in India. The maximum concentrations of Mn is reported in Mint (3.28 mg/Kg) and followed by spinach (3.08 mg/Kg), cabbage (2.86 mg/Kg), radish (2.74 mg/Kg), carrot (2.52 mg/Kg) and coriander (2.17 mg/Kg) respectively.

Table 4: Mean and (Range) of Heavy metal concentration (mg/Kg dry weight) in vegetables grown in wastewater irrigated rural land of Allahabad.

	Cu	Fe	Mn	Zn	Pb	Ni
Spinach	0.84 (0.76-0.92)	5.76 (4.88-6.12)	3.08 (2.82-3.16)	1.274 (1.268-1.28)	0.0147 (0.0141-0.0149)	0.0045 (0.0045-0.0046)
Coriander	0.72 (0.68-0.75)	3.26 (3.03-3.4)	2.17 (2.01-2.24)	1.082 (1.07-1.088)	0.0092 (0.0084-0.0106)	0.0033 (0.0032-0.0034)
Radish	0.78 (0.86-0.72)	4.38 (4.2-4.54)	2.74 (2.62-2.78)	0.976 (0.952-1.014)	0.0171 (0.0167-0.0176)	0.0032 (0.0032-0.0033)
Carrot	0.63 (0.58-0.67)	3.72 (3.64-3.78)	2.52 (2.48-2.56)	1.228 (1.216-1.234)	0.0159 (0.0156-0.162)	0.0032 (0.0031-0.0032)
Mint	0.67 (0.63-0.72)	2.39 (2.32-2.45)	3.28 (3.14-3.36)	1.154 (1.146-1.162)	0.0064 (0.0058-0.0072)	0.0028 (0.0027-0.0028)
Cabbage	1.28 (0.98-1.42)	5.01 (4.78-5.23)	2.86 (2.76-2.88)	1.436 (1.428-1.44)	0.0092 (0.0072-0.0118)	0.0044 (0.0042-0.0045)
Safe Limit[a]	40	450	NA	60	5	20
Safe Limit[b]	30	NA	NA	50	2.5	1.5

a. FAO /WHO standard (Codex Alimentarious Commission 1984).
b. Indian standard Awashthi (2000).

The highest concentration of Zn was found in cabbage (1.436 mg/Kg) followed by spinach (1.274 mg/Kg), carrot (1.228 mg/Kg), mint (1.154 mg/Kg), coriander (1.082 mg/Kg) and radish (0.976 mg/Kg) respectively. The mean concentrations of Zn (0.976 -1.436 mg/Kg) in vegetables study area of Allahabad was very low to the vegetables of Rajasthan, India (21.1-46.4 mg/Kg) (Arora et al. 2008), Titagarh West Bengal, India (3.00-171.03 mg/Kg) (Gupta et al. 2008), Harare, Zimbabwe (1,038-1,872 mg/Kg) (Tandi et al. 2004), Varanasi, India (59.61-79.46 mg/Kg) (Sharma et al. 2008) and also from Delhi India (46.7-91.9 mg/Kg) (Rattan et al. 2005). The concentration of Pb and Ni was found very low in the vegetables grown is the study area with maximum concentration of Pb was exhibited by radish (0.0171 mg/Kg) and spinach (0.0045 mg/Kg). The mean Pb content in vegetables (0.0064-0.0171 mg/Kg) was lower than the values reported by Titagarh, West Bengal, India (21.59-57.63 mg/Kg) (Gupta et al. 2008) and in

Varanasi, India (3.09-154.74 mg/Kg) (Sharma et al. 2007). Mean Ni concentrations in vegetables varied from (0.0028 - 0.0045mg/Kg) which were lower than the data reported for vegetables in Titagarh, West Bengal, India by Gupta et al. (2008), Sharma et al. (2007) (1.81-7.87 mg/Kg) in Varanasi, India and also of Rattan et al. (2005) (8.78-21.5 mg/Kg) in Delhi India.

4. Daily intake of metals

The daily intake of metals (DIM) was determined by the following equation:

$$DIM = mc \times cf \times di / bw$$ (Gupta et al. 2008)

where, "mc" is the metal concentration in vegetables (in milligrams per kilogram) on dry weight basis, cf or the conversion factor of 0.085 was used to convert fresh weight of the vegetables to dry weight as mentioned by Rattan et al. (2005) and "bw" in the equation denotes the body weight (in kilograms). The average daily vegetable intake for adult and children were considered to be 0.345 and 0.232 Kg person/day, respectively, while the average adult and child body weights were considered to be 55.9 and 32.7 Kg, respectively as reported by Wang et al. (2005).

Table 5: Daily intake of heavy metals (in µg/Kg/Day) by an adult for individual metal in different vegetables grown in wastewater irrigated rural land of Allahabad.

	Spinach	Coriander	Radish	Carrot	Mint	Cabbage	RfDa
Cu	0.440662	0.37771	0.409186	0.330496	0.35148	0.671485	400
Fe	3.021682	1.710188	2.297737	1.951503	1.253788	2.628233	850b
Mn	1.61576	1.138377	1.437397	1.321986	1.72068	1.500349	335b
Zn	0.668337	0.567614	0.512007	0.644206	0.605386	0.753322	300
Pb	0.007738	0.004837	0.008971	0.008373	0.003352	0.004826	4
Ni	0.002387	0.001747	0.001689	0.001673	0.001479	0.002287	20

a. Oral reference dose (RfD) by (USEPA, IRIS 2006)
b. Dietary intake limit WHO 1996

The dietary intake of heavy metals for adults in the study area is listed in Table 5. This study shows that the DIM values for heavy metals were low through the consumption of food crops grown with contaminated water to wastewater irrigated vegetables in rural agricultural areas of Allahabad. Oral reference dose (RfD) is an estimate of a daily exposure to human population that is likely to be without an appreciable risk of deleterious effects during a life time (USEPA, IRIS 2006). The highest intake of heavy metals is from consumption of leafy vegetables, spinach and cabbage followed by radish, carrot, mint and coriander (Table 5, all the value are in µg/Kg/Day to avoid calculation error due to very low values of metal content). Dietary intakes of heavy metals for adult the consumption of vegetables are in the safe oral reference RfD limit. Thus, the findings of this study regarding DIM suggest no potential health risk for adults and children with respect to amount of daily intake of heavy metals through ingestion of wastewater irrigated vegetable crops grown nearby fields of Bairagiya nala of Allahabad.

V. CONCLUSION

Heavy metal in wastewater of Bairagiya nala used for irrigation, soil and food crops in the study area of Allahabad were compared with the safe limit provided by WHO (2007), SEPA (2005), FAO /WHO standard (Codex Alimentarious Commission 1984) and Indian standard. The main advantage of wastewater irrigation is increased yield of crops compared to irrigated with well water; it also increase total N, P, K and organic carbon of soil (Ladwani et al. 2012; Hamilton et al. 2005; Singh et al. 2012). The ill effect of the same is uptake of heavy metals by the crops from wastewater treated soil finally inters the food, but it can safe to state that irrigation of agricultural land of rural areas of Allahabad with wastewater has not led any contamination to food crops with heavy metals. Chances of heavy metals contaminations of crops may occur if the rural drainage system get link to any industrial discharge or any other source of contamination in future. Harmful contaminants in untreated industrial wastewater have environmental risks, such as transport in soils, pollution of groundwater and surface-water, degradation of soil quality e.g. salinisation, impacts on plant growth, the transmission of disease via the consumption of wastewater-irrigated vegetables, and even increased greenhouse gas emissions. The challenge facing wastewater reuse is to minimize such risks so as to maximize the net environmental gain.

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