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RESEARCH ARTICLE

IMPACT OF INDUSTRIAL EFFLUENTS DISPOSAL ON SOIL AND CABBAGE GROWN IN DISTRICT HARIDWAR (UTTARAKHAND), INDIA

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ABSTRACT

This investigation was carried out to determine the accumulation of the heavy metals in the cabbage grown in Industrial Estate (IE) effluent irrigated soil in the different villages of district Haridwar (Uttarakhand), India. The results revealed that wastewater discharged from IE was highly rich in plant nutrients and heavy metals. The wastewater irrigation significantly ($P<0.05/P<0.01/P<0.001$) increased the contents of heavy metals in the soil and cabbage grown in wastewater irrigated soil. Agronomical performance of Cabbage is increased due to irrigation with IE effluent. Among the all heavy metals the maximum accumulation of Fe, Cd and Cu were recorded in edible part of cabbage. The translocation of various metals were recorded in the order of Mn >Zn > Cr > Fe>Cu > Cd in the cabbage. Although, the contents of Cd and Cr cabbage were recorded above the prescribed limit of WHO/FAO standards and remaining metals are continuously increasing as per number of effluent irrigation. Therefore, regular monitoring of effluent irrigated cabbage must be required to prevent possible hazards caused due to the consumption of heavy metals contaminated vegetables.

Key words: Accumulation, Cabbage, Effluent, Heavy metals, Irrigation, Translocation

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INTRODUCTION

Wastewater disposal is a common phenomenon in many countries including India due to generation of huge volume of effluent and lack of treatment facilities (Chopra *et al.,* 2013; Kumar and Chopra, 2014; Kumar *et al*., 2017a). Water plays a vital role in the human life. The consequence of urbanization and industrialization leads to spoiling the water (Raj and Thakur, 2017). In the recent time, there has been increasing awareness regarding heavy metals contaminations in the surroundings, speciously due to their toxicity and perceived persistency within the aquatic systems. More than 97% of the mass transport of heavy metals to the oceans is connected with river sediments (Kumar and Thakur, 2017). Heavy metals accumulation in agricultural soils is of increasing worldwide concern and particularly in India with the rapid development of industrialization and urbanization (Hati *et al.,* 2007; Pandey *et al.,* 2008). The crop plants take up heavy metals and accumulate them in their edible and inedible parts in quantities high enough to cause clinical problems both to animals and human beings consuming these metal-rich plants (Muchuweti *et al.,* 2006; Khan *et al.,* 2008).

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Recently, heavy metal pollution is one of the utmost severe environmental issues and has become a matter of environmental anxiety among the environmental researchers (Kiran *et al*., 2005). Cadmium, chromium, copper, iron, lead, nickel, zinc, etc. are the most common heavy metals found in industrial wastewater (Sheng *et al*., 2004). The important sources of adding those heavy metals to the water and wastewater are the effluents of mining, tannery, jewellery, chemical, metallurgical, electrical, and electronics industries in the industrial nations, and also arts and crafts industries in developing countries (Hossain *et al*., 2014).Surplus accumulation of heavy metals in the agronomic soils through industrial wastewater irrigation may not only result in the soil contamination but also lead to higher heavy metals uptake by plants and thus affect food quality and safety(Kumar and Chopra, 2014; Kumar *et al*., 2017). The quality of food is a key issue affecting morbidity and mortality. As the quality of life advances, more and more people have become conscious that food quality affects their well-being and their day-to-day life. Metal pollution in agronomic production is one of the significant factors affecting vegetable, fruit, and meat superiority (Zhou *et al*., 2000). The primary heavy metals in the environment damaging to people's health include mercury, cadmium, chromium, lead, nickel, copper, zinc, and non-metallic arsenic. They enter the environment primarily as a result of industrial and agricultural practices. They are constant unlike some potentially toxic organic compounds.

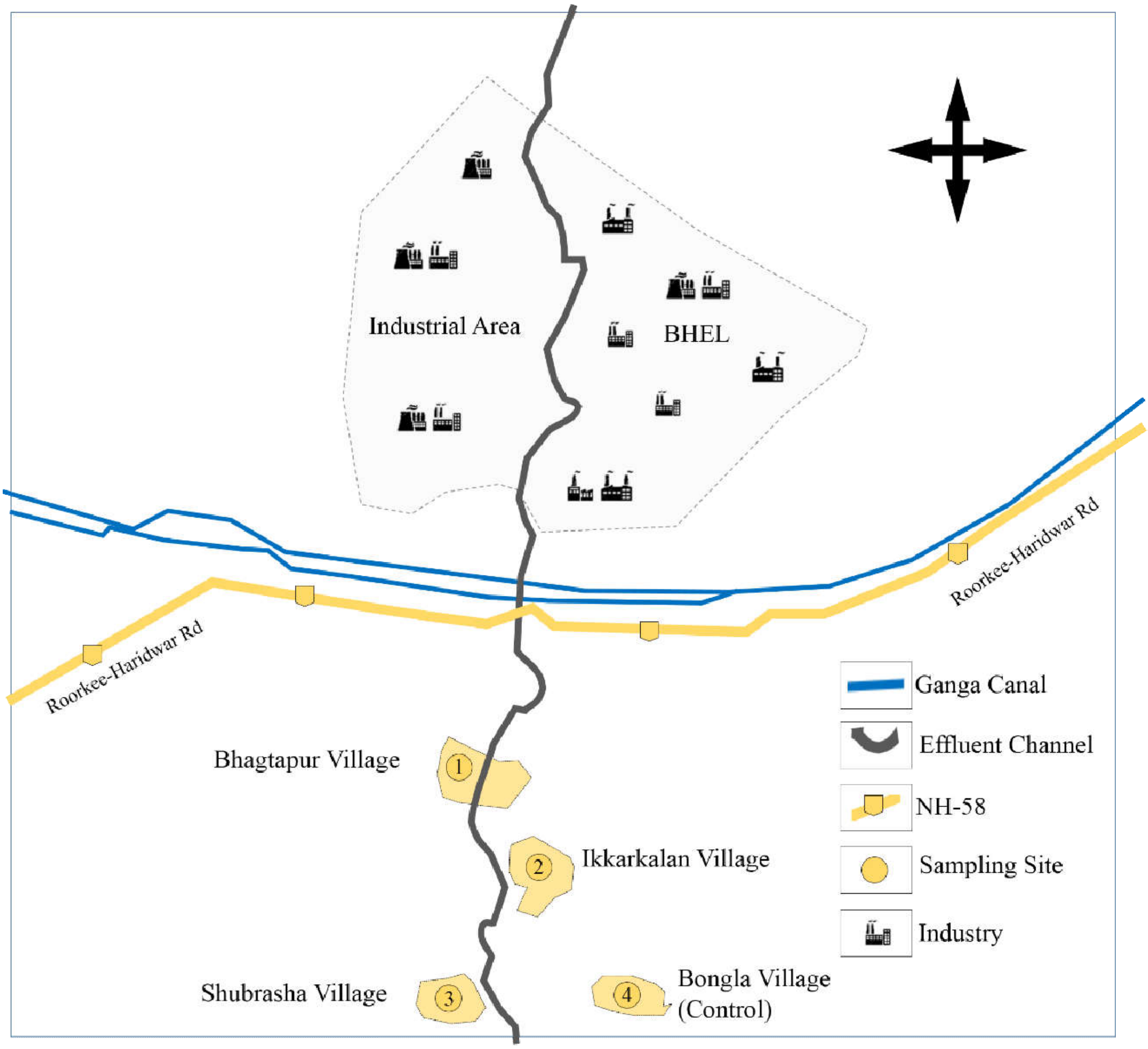

Figure 1. Diagrammatic map of different sampling sites

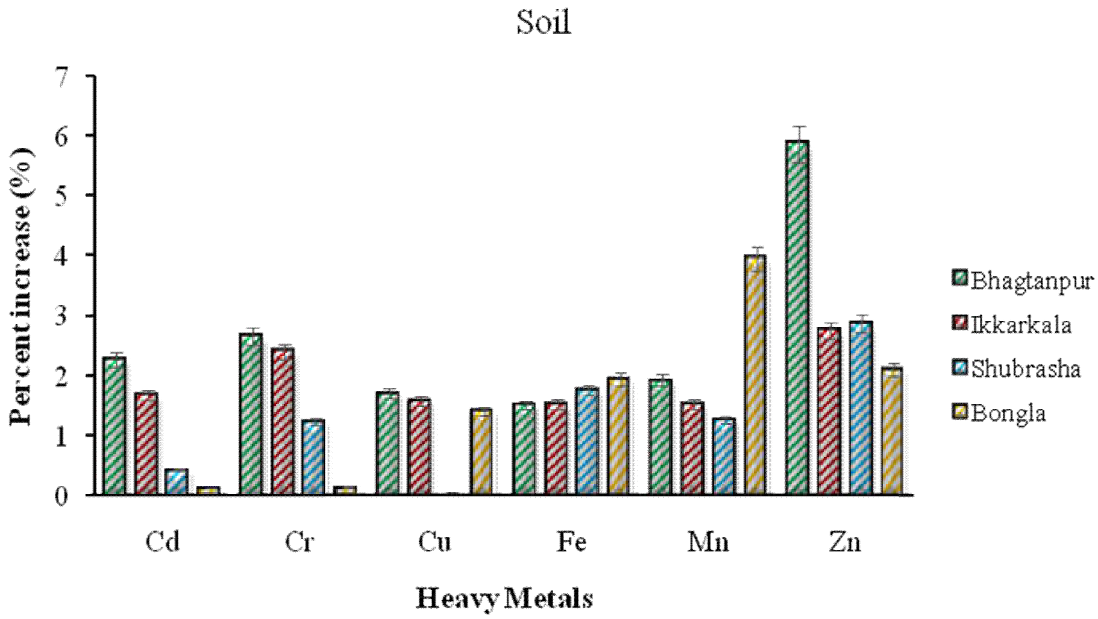

Figure 2. The increase of heavy metals in the soil after irrigated with IIE and bore well water.

Once ingested, they are difficult to abolish and accumulate in the body (Lee *et al*., 2010). Cabbage (*Brassica oleracea* var. *capitata*) is a known for high yield, ecological plasticity, and valuable biochemical composition, having a high water gratified, low caloric value, having high quality protein, carbohydrates, fiber, vitamins, and minerals (Artemyeva and Solovyeva 2006, Laczi *et al*., 2017). This vegetable, as well as other crucifer species, is categorised by the high ability to adapt to a wide range of habitats and growing conditions (Larkcom 2008; Maršalkienė *et al*., 2014). All cruciferous plants, including cabbage, are important source for anticancer substances like: beta-carotene, vitamin C, fibres, calcium (Ca), lute in, and zeaxanthin, but many issues including soil, fertilization, irrigation, weather, and others can affect the chemical structure of plants (Lee *et al*., 2010). Like other cruciferous vegetables, it has a shallow root system, which bounds its ability to take up water and nutrients from a deeper soil profile (Indrea *et al*., 2014; Pasakdee *et al*., 2006), and because it produces significant leaf mass in a moderately short vegetation period, the nutritional demand is very high (Kumar *et al*., 2017b). It was chosen as a test crop because it is a fast growing vegetable with high nutritional value, responding efficiently to nutrient availability in soil and requiring satisfactory availability of soil water and nutrients for optimum growth. Therefore, the present investigation was conducted to impact of industrial effluents disposal on soil and cabbage grown in district Haridwar (Uttarakhand), India.

MATERIALS AND METHODS

Samples of IE wastewater was collected from Bhagtanpur Village (29°53'36.39"N, 78°4'27.64"E), Ikkarkala Village (29°52'38.85"N, 78°4'36.91"E), and Shubrasha Village (29°52'17.36"N, 78°4'26.57"E) where cabbage is being cultivated in these locations using IIE effluents. The bore well water irrigated cabbage at Bongla Village (29°51'57.81"N, 78°4'41.00"E) was selected as control site. The soils of wastewater and bore well water irrigated sites were sandy loam and slightly alkaline, pH 7.8. Cultivation practices in different villages i.e. Bhagtanpur, Ikkarkala, Shubrasha and Bongla (Control) of cabbage at all sites were similar and irrigation of cabbage was twice weekly at all sites. The IIE samples were collected in plastic bottles, immediately acidified with HNO_3, and transported to the laboratory. Samples were filtered through Whatman No. 42 filter paper and stored in a refrigerator at 4°C. Soil samples from each site were composited separately for analysis. Samples of harvest ready cabbage were collected from different sampling sites. At each sampling leaves, roots of cabbage and soils surrounding roots of cabbage were collected from 3 or 4 plots of these sites. All the samples of cabbage collected from different samples sites were washed with double distilled water and plants separated by hand into different parts which were dried at room temperature for 24 hrs. Various parts (root and leaves) of cabbage were separately chopped and placed in a hot air oven at 60°C for 48 hrs to dry. Samples were ground into powder using a mortar and pestle and stored in plastic bags for further use. For analysis of heavy metals, plant, soil and water samples were digested (Anonymous, 1990). A 0.5 g of powdered samples of cabbage and soil, and a 10 mL sample of water, were placed in a digestion tube and 10 mL of nitric acid (HNO_3) and 5 mL of perchloric acid ($HClO_4$) added and digestions completed on digestion blocks (FOSS, Mumbai, India) following standard procedures (Chaturvedi and Sankar, 2006; APHA, 2012).

After digestion samples were filtered through Whatman No. 42 filter paper and volume made up to 50 mL. The Cd, Cu, Cr, Fe, Mn and Zn contents in the digested aliquot were determined with an atomic absorption spectrophotometer (model 5000, Perkin-Elmer, Gen Tech Scientific Inc., Arcade, NY).

Statistical analysis

Data was analyzed with appropriate statistical tools like Mean±SE, one-way and two way analysis of variance (ANOVA) and graphs with the help of MS Excel 2013 and Origin Lab Pro 9.1.

Enrichment factor (Ef)

To examine the translocation of heavy metals in the soil and in the edible portion of cabbage, and to show the difference in metal concentrations in the plants between the sites, the enrichment factor (EF) was determined by using the formula given by Buat-Menard and Chesselet (1979).

Translocation index (Ti)

Translocation index is used to work out the ability of plants to translocate heavy metal from roots to harvestable aerial plant parts (Yanqun*et al*., 2005).

Bioconcentration factor (BCF)

Bioconcentration factor is a parameter used to describe the transfer of trace elements from soil to plant Edible parts of cabbage. It is calculated using the methods given by Liu *et al*.(2006).

Health risk index (HRI)

The health risk index was calculated as the ratio of projected exposure of respected crops and oral dose (Cui *et al.,* 2004). Oral reference doses were 4×10^{-2}, 0.3 and 1×10^{-3} mg kg^{-1} day^{-1} for Cu, Zn and Cd, respectively (USEPA, 2002) and 0.004, 0.02 and 1.5 mg $kg^{-1}day^{-1}$ for Mn, Fe and Cr, respectively (USEPA, 1997). Projected exposure is gained by dividing daily intake of heavy metals by their safe limits. An index more than 1 is measured as not safe for human health (USEPA, 2002).The average daily vegetable intake rate was examined by conducting a survey where 100 people having average body weight of 60 kg were asked for their daily intake of specific vegetable from the study area in each month of sampling (Ge, 1992; Wang *et al.,* 2003).

RESULTS AND DISCUSSION

Characteristics of IE effluent

The mean ±SE values of various physico-chemical, heavy metals and microbiological characteristics of control (Bore well water) and IE effluent of different sites are presented in table 1. The results revealed that IE effluent contained significant quantity of nutrients like Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, TKN, $PO_4^{3-}$and heavy metals such as Cd, Cr, Cu, Fe, Mn and Zn. These are very important parameters that determine the soil fertility and crop yield of cultivated crops. The values of various wastewater characteristics like BOD (245.85mg L^{-1}), COD (742.40mg L^{-1}), TKN (163.77mg L^{-1}), Cd (4.99mg L^{-1}), Cr (2.53mg L^{-1}), Cu (2.80mg L^{-1}1), Fe (9.22mg L^{-1}), Mn (6.88 mg L^{-1}) and SPC (7.21×10^{7}SPC ml^{-1}) were recorded beyond the prescribed BIS standards of irrigation water (Table 1).

Table 1: Physico-chemical, heavy metals and microbiological parameters of integrated industrial effluents at different sampling sites

Parameter	Sampling Sites					BISfor irrigation water
	Bongla (Control)	Effluent disposal Channel near Pentagon mall	Bhagtanpur Village	Ikkarkala Village	Shubrasha Village	
EC (dc·cm^{-1})	0.47±0.03	3.17**±0.18	3.07**±0.17	3.04**±0.15	2.97**±0.18	-
TDS (mg·L^{-1})	156.59±3.13	876.24**±19.65	860.41**±15.96	858.74**±8.56	841.24**±13.20	1,900
pH	7.16±0.04	6.09*±0.97	6.40^{ns} ±0.28	6.38 ns ±0.27	6.47 ns ±0.24	5.5-9.0
DO (mg·L^{-1})	7.25±0.04	0.09***±0.01	0.10***±0.07	0.13***±0.04	0.19***±0.04	-
BOD (mg·L^{-1})	3.13±0.04	245.85***±21.15	245.02***±27.53	238.35***±23.49	221.68***±19.40	100
COD (mg·L^{-1})	4.41±0.32	742.40***±27.09	674.90***±17.00	669.90***±12.07	658.24***±14.02	250
Ca (mg·L^{-1})	21.57±0.49	265.53**±18.58	263.79**±16.11	261.29**±14.28	254.46**±9.44	200
Mg (mg·L^{-1})	8.67±0.06	174.14***±14.89	173.26***±11.75	170.76***±10.23	164.93***±6.41	-
Na (mg·L^{-1})	6.58±0.10	128.84***±9.62	136.34***±9.88	134.68***±7.40	130.51***±5.37	-
K (mg·L^{-1})	4.18±0.08	69.94**±5.43	73.27**±6.76	71.60**±4.45	65.27**±5.69	-
TKN ^{d} (mg·L^{-1})	1517±0.06	163.77**±12.10	162.09**±11.40	161.26**±10.32	156.26**±6.77	100
PO_4^{3-} (mg·L^{-1})	0.05±0.01	22.63***±0.11	22.35***±1.76	21.85***±1.52	21.18***±1.15	-
Cd (mg·L^{-1})	0	4.99***±0.57	4.83***±0.77	4.64***±0.82	4.39***±0.42	2.00
Cr (mg·L^{-1})	0	2.53***±0.13	2.50***±0.57	2.46***±0.54	2.38***±0.46	2.00
Cu (mg·L^{-1})	0.03±0.01	2.80***±0.09	2.80***±0.60	2.74***±0.54	2.65***±0.29	3.00
Fe (mg·L^{-1})	1.18±0.06	9.22**±0.54	9.18**±0.50	9.10**±0.46	8.89**±0.35	1.00
Mn (mg·L^{-1})	0.05±0.01	6.88***±0.34	6.88***±0.34	6.79***±0.32	6.66***±0.35	1.00
Zn (mg·L^{-1})	0.27±0.04	10.74***±0.34	10.66***±0.31	10.48***±0.23	10.02***±0.47	15
SPC ^{f} (SPC·mL^{-1})	3.01×10^{3}±23.24	7.21×10^{7}***±240.72	7.08×10^{7}***±235.47	6.98×10^{7}***±236.21	6.86×10^{7}***±238.4	10,000
MPN ^{g} (MPN/100 mL)	1.89×10^{3}±36.65	4.28×10^{4}**±180.65	4.25×10^{4}**±182.67	4.21×10^{4}**±179.66	4.15×10^{4}**±172.75	5,000
Total Fungi ^{h} (CFUs/ mL)	3.26×10^{3}±28.14	5.62×10^{5}**±225.97	5.52×10^{5}**±245.21	5.32×10^{5}**±235.78	5.12×10^{5}**±230.63	-

Data in the interaction analyzed with Least Squares Means and means separated with LSD. Values followed by ns, *, ** and *** are significantly different to the control at P≤0.05, P≤0.01, P≤0.001 level of ANOVA, respectively.

Table 2. Physico-chemical, heavy metals and microbiological parameters of integrated industrial effluents irrigated soil at different sampling sites

Parameter	Sampling Sites				Maximum limit (mg^{-}Kg) (MEF, 2007)
	Bongla (Control)	Bhagtanpur Village	Ikkarkala Village	Shubrasha Village	
EC (dc·cm^{-1})	2.29±0.07	8.50**±0.17	8.45**±0.29	8.12**±0.24	-
pH	7.58±0.15	5.83*±0.22	5.84*±0.23	5.88*±0.18	-
Ca (mg·Kg^{-1})	20.98±0.75	310.55***±9.75	307.22***±12.42	299.72***±11.27	-
Mg (mg·Kg^{-1})	3.46±0.23	74.36***±4.01	71.95***±4.40	70.53***±4.76	-
Na (mg·Kg^{-1})	25.72±1.19	112.17**±5.90	109.67**±7.69	106.75**±7.17	-
K (mg·Kg^{-1})	62.75±1.40	256.73*±6.19	250.89*±8.58	231.73*±9.92	-
TKN ^{d} (mg·Kg^{-1})	28.54±1.27	213.75**±7.56	209.92**±8.24	209.59**±7.27	-
PO_4^{3-} (mg·Kg^{-1})	45.93±1.92	104.31*±5.56	104.25*±5.59	102.92*±5.08	-
Cd (mg·Kg^{-1})	0.23±0.02	8.03***±1.10	7.65***±1.17	7.32***±0.89	1
Cr (mg·Kg^{-1})	0.19±0.02	14.44***±1.21	13.88***±1.37	13.63***±1.23	100
Cu (mg·Kg^{-1})	3.49±0.21	24.06**±1.63	23.81**±1.89	23.22**±1.45	200
Fe (mg·Kg^{-1})	5.05±0.19	65.21**±3.74	64.96**±4.00	62.79**±2.13	150
Mn (mg·Kg^{-1})	1.22±0.11	35.52**±3.33	34.97**±3.62	33.97**±2.61	100
Zn (mg·L^{-1})	2.10±0.13	28.41**±3.38	28.16**±3.37	26.16**±2.83	200
Total bacteria ^{c} (CFU g^{-1})	2.72×10^{5}±214.68	7.78×10^{8}**±458.71	7.42×10^{8}**±465.87	7.13×10^{8}**±438.48	-
Total fungi (CFU g^{-1})	1.86×10^{3}±112.14	6.76×10^{6}**±384.25	6.51×10^{6}**±402.31	6.24×10^{6}**±372.47	-
Actenomycetes (CFU g^{-1})	1.95×10^{3}±162.27	8.75×10^{4}**±241.54	8.42×10^{4}**±246.62	8.26×10^{4}**±236.32	-

Data in the interaction analyzed with Least Squares Means and means separated with LSD. Values followed by ns, *, ** and *** are significantly different to the control at P≤0.05, P≤0.01, P≤0.001 level of ANOVA, respectively.

Table 3: Agronomical parameters of cabbage grown inintegrated industrial effluents and bore well water irrigated soilat different sites.

Parameter	Sampling sites			
	Bongla Village (Control)	Bhagtanpur Village	Ikkarkala Village	Shubrasha Village
Plant height (cm)	20.53±0.31	22.14*±1.13	22.23*±1.08	22.31*±0.94
Root length (cm)	8.60±0.14	9.07*±0.81	8.98 ns ±0.72	9.07*±0.59
Number of leaves/plant	11.71±0.76	12.25*±0.87	12.50*±0.67	12.67*±0.49
Dry weight (g)	48.20±1.58	53.78*±1.63	54.11*±1.57	53.89*±1.50
Chlorophyll content (mg/g f.wt.)	2.84±0.11	3.05*±0.22	3.04*±0.20	3.04*±0.20
Crop yield/plant (g)	408.41±11.46	464.89*±6.13	463.22*±6.35	459.89*±7.75
Cd (mg·Kg^{-1})	0.04±0.01	0.35*±0.03	0.34*±0.03	0.32*±0.02
Cr (mg·Kg^{-1})	0.45±0.02	5.78**±0.09	5.73**±0.09	5.70**±0.07
Cu (mg·Kg^{-1})	2.60±0.11	8.51*±0.38	8.44*±0.51	8.37*±0.47
Fe (mg·Kg^{-1})	6.86±0.21	24.03**±0.82	23.67**±1.09	23.52**±1.01
Mn (mg·Kg^{-1})	3.77±0.16	16.66**±0.68	16.55**±0.59	16.46**±0.59
Zn (mg·L^{-1})	3.59±0.11	15.18**±0.45	15.12**±0.51	14.96**±0.35

Data in the interaction analyzed with Least Squares Means and means separated with LSD. Values followed by ns, * and ** are significantly different to the control at P≤0.05, P≤0.01 level of ANOVA, respectively.

The values of all the physico-chemical, heavy metals and microbiological parameters of IE effluent was at different sampling sites namely, effluent disposal Channel near Pentagon mall, Bhagtanpur, Ikkarkala and Shubrasha Village recorded to be significantly different to the Bongla (Control) village at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$ levels of ANOVA, respectively. The more BOD and COD are associated with the presence of higher biodegradable organic waste in the wastewater.

(3225.00 mg L^{-1}), TKN (420.70 mg L^{-1}), Cd (1.86 mg L^{-1}), Cr (1.24 mg L^{-1}), Cu (10.36 mg L^{-1}), Fe (16.84 mg L^{-1}1), Mn (6.67 mg L^{-1}) and SPC (7.68×10^{8} SPC ml $^{-1}$) in wastewater.

Effects of IE effluent irrigation on soil characteristics

Table 2 shows the physico-chemical, heavy metals and microbiological characteristics of control (Bore well water) and IE effluent irrigated sites of soil used in the cultivation of cabbage.

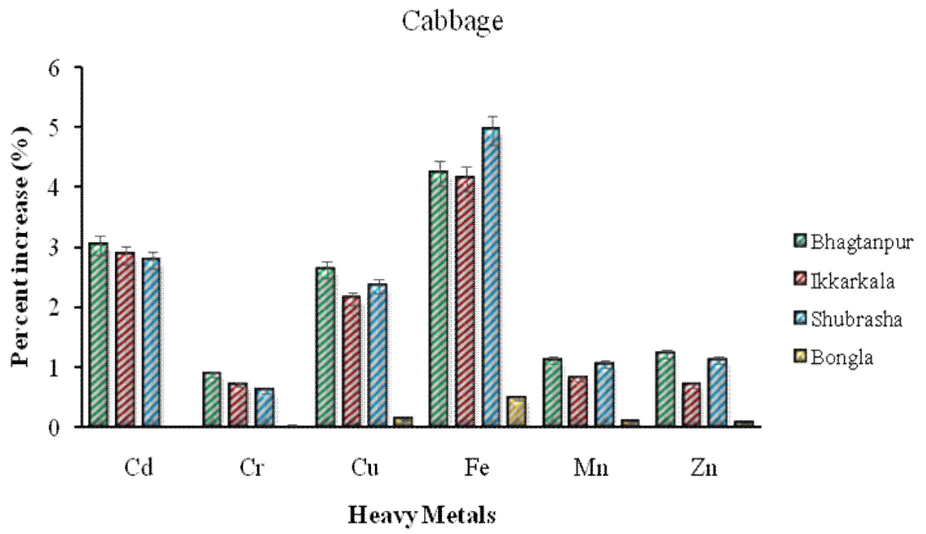

Figure 3. The increase of heavy metals in the Cabbage after irrigated with IIE and bore well water

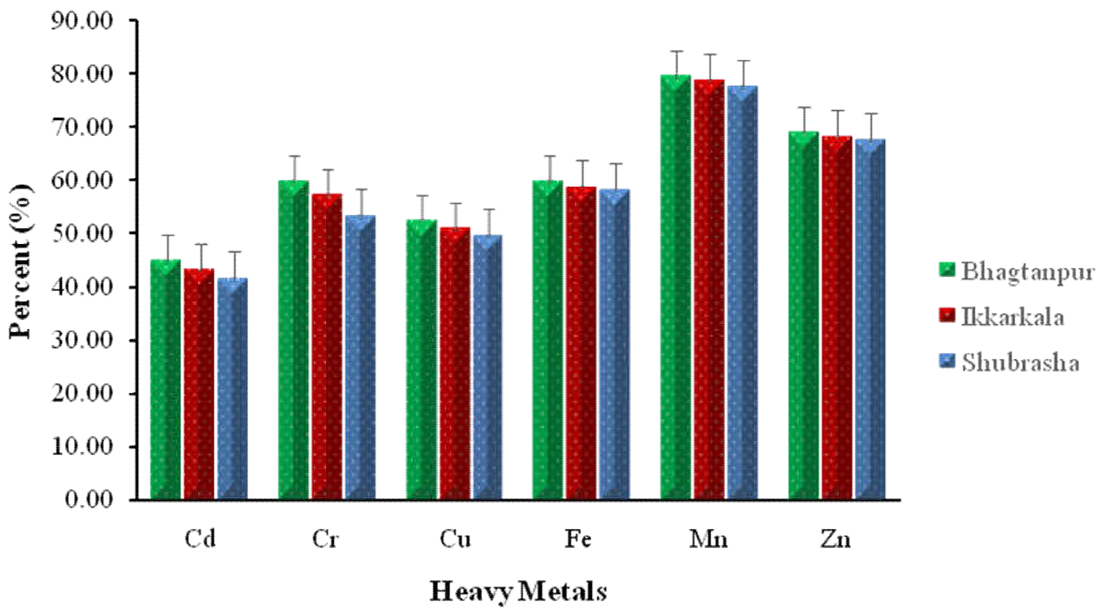

Figure 4: Enrichment factor (Ef) of the heavy metals in the cabbage grown at different sites.

The higher number of SPC and MPN in the wastewater are the indicator of fecal pollution and pathogens. The more contents of heavy metals Cd, Cr, Cu, Fe, Mn and Zn in the wastewater is likely due the discharge of effluent from various metals works based industries located in the vicinity. TKN and PO_4^{3-} were also recorded higher in the wastewater and are associated with eutrophication of aquatic ecosystems. Therefore, various parameters clearly indicated that the IE effluent was highly rich in nutrients, heavy metals and contagious. Kumar *et al.* (2016) also reported high BOD (1450.30 mg L^{-1}), COD

The results revealed that wastewater irrigation significantly ($P<0.05/P<0.01/P<0.001$) increased the contents of EC, Ca, Mg, Na, K, TKN, P, Cd, Cr, Cu, Fe, Mn, Zn and microbiological parameters total bacteria, total fungi and actenomycetes in the soil used in the farming of cabbage when compared to bore well water irrigated soil. The EC of the wastewater irrigated soil was recorded higher and associated with the presence of more ionic species in the soil. Kumar*et al.* (2016) also reported higher EC (3.75 dS m^{-1}) of wastewater irrigated soil in Haridwar (Uttarakhand), India.

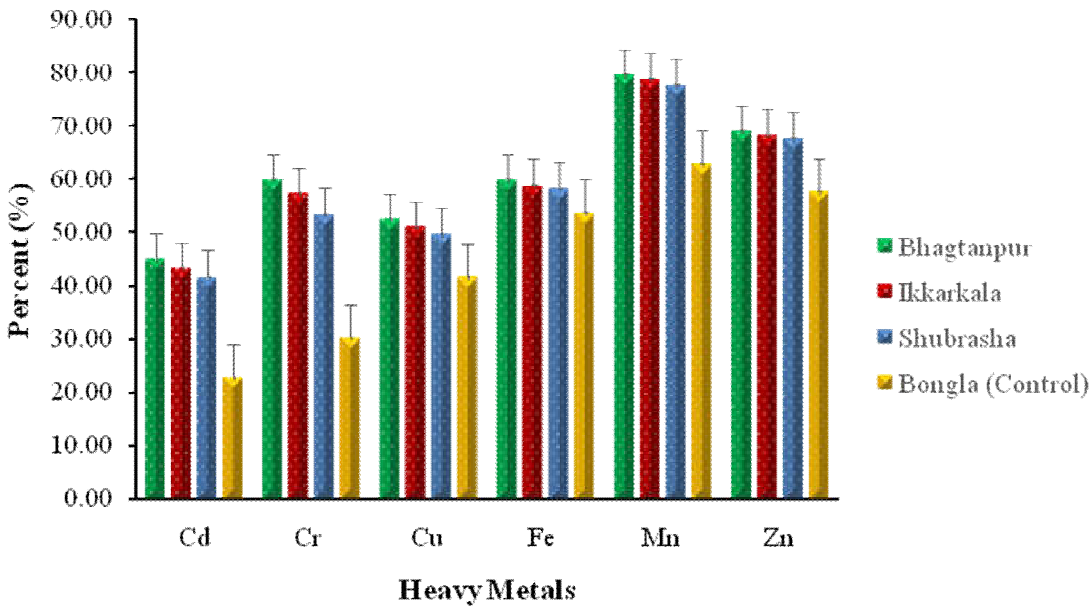

Figure 5. Translocation index (Ti) of the heavy metals in the cabbage grown at different sites.

Table 4. Bio-concentration factor (BCF) of heavy metals in the edible part of cabbage grown at different sampling sites

Parameter	Sampling sites			
	Bongla Village (Control)	Bhagtanpur Village	Ikkarkala Village	Shubrasha Village
Cd	0.01	0.04	0.04	0.04
Cr	0.15	0.40	0.41	0.42
Cu	0.26	0.35	0.35	0.36
Fe	0.16	0.37	0.36	0.37
Mn	0.23	0.47	0.47	0.48
Zn	0.21	0.53	0.54	0.57

Table 5. Health risk index (HRI) of heavy metals in the edible part of cabbage grown at different sampling sites.

Parameter	Sampling sites			
	Bongla Village (Control)	Bhagtanpur Village	Ikkarkala Village	Shubrasha Village
Cd	0.46	1.42	1.33	0.17
Cr	0.02	0.02	0.02	0.00
Cu	0.89	0.88	0.87	0.27
Fe	0.71	2.47	2.45	2.50
Mn	0.39	1.72	1.71	1.74
Zn	0.21	0.21	0.21	0.05

During the present investigation the contents of various cations Na^+, K^+, Ca_2^+ and Mg_2^+ and anions PO_4^{3-} were recorded significantly higher in the wastewater irrigated soil in comparison to bore well water irrigated soil and this might be due to the presence of higher values of these ions in the wastewater. Bhise*et al*. (2007) also reported that wastewater irrigation significantly increased the calcium, magnesium, potassium and sodium in the agricultural soil.

There was increase of Cd, Cr, Cu, Fe, Mn and Zn in the soil after irrigated with IE effluent and bore well water shown in figure 2. The highest enrichment of various heavy metals in the soil were recorded in the order Zn > Cr > Cd > Mn > Cu > Fe in Bhagtanpur, Zn > Cr > Cd > Cu > Fe > Mn in Ikkarkala, Zn > Fe > Cr > Mn > Cd > Cu in Shubrasha and Mn > Zn > Fe > Cu > Cr > Cd in Bongla (Control) village. The findings are in accordance with Mireles *et al*. (2004) who reported that wastewater irrigation significantly enhanced the contents of Cr, Co, Cu, Fe, Mn, Ni, Pb and Zn in the soil of Mexico City. The diverse accumulation of these metals in the soil used for the farming of cabbage are likely due to the chemical speciation, availability and uptake by the crop plants.

Although, the contents of Cr (14.44 mg Kg^{-1}), Cu (24.06 mg Kg^{-1}), Fe (65.21 mg Kg^{-1}) Mn (35.52 mg Kg^{-1}) and Zn (28.41 mg Kg^{-1}) in the soil were found within the permissible limit of MEF, 2007 standards but long term IE effluent irrigation may builds up the contents of these metals in the soil. Thus, IE effluent irrigation significantly increased the contents of Cd, Cr, Cu, Fe, Mn, and Zn in the soil.

Effect of IE effluent on agronomical characteristics of Cabbage

During the present study, at vegetative growth at 70 days the maximum plant height (22.31 cm) in Shubrasha, root length (9.7 cm) in Shubrasha and Bhagtanpur, dry weight (54.11 g) in Ikkarkala, chlorophyll content (3.5 mg/g FW) in Bhagtanpur, number of leaf/plant (12.67) in Shubrasha and crop yield/plant (464.89 g) in Bhagtanpur village of cabbage were observed with 100% concentration of IE effluent in cultivation session. The minimum plant height (22.14 cm) in Bhagtanpur, root length (8.98 cm) in Ikkarkala, dry weight (53.78 g) in Bhagtanpur, chlorophyll content (3.04 mg/g FW) in Ikkarkala and Shubrasha, number of leaf/plant (12.25) in Bhagtanpur and crop yield/plant (459.89 g) in Shubrasha village of cabbage were observed.While comparing with control site Bongla the plant height (20.53 cm), root length (8.60 cm), dry weight (48.20 g), chlorophyll content (2.84 mg/g FW), number of leaf/plant (11.71) and crop yield/plant (408.41 g) of cabbage were observed with bore well water irrigation in cultivation seasons. The values of agronomical characteristics of Cabbage in IE effluent irrigated soil was at different sampling sites namely, Bhagtanpur, Ikkarkala and Shubrasha Village recorded to be significantly different to the Bongla (Control) village at $P \leq 0.05$ and $P \leq 0.01$ level of ANOVA, respectively. Kumar and Chopra (2015) reported agronomic performance of *S. oleracea* increased when treated with 5% to 25% paper mill effluent and decreased when treated with 50 to 100% paper mill effluent. Effluent is a good nutrient sources of vegetables and other crops but excess of nutrient in soil due to effluent irrigation can damage plants part as well as yield of plants.

Accumulation of heavy metals in the Cabbage

There are concerns about accumulation of heavy metals present in the IE effluent used for irrigation, and consequently their transference to plants and their eventual entrance into the food chain. The contents of heavy metals in edible parts of cabbage grown in the IE effluent and bore well water irrigated soil varied (Table 3). The highest concentration of Fe (24.03 $mg \cdot Kg^{-1}$) was in Bhagtanpur and the lowest concentration of Cd (0.32 $mg \cdot Kg^{-1}$) was in the Shubrasha village. Levels of Fe in cabbage were below but Cd were above safe limits (WHO/FAO 2007). Contents of Cr, Cd, Cu, Fe, Mn and Zn in the soil increased as the number of effluent irrigation increased. The enrichment factor was highest for Mn and lowest for Cd at all sampling sites irrigated with IE effluent figure 4. The concentration of Cd, Cr, Cu, Fe, Mn and Zn were higher in soil irrigated with effluent than in soil irrigated with well water figure 3. Singh *et al*. (2010) also reported higher accumulation of heavy metals (Cd, Cu, Pb, Zn, Ni and Cr) in cabbage due to wastewater irrigation in Varanasi. Fertigation with IE effluent increased nutrients as well as metals content in soils used for the cultivation of cabbage.

Bio-concentration factor (BCF)

The BCF for transfer of heavy metals from soils to cabbage varied (Table 4). The BCF for heavy metals due to irrigation with IE effluent was in the order: Zn>Mn>Cr>Fe>Cu>Cd in Bhagtanpur, Ikkarkala and Shubrasha village; for the control, the order was: Cu>Mn>Zn>Fe>Cr>Cd. The BAF values for Mn and Cd in cauliflower plants were comparatively low. The highest BCF values were for Zn, Mn and Cr due to irrigation with IE effluent. The food chain (soil–plant–human) is recognized as the main route whereby humans are exposed to contaminants in the soil (Zhuang *et al*., 2009). When the BCF is <1 or BAF = 1, it indicates the plant absorb, but does not store heavy metals; when the BCF is >1 the plant accumulates metals. BAF values of <1 were obtained for Cd, Cr, Cu, Fe, Mn and Zn in cabbage. The bioavailability of metals was low in the areas of study.

Translocation factor (Tf)

The translocation index of heavy metals in the cabbage irrigated with IE effluent, or well water, varied (Figure 5). Concentrations of heavy metals in cabbage confirmed translocation of metals into different parts of cabbage from IE effluent irrigated soil and is evident from the higher translocation factor (Tf) of Mn followed by Zn and Cr in plants grown in the IIE irrigated soil. Cabbage efficiently translocates higher contents of Cd, Cr, Cu, Fe, Mn and Zn in to edible part of plants irrigated with IE effluent. These results agree with Sharma *et al*. (2007) who reported higher contents of heavy metals in tissues of cabbage after irrigation with municipal wastewater, and concluded that vegetable crops are capable of taking up, accumulating, and translocating higher concentrations of heavy metals.

Health risk index (HRI)

To assess the health risk associated with heavy metal contamination of plants grown locally, estimated exposure and risk index were calculated. The results showed that Cd, Fe and Mn contamination in plants had greatest potential to pose health risk to the consumers (Table 5). Health risk index was more than 1 for Cd, Fe and Mn only the health risk index for Cu was less than 1 except in cauliflower. Although, cauliflower have lesser concentrations of metals than other two vegetables, but the health risk index was higher. In the present study, only Cu was not found to cause any risk to the local population. Cui *et al.*(2004) have also reported that local residents of an area near a smelter in Nanning, China have been exposed to Cd and Pb through consumption of vegetables, but no risk was found due to Cu and Zn. Kumar and Thakur (2018) reported higher health risk impact in the different vegetables grown in waste water irrigated soil. Metal transfer factor from soil to plants is a crucial component of human exposure to heavy metals via food chain. Transfer aspect of metals is essential to investigate the human health risk index (Cui *et al.,* 2004).

Conclusion

This study concluded that wastewater was considerably loaded with different nutrients (Na^+, K^+, Ca^{2+}, Mg^{2+}, TKN and PO_4^{3-}) and heavy metals (Cd, Cr, Cu, Fe, Mn and Zn). The irrigation by IE effluent has increased the heavy metal concentrations in soil and plants of the receiving area.Vegetables are the staple foods in India. Therefore more attention should be paid to minimizing heavy metal contamination in farming. The result showed that heavy metal contamination in vegetables is an increasing and can cause public health problem as greater amounts of heavy metals are discharged into the environment. It is essential that the farmers be educated and encouraged to reduce heavy metal accumulations in vegetables by instituting effective countermeasures.Although the cabbage showed the diverse accumulation strategy for Cd, Cr, Cu, Fe, Mn and Zn and roots of the plant act as a barrier for translocation of these metals in rest of the parts of the plants. Therefore, continuous monitoring of effluent irrigated crops should be needed to control the hyper accumulation of various toxic metals in the plant parts and to prevent the possible health hazards due to the consumption of toxic metals contaminated agricultural products.

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