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Research Article

EFFECT OF WASTEWATER IRRIGATION ON HEAVY METALS ACCUMULATION IN TOMATO (*Lycopersicum esculentum*) GROWN ON VERTISOL

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Abstract- A field trial was conducted at ICAR-Directorate of Weed Research, Jabalpur, (Madhya Pradesh) during *Rabi* 2012-13 to study the effect of wastewater irrigation on heavy metals accumulation in tomato grown on Vertisol. Eight treatment combinations were made including four main treatments such as drain water, filtered water-I (*Typha* based), filtered water-II (*Vetiveria* based) and tube well water (control), which were split-up in two levels of EDTA application @ 0 and 0.25 $kgha^{-1}$. The tomato variety-*Dhamini* was transplanted in net plot size of 1.5x2 =3 m^2 with 50 cm row to row and 30 cm plant to plant spacing. Results revealed that the yield of tomato was registered significantly higher under plots irrigated with drain water than tub well water irrigation. Higher nutrients content in tomato and availability of N, P and K in soil was recorded under plots irrigated with drain water than tube well water irrigation. However, tomato absorbed higher concentration of heavy metal in plots irrigated with drain water than tube well water irrigation. EDTA application enhanced the translocation of heavy metals in tomato. Nearly two-fold increase in concentration of heavy metals was observed in tomato shoot. Comparatively lower concentrations of heavy metals were retained in fruits of tomato than its shoot part. The sequence of heavy metals accumulation in soil was Cu >Mn> Pb >Zn >Ni >Cd. Lower metal accumulation was observed in lower layer of soil as compared to surface layer.

Keywords- Wastewater, Heavy Metal, Tomato and Vertisol

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Introduction

Due to anthropogenic activities, elevated amounts of heavy metals discharge into water, soils and then accumulation in crop plants is of great alarm due to the prospect of food contamination. Though the heavy metal *viz.* Cd, and Pb are not essential for plant growth, they are readily taken up and accrue by plants in toxic levels. Ingestion of vegetables irrigated with wastewater and grown in soils contaminated with heavy metals poses a possible risk to human health [1]. [2-3] reported that the irrigation with heavy metals contaminated wastewater over long period of time buildup in soils above safe limits. Finally, increases the uptake by plants depending upon the soil type, plant growth stages and plant species [4].

The use of wastewater for farming purpose is enormously increasing in the urban areas for additional income and food security [5]. Growing volumes of wastewater will become the added irrigation option for farming in water scarce countries [6-7] because it contains a small amount of N, P and K and can contribute to organic matter recycling [8]. However, the long-term use of untreated wastewater elevates levels of heavy metals in vegetables [9-11].The trend of metal accumulation in wastewater-irrigated soil is in the following order: Fe > Mn > Pb > Cr > Cd [12]. [13-14] concluded that the use of conventionally treated and untreated wastewater for irrigation increased the contamination with Cd, Pb and Ni in the edible portions of vegetables, causing a potential health risk in the long term. The trend of metal contents in well water and wastewater were Pb > Zn > Mn > Cr > Cd > Cu and Pb > Mn > Zn > Cr > Cd > Cu, respectively [15].

The nutrients and organic matter added by sewage irrigation may enhance the activities of soil microorganisms and also increment of organic carbon (OC) level in soil with wastewater irrigation [14]. [1] reported an increment of 59% in OC content of soil having long-term use of sewage irrigation of peri-urban agricultural land under the Keshopur effluents irrigation scheme (KEIS) of the Delhi government, India. Similarly, [16] reported a 47.9% increase in OC content of topsoil (0–15 cm) receiving industrial wastewater for irrigation as compared to the soil irrigated with tube well water at a site situated in Jamalpur, a village near the industrial town of Ludhiana, Punjab. Higher OC content increase organic matter in soil with in turn increases the cation exchange capacity (CEC) in soil. The mean levels of Pb, Zn and Cu content in both type of irrigated soil were within the recommended limit, but Cd level exceeded in case treated soil [17].

In India, use of wastewater poses serious health threats, such as a risk of biomagnifications of heavy metals [18]. Indeed, there is no way to stop wastewater use, but can try and make their usage safer by investigating and thus recommend which parts are safe to eat [19-20]. In Indian diets, tomato (*Lycopersicum esculentum*) is one of the most important fruit vegetable which is consumed as a raw as salad and as a major component of cooking of several vegetables. Therefore, the present study was undertaken to evaluate the effect of wastewater irrigation on heavy metal buildup in soil and tomato grown under field conditions.

Materials and Methods

Jabalpur is situated at 23.90° N latitude and 79.58° E longitude at an altitude of 411.78 meter above the mean sea level [Fig-1]. The maximum temperature ranged from 24 ^{0}C to 45 ^{0}C and minimum from 2 ^{0}C to 32 ^{0}C within a year. The normal rainfall is about 1350 mm and nearly 90% is mostly received during the period between end of June to end of September. The relative humidity ranged from 80 to 90% during rainy season, which reduces as 60 to 70% during winter season and 30 to 40% during summer season.

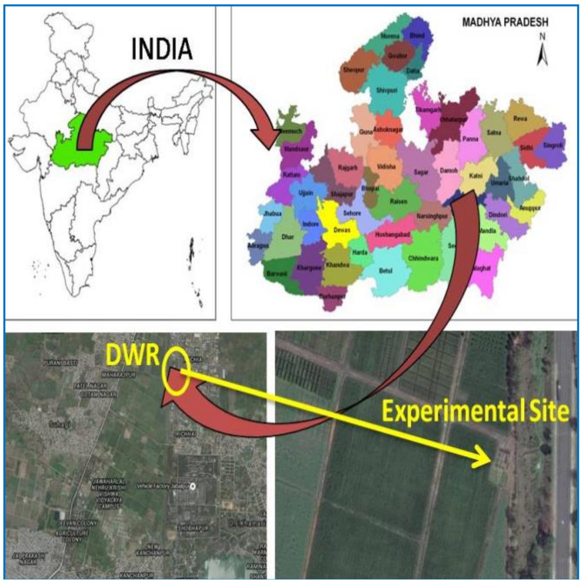

Fig-1 Location map of the experiment

Description of experimental location

Data on weather showed that the mean weekly maximum and minimum temperature ranged between 21.4 ^{0}C to 33.4 ^{0}C and 5 ^{0}C to 16.2 ^{0}C, respectively during entire crop season. The relative humidity varied from 77 to 93 percent in morning and 26 to 60 percent in the evening hours. The mean sunshine hours varied between 4.1 to 9.8 hours per day. The total rainfall of 89.5 mm was received in total 7 rainy days. Therefore, the crop was irrigated by giving flood irrigation, which protects the crop from moisture stress during the growth and development stages. As a whole, the weather conditions were almost conducive for proper growth, development and yield of tomato crop [Fig-2].

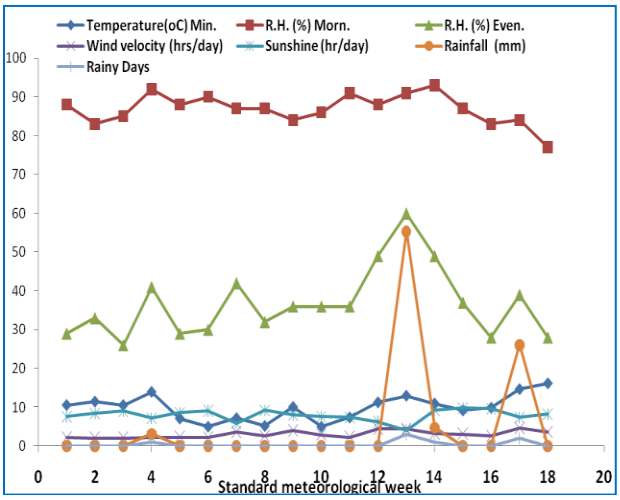

Fig-2 Meteorological data of Jabalpur

Description of experiment

A field research was conducted at ICAR-Directorate of Weed Science Research (DWR), Maharajpur, Jabalpur (Madhya Pradesh) during *Rabi* 2012-13. Eight treatment combinations were made including four main treatment as drain water, filtered water-I (*Typha* based) and filtered water-II (*Vetiveria* based) and tube well water as control. These treatments were split -up with two level of EDTA treatment (Control and EDTA @ 0.25 kgha^{-1}). The net plot size 1.5x2 =3 m^2 and row to row and plant to plant spacing 50x30 cm in tomato crop variety- *Dhamni*.

Quality of irrigation water

In order to know the quality of industrial waste water, samples were collected from waste water carrying drain emanated from industrial area ***Richhai***, Jabalpur including waste water from vehicle factory and some recently established industries like welding, plastic etc. The pH and Electrical conductivity (EC) were determined by using pH and EC meter, respectively (Jackson, 1973).The heavy metals concentration in water samples were analyzed using atomic absorption spectrometer. The pH values of water irrigation ranged from 7.2 (tube well water) to 8.5 (drain water). The data presented in [Table-1] showed neutral in reaction and within the permissible limits of pH for irrigation. The electrical conductivity (EC) value of drain water was 0.67 dSm^{-1}, which was higher than tube well water (0.43 dSm^{-1}). The EC of water samples also in safe limit recommended by [21]. The concentration of Cu, Cd, Ni, Pb, Mn and Zn 0.270 and 0.01; 0.021 and 0.009; 0.390 and 0.046; 0.260 and 0.053; 0.785 and 0.028; 0.326 and 0.095 mgkg^{-1} in drain and tube well water, respectively. The data showed higher concentration in drain water as compared to tube well water. The pH and EC were found under filtered water-I and filtered water-II, were 7.4 and 7.7; 0.48 and 0.55 dSm^{-1}, respectively. The concentration of Cu, Cd, Ni, Pb, Mn and Zn was analyzed under filtered water-I and II, was 0.011 and 0.013; 0.009 and 0.011; 0.048 and 0.051; 0.055 and 0.066; 0.15 and 0.18; 0.22 and 0.26 mgkg^{-1}, respectively. The heavy metals exhibited the sequence of their concentration in water in the order of Mn > Ni >Zn > Cu > Pb > Cd. [22] recommended that water had EC >3 dS m^{-1} are not safe for irrigation purpose. The results of study are in line with the findings of [23-24].

Soil type

As per the USDA Soil Taxonomic classification the soil of experimental field was belongs to *Kheri* series *Typic Haplustert* (Vertisols), popularly known as "Black soil". The pH of experimental soil was 7.2, EC 0.25 dSm^{-1} and OC of 6.5 gkg^{-1} showed the soil was neutral in reaction, safe in EC and medium in OC. Data of available N, P and K of 226.9, 33.5 and 316.8 kg ha^{-1}, showed the N was Low but P and K was medium in status. The initial heavy metals concentration in soil was given in [Table-1].

Plant height, biomass and root length measurement

The height of plant (cm) was measured for four tagged tomato plants randomly selected in sub plot area at different growth stages (30 DAT, 60 DAT and at harvest) from the base of the plant to the tip of the top most leaf with the help of measuring scale. From each net plot, three plants were uprooted then washed with running water. The root length (cm) was measured with scale and then place for dried in hot air oven. The fresh plant biomass was recorded and dried in a hot air oven at 60 ^{0}C for 3-5 days (till constant weight) to record the dried plant biomass. The samples were ground in electric grinder for further analytical work.

Collection, processing and analysis of soil samples

Soil samples were collected with the help of tube auger from 0-10 and 10-20 cm depth of each plot after harvesting of crop. These samples were air dried, crushed with wooden pestle and mortar and sieved through 2 mm sieve. The pH was determined in 1: 2.5 soil-water suspensions using digital pH meter and same extract was measured using electrical conductivity [25]. The organic carbon was determined as described by [26]. Available nitrogen in soil samples was determined by adopting the alkaline permanganate method [27]. The phosphorus content of soil estimated by extraction procedure as described by [28]. The available potassium extracted by neutral normal ammonium acetate and take reading on flame photometer [29].The DTPA (pH 7.3) extractable Zn, Cu, Mn, Ni, Cd, and Pb extracted by 0.005 M DTPA, 0.01 M $CaCl_2$ and 0.1 M tri ethanol amine (TEA) and analyzed on atomic absorption spectrometer [30].

Digestion and analysis of plant samples

Weigh (1.0 g) plant samples in a conical flask and add 10 ml of di acid mixture (1 part perchloric + 3 part nitric acid) and digested the mixture on hot plate till the residue was colourless. Dilute the samples with distilled water and filtered through Whatman No.1 filter paper, made up the volume of digested to 50 ml, and read the samples for heavy metals content on atomic absorption spectrophotometer as described by [29] Lindsay & Norvell (1978). N analysis of plant samples as described by [31], P and K as described by [32]. The nutrient uptake (kg ha^{-1}) = nutrient content (%) X yield (kgha^{-1}) for N, P and K and heavy metal uptake (gha^{-1}) = Heavy metal concentration (mgkg^{-1}) X yield (kgha^{-1}). The data obtained from various observations analyzed by the method of analysis of variance technique [33].

Table-1 *Initial mean concentration of heavy metals (mgkg^{-1}) in soil and water used for irrigation*

Metals	Soil	Permissible limit in soil Indian standard [17]	DW	FW-I	FW-II	TW	Permissible limit in water as per FAO	Permissible limit in water as per Indian standard [17]
Cu	2.697	135-270	0.27	0.011	0.013	0.01	0.2	0.05
Mn	3.968	2000 [49]	0.785	0.15	0.186	0.028	0.2	0.1
Ni	0.343	75-150	0.39	0.048	0.051	0.046	0.2	1.4
Cd	0.08	3-6	0.021	0.009	0.011	0.009	0.01	0.01
Zn	0.798	300-600	0.326	0.225	0.26	0.095	2	5.0
Pb	1.024	250-500	0.26	0.055	0.066	0.053	5	0.1

Table-2 *Effect of irrigation water and EDTA on heavy metals accumulation in soil*

Treatment	Cd (mgkg^{-1})		Pb (mgkg^{-1})		Cu(mgkg^{-1})		Mn(mgkg^{-1})		Zn(mgkg^{-1})		Ni(mgkg^{-1})	
Depth(cm)	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20	0-10	10-20
TW	0.15	0.12	2.59	2.02	4.81	3.93	4.18	3.93	1.18	1.07	0.66	0.59
Filter I	0.22	0.18	2.67	2.2	4.99	4.36	3.78	3.53	1.44	1.13	0.67	0.6
Filter II	0.24	0.18	2.71	2.37	5.7	4.72	5.59	2.12	1.68	1.31	0.74	0.5
DW	0.3	0.24	3.08	2.53	6.16	5.51	4.79	4.67	1.79	1.35	0.74	0.58
SEm±	**0.01**	**0.003**	**0.07**	**0.06**	**0.13**	**0.11**	**1.15**	**0.08**	**0.04**	**0.03**	**0.01**	**0.01**
LSD (p=0.05)	**0.04**	**0.01**	**NS**	**NS**	**0.45**	**0.39**	**NS**	**0.29**	**0.14**	**0.12**	**0.04**	**0.02**
Control	0.22	0.17	2.61	2.07	5.01	4.15	3.61	3.45	1.44	1.12	0.68	0.56
EDTA	0.23	0.19	2.92	2.49	5.81	5.11	5.56	3.67	1.61	1.32	0.73	0.58
SEm±	**0.01**	**0.003**	**0.07**	**0.07**	**0.14**	**0.1**	**1.67**	**0.08**	**0.03**	**0.04**	**0.01**	**0.001**
LSD (p=0.05)	**NS**	**0.01**	**0.23**	**0.23**	**0.47**	**0.34**	**NS**	**NS**	**0.11**	**0.12**	**0.04**	**0.01**
SEm±	0.003	0.002	0.1	0.1	0.2	0.15	0.55	0.44	0.05	0.05	0.02	0.01
Interaction I LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.004	0.003	0.12	0.11	0.23	0.19	0.6	0.63	0.07	0.06	0.02	0.01
Interaction II LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Initial	**0.080**		**1.024**		**2.697**		**3.96**		**0.798**		**0.343**	

Results and Discussion

Plant height, root length and tomato yield

The increase in plant height and root length were observed in plots where wastewater applied with directly drain as compared to tube well water but the differences between these treatments could not be converted into significant trend. However, the yield of tomato increased significantly with drain water irrigation directly. The yield of tomato was found to be 10.04, 8.08, 8.54 and 8.17 t ha^{-1} in plots, where drain water, filtered water-I, filtered water–II and tube well water application, respectively. There was no significant increase in yield of tomato was found to be 8.79 and 8.62 t ha^{-1} in plots, where with and without EDTA application, respectively. The interaction between wastewater irrigation and EDTA application was not significant. Irrigation with wastewater enhanced the growth may be due to higher content of nutrients. The higher biomass yield and plant height in the wastewater treated plots may be associated with its enrichment with the essential plants nutrients. Further, the higher levels of N, P and Kin the treated wastewater resulted positive impact on the crop productivity [34-35].

Concentration of heavy metals in root, shoot and fruit of tomato

The data given in [Table-3] indicated that the significant differences due to wastewater irrigation and EDTA application, while their interaction was found non-significant. On dry weight basis, the Zn concentration in root, shoot and fruit was analyzed to be 46.39, 55.54 and 25.83 mgkg^{-1}; 46.40, 61.04 and 26.97 mgkg^{-1}; 49.23, 63.20 and 27.01 mgkg^{-1}; 53.34, 68.21 and 27.19 mgkg^{-1} under tube well water, filtered water-I, filtered water–II and drain water, respectively. However, its concentration in root, shoot and fruit was found to be 51.35, 64.43 and 28.31 mgkg^{-1} and 46.34, 59.56 and 25.19 mgkg^{-1} where with and without EDTA application, respectively. The concentration of Cu in root, shoot and fruit was 13.37, 5.40 and 4.47 mgkg^{-1}; 13.49, 6.13 and 4.98 mgkg^{-1}; 17.19, 6.80 and 5.93 mgkg^{-1} and 18.89, 6.52 and 6.61 mgkg^{-1} under tube well, filtered water-I, filtered water–II and drain water, respectively. The Cu concentration in root, shoot and fruit was observed to be 16.58, 6.74 and 5.96 mgkg^{-1} and 14.89, 5.69 and 5.04 mgkg^{-1} ^{1}with EDTA and control, respectively. The concentrations of Mn in root, shoot and fruit was recorded to be 11.99, 4.87 and 3.11 mgkg^{-1}; 12.86, 6.07 and 3.49 mgkg^{-1}; 12.88, 6.29 and 3.54 mgkg^{-1}; 13.20, 6.39 and 3.55 mgkg^{-1} under tube well, filtered water-I, filtered water–II and drain water, respectively. While its concentration in root, shoot and fruit was found to be 13.33, 6.52 and 3.68 mgkg^{-1} and 12.14, 5.29 and 3.16 mgkg^{-1} where with EDTA and no EDTA, respectively. The concentrations of Pb in root, shoot and fruit was found to be 1.51, 2.15 and 0.62 mgkg^{-1}; 3.10, 4.77 and 1.33 mgkg^{-1}; 3.27, 4.92 and 1.33 mgkg^{-1} and 5.44, 7.37 and 2.12 mgkg^{-1} under tube well, filtered water-I, filtered water–II and drain water, respectively. While, the concentration of Pb in root, shoot and fruit was observed to be 3.72, 5.01 and 1.44 mgkg^{-1} and 2.94, 4.59 and 1.26 mgkg^{-1} under EDTA and control, respectively. The concentration of Ni in root, shoot and fruit was observed to be 7.83, 6.04 and 4.05 mgkg^{-1}; 8.32, 6.67 and 4.21 mgkg^{-1}; 8.06, 6.74 and 4.79 mgkg^{-1};10.36, 7.16 and 5.57 mgkg^{-1} under tube well, filtered water-I, filtered water–II and drain water, respectively. Nevertheless, its concentration in root, shoot and fruit was observed to be 9.10, 6.95 and 4.96 mgkg^{-1} and 8.19, 6.36 and 4.36 mgkg^{-1} under EDTA and control, respectively. On dry weight basis, the concentrations of Cd in root, shoot and fruit was recorded to be 0.10, 0.19 and 0.06 mgkg^{-1}; 0.23, 0.37 and 0.12 mgkg^{-1}; 0.24, 0.38 and 0.13 mgkg^{-1} and 0.41, 0.56 and 0.23 mgkg^{-1} under tube well, filtered water-I, filtered water–II and drain water, respectively. The increase concentration of Cd was observed to be 0.27, 0.37 and 0.15 mgkg^{-1} in root, shoot and fruit under EDTA over the control (0.23, 0.38 and 0.12 mgkg^{-1}), respectively.

The concentrations of heavy metals in different parts (root, shoot and fruit) of tomato in plots under wastewater irrigation might be attributed to fact that drain water was composed of various types of industrial effluents, which contained a variety of chemical compounds having different metals. The chemical analysis of drain water confirms this fact [Table-1]. Higher Zn and Mn contents, compared to other may be attributed to the fact that Zn and Mn accumulates more than any other metal ion in plants [36]. Between the plant parts, lower content of heavy metals were observed in fruit than the shoot and root parts, which were lower than the permissible limits, set by the WHO, 1996. The accumulation of heavy metals also depends on plant age and plants parts. Irrigation by effluents is the main reason for the accumulation of heavy metals in vegetables [10-11]. The present study was corroborated with [1, 9, 38, 39, 14]. Heavy metals enrichment in vegetables through irrigation water also highlighted by [12, 40-42].

Heavy metal uptake by tomato

The use of wastewater and EDTA exhibited a significant influence on heavy metals uptake but their interaction effects were not significant [Table-4]. The uptake of Zn, Cu, Mn Ni, Cd and Pb was analyzed to be 63.60, 73.69, 74.43 and 81.46 gha^{-1}; 11.08, 13.51, 16.30 and 19.79 gha^{-1} ; 7.73, 9.48, 9.75 and 10.61 gha^{-1} ; 4.24, 11.59, 11.23 and 15.04 gha^{-1}; 0.14, 0.32, 0.36 and 0.68 gha^{-1} and 1.53, 3.61, 3.67 and 6.35 gha^{-1} under tube well water, filtered water-I, filtered water-II and drain water irrigation, respectively. The Cu Mn Ni Cd and Pb uptake with and without EDTA application was found to be 16.92 and 13.41 gha^{-1},10.41 and 8.37 gha^{-1}, 11.57 and 9.48 gha^{-1} ,0.43 and 0.32 gha^{-1} and 4.14 and 3.44 gha^{-1}, respectively. While, Zn uptake was statistically significant (80.32 g ha^{-1}) with EDTA application over control (66.27 g ha^{-1}) and uptake of Mn, Ni, Cd, Pb and Cu significantly increased with EDTA application.

Data revealed that the irrigation with wastewater an increased uptake of Cu, Cd, Pb, Mn & Zn by tomato was observed whereas tube well irrigation reflected minimum uptake of heavy metals in plant matter. The drain water irrigation, heavy metals tended to accumulate in soil and thus their availability increased in soil solution and ultimately higher metal uptake was observed in tomato shoot. It is fact that Zn and Mn accumulates more than any other metal ion in plants [36]. Higher heavy metals uptake by tomato was observed under EDTA, which is the most effective chelating agent [48]. [43-44] reported that the accumulation of metals in the above ground parts of plants due to development a metal chelate complex and enhances its mobility within the plant by increasing its transport from roots to aerial parts. A number of studies showed elevated levels of heavy metals in vegetables grown in areas having long-term use of treated or untreated wastewater. Absorption and accumulation of heavy metals in plant tissues depends on several factors *viz.,* pH, EC, CEC, OC and nutrients level in soil, plant species, metal transfer factor and degree of maturity etc. [3, 9, and 45].

Table-3 *Effect of irrigation water and EDTA on heavy metals concentration in different parts of plant*

Treatment	Cd ($mgkg^{-1}$)			Pb ($mgkg^{-1}$)			Ni ($mgkg^{-1}$)			Cu ($mgkg^{-1}$)			Mn ($mgkg^{-1}$)			Zn ($mgkg^{-1}$)		
	Root	Shoot	Fruit	Root	Shoot	Fruit	Root	Shoot	Fruit	Root	Shoot	Fruit	Root	Shoot	Fruit	Root	Shoot	Fruit
TW	0.10	0.19	0.06	1.51	2.15	0.62	7.83	6.04	4.05	13.37	5.4	4.47	11.99	4.87	3.11	46.39	55.54	25.83
FW-I	0.23	0.37	0.12	3.1	4.77	1.33	8.32	6.67	4.21	13.49	6.13	4.98	12.86	6.07	3.49	46.4	61.04	26.97
FW- II	0.24	0.38	0.13	3.27	4.92	1.33	8.07	6.74	4.8	17.19	6.8	5.93	12.88	6.29	3.54	49.23	63.2	27.01
DW	0.41	0.56	0.23	5.44	7.37	2.12	10.37	7.16	5.57	18.89	6.52	6.61	13.2	6.39	3.55	53.34	68.21	27.19
SEm±	**0.01**	**0.02**	**0.01**	**0.16**	**0.13**	**0.05**	**0.26**	**0.17**	**0.14**	**0.39**	**0.17**	**0.15**	**0.24**	**0.21**	**0.09**	**1.28**	**1.78**	**0.8**
LSD (p=0.05)	**0.03**	**0.05**	**0.03**	**0.56**	**0.44**	**0.16**	**0.89**	**0.58**	**0.47**	**1.37**	**0.58**	**0.53**	**0.83**	**0.74**	**0.32**	**NS**	**NS**	**NS**
Control	0.23	0.38	0.12	2.94	4.59	1.26	8.19	6.36	4.36	14.89	5.69	5.04	12.14	5.29	3.16	46.34	59.56	25.19
EDTA	0.27	0.37	0.15	3.72	5.01	1.44	9.1	6.95	4.96	16.58	6.74	5.96	13.33	6.52	3.68	51.35	64.43	28.31
SEm±	**0.01**	**0.01**	**0.003**	**0.07**	**0.06**	**0.02**	**0.12**	**0.06**	**0.1**	**0.39**	**0.17**	**0.18**	**0.16**	**0.06**	**0.05**	**1.61**	**1.28**	**0.67**
LSD (p=0.05)	**0.02**	**NS**	**0.01**	**0.22**	**0.18**	**0.06**	**0.41**	**0.2**	**0.32**	**1.27**	**0.56**	**0.59**	**0.53**	**0.21**	**0.17**	**5.24**	**4.18**	**2.19**
SEm±	0.01	0.02	0.001	0.13	0.11	0.04	0.25	0.12	0.19	0.55	0.24	0.26	0.32	0.13	0.1	2.27	1.81	0.95
Interaction I LSD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.03	0.05	0.02	0.48	0.38	0.14	0.8	0.48	0.51	1.75	0.76	0.74	0.87	0.58	0.3	6.35	7.14	3.35
Interaction II LSD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table-4 *Effect of irrigation water and EDTA on metals uptake (g ha^{-1}) by tomato*

Treatment	Mn (g ha^{-1})	Ni (g ha^{-1})	Cd (g ha^{-1})	Pb (g ha^{-1})	Zn (g ha^{-1})	Cu (g ha^{-1})
TW	7.73	4.24	0.14	1.53	63.6	11.1
FW-I	9.48	11.59	0.32	3.61	73.69	13.5
FW- II	9.75	11.23	0.36	3.67	74.43	16.3
DW	10.6	15.04	0.68	6.35	81.46	19.8
SEm±	**0.43**	**0.68**	**0.03**	**0.21**	**5.49**	**1.00**
LSD (p=0.05)	**1.49**	**2.34**	**0.09**	**0.72**	**NS**	**3.47**
Control	8.37	9.48	0.32	3.44	66.27	13.4
EDTA	10.4	11.57	0.43	4.14	80.32	16.9
SEm±	**0.27**	**0.39**	**0.01**	**0.09**	**2.23**	**0.38**
LSD (p=0.05)	**0.89**	**1.26**	**0.04**	**0.28**	**7.27**	**1.23**
SEm±	1.83	2.06	0.02	0.17	4.46	0.76
Interaction I LSD (p=0.05)	NS	NS	NS	NS	NS	NS
SEm±	1.82	1.69	1.94	1.61	1.87	1.7
Interaction II LSD (p=0.05)	NS	NS	NS	NS	NS	NS

Nutrients content and uptake by tomato

Data presented in [Table-5] on N concentration in root, shoot and fruit of tomato was found to be 0.64, 0.90 and 1.65 %; 0.68, 0.95 and 1.66 %; 0.66, 1.01 and 1.73 %; 0.77, 1.04 and 1.89% ; P concentration in root, shoot and fruit 0.18, 0.22 and 0.53 %; 0.19, 0.23 and 0.57 %; 0.20, 0.24 and 0.57%; 0.21, 0.26 and 0.58 % and K concentration in root, shoot and fruit 1.27, 0.66 and 1.88 %; 1.62, 0.71 and 1.99 %; 1.73, 0.80 and 2.02 %; 1.84, 0.87 and 2.05%, with tube well, filtered water-I, filtered water–II and drain water irrigation, respectively. However, with the application of EDTA, the concentration of N, P and K observed to be 0.70, 0.99 and 1.77%; 0.20, 0.24 and 0.57 %; 1.65, 0.81 and 2.04 % over without EDTA application 0.67, 0.96 and 1.69 % and 0.19, 0.23 and 0.55% and 1.58, 0.71 and 1.93% in root, shoot and fruit respectively. Higher N, P and K was observed in drain water may be due to containing high organic load in waste water which was enabled to supply the nutrients during different irrigations to tomato plant.

The N, P and K uptake was found to be 40.83, 45.49, 47.91 and 57.13 $kgha^{-1}$; 13.20, 15.67, 15.77 and 17.58 $kgha^{-1}$ and 14.88, 17.59, 17.40 and 23.92 $kgha^{-1}$ under tube well water, filtered water-I, filtered water–II and drain water, respectively. However, with or without EDTA application, the N, P and K uptake analyzed to be 50.70 and 44.99 $kgha^{-1}$; 16.41 and 14.70 $kgha^{-1}$ and 20.74 and 16.16 kg ha^{-1}, respectively [Table-5]. The highest N, P and K uptake was recorded under drain water application, while the lowest P-uptake by plant showed by tube well water. The P and K uptake with EDTA application was statistically significant over without EDTA treatment. Soil irrigated with wastewater contains high amount of available phosphorus and nitrate concentration increase productivity in agriculture [46-47].

Fertility status after harvest of crop

Data presented in [Table-6] showed that the soil pH and EC were slightly increased but statistically non-significant at 0-10 and 10-20 cm depth. The availability of OC in soils was found to be 6.69, 6.93, 7.39 and 7.46 gkg^{-1} and 6.29, 6.52, 6.91 and 7.18 gkg^{-1} under tube well water, filtered water-I, filtered water–II and drain water irrigated plots, respectively. However, the OC resulted 7.3 and 6.85 gkg^{-1}; 6.9 and 6.61 gkg^{-1} where with and without EDTA at 0-10 and 10-20 cm depth, respectively. The availability of N in soils was analyzed to be 221.22, 232.52, 250.40 and 271.04 $kgha^{-1}$ and 210.22, 212.85, 221.73 and 245.71 $kgha^{-1}$ at 0-10 and 10-20 cm depth under tube well water, filtered water-I, filtered water–II and drain water irrigated plots, respectively. Data showed that the highest available N with drain water followed by filtered-II, filtered-I and tube well water. With EDTA application, resulted 256.01 and 231.10 $kgha^{-1}$ whereas the control showed 231.57 and 214.16 $kgha^{-1}$ at 0-10 and 10-20 cm depth, respectively. Data showed drain water left the highest amount of available P in soil followed by filtered-II, filtered-I and tube well water and was significantly superior over the remaining types of water at both the depth. It is obvious from the drain water was found to left the highest available K whereas tube well water left the lowest K content. The EDTA application showed the highest available K and the lowest in control. The availability of major nutrients were high in soils under wastewater irrigation may be due to higher content of these nutrients in the drain water. In recent years, it has become an important agronomic procedure because it contains some amount of N, P and K nutrients and can contribute to organic matter recycling and restoring the soils fertility [34 and 8].

Table-5 *Effect of irrigation water and EDTA on growth and tomato yield, N, P and K concentration in different parts of plant and uptake by of tomato*

Treatment	Plant height (cm)			Root length (cm)	Yield (t/ha)	N(%)			P(%)			K(%)			(Uptake kgha-1)		
	30DAT	60DAT	at harvest			Root	Shoot	Fruit	Root	Shoot	Fruit	Root	Shoot	Fruit	N	P	K
TW	31.9	50.12	57.88	35.4	8.17	0.64	0.9	1.65	0.18	0.22	0.53	1.27	0.66	1.88	40.83	13.2	14.88
Filter II	35.29	50.13	57.25	37.86	8.54	0.68	0.95	1.66	0.19	0.23	0.57	1.62	0.71	1.99	45.49	15.67	17.59
Filter I	32.48	48.62	57.59	37.15	8.08	0.66	1.01	1.73	0.2	0.24	0.57	1.73	0.8	2.02	47.91	15.77	17.4
DW	30.75	52.02	59.21	37.54	10.04	0.77	1.04	1.89	0.21	0.26	0.58	1.84	0.87	2.05	57.13	17.58	23.92
SEm±	0.79	0.77	1.24	1.62	0.28	0.01	0.02	0.03	0.003	0.003	0.006	0.02	0.02	0.04	1.49	0.47	0.73
LSD (p=0.05)	NS	NS	NS	NS	2.9	0.04	0.07	0.12	0.01	0.01	0.018	0.07	0.07	NS	5.15	1.64	2.54
Control	31.71	49.3	57.8	37.01	8.62	0.67	0.96	1.69	0.19	0.23	0.55	1.58	0.71	1.93	44.99	14.7	16.16
EDTA	33.51	51.14	58.17	36.96	8.79	0.7	0.99	1.77	0.2	0.24	0.57	1.65	0.81	2.04	50.7	16.41	20.74
SEm±	1.72	0.61	1.74	2.64	0.25	0.01	0.01	0.03	0.004	0.003	0.01	0.01	0.02	0.02	1.51	0.55	0.57
LSD (p=0.05)	NS	2	NS	NS	NS	0.03	0.03	0.08	0.01	0.01	0.02	0.04	0.05	0.06	4.91	1.78	1.85
SEm±	2.43	0.87	2.46	3.74	0.35	0.01	0.01	0.04	0.001	0.002	0.01	0.02	0.02	0.03	2.13	0.77	0.8
Interaction I LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	2.05	1.25	2.47	3.5	1.52	0.02	0.03	0.05	0.01	0.01	0.02	0.08	0.09	0.15	2.59	0.86	1.18
Interaction II LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table-6 *Effect of irrigation water and EDTA on physicochemical properties and available N, P and K in soil at 0-10 and 10-20 cm depth*

Treatment	pH		EC (dSm^{-1})		OC (gkg^{-1})		N ($kgha^{-1}$)		P ($kgha^{-1}$)		K ($kgha^{-1}$)	
Depth(cm)	**0-10**	**10-20**	**0-10**	**10-20**	**0-10**	**10-20**	**0-10**	**10-20**	**0-10**	**10-20**	**0-10**	**10-20**
TW	7.04	7.18	0.55	0.48	6.69	6.29	221.2	210.2	34.9	31.57	300	287.9
Filter I	7.22	7.22	0.53	0.48	6.93	6.52	232.5	212.8	36.2	32.69	307	286.2
Filter II	7.44	7.3	0.55	0.49	7.39	6.91	250.4	221.7	38.5	33.02	314.7	297.7
DW	7.43	7.35	0.59	0.55	7.46	7.18	271.04	245.7	41.3	37.45	363.8	336.3
SEm±	**0.08**	**0.04**	**0.01**	**0.01**	**0.12**	**0.12**	**5.09**	**4.38**	**0.77**	**0.48**	**5.11**	**7.09**
LSD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**0.3**	**0.43**	**17.6**	**15.17**	**2.68**	**1.64**	**17.69**	**24.53**
Control	7.26	7.25	0.55	0.51	6.9	6.61	231.5	214.1	36.07	32.99	311.5	293.7
EDTA	7.3	7.27	0.56	0.49	7.3	6.85	256	231.1	39.38	34.38	331.3	310.4
SEm±	**0.02**	**0.01**	**0.01**	**0.01**	**0.1**	**0.03**	**6.34**	**3.45**	**0.44**	**0.21**	**5.5**	**3.68**
LSD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**0.3**	**0.1**	**20.67**	**11.25**	**1.42**	**0.68**	**17.93**	**12**
SEm±	0.03	0.01	0.01	0.02	0.1	0.1	8.96	4.88	0.62	0.29	7.77	5.2
Interaction I LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.11	0.05	0.02	0.02	0.2	0.1	9.59	7.09	1.18	0.7	9.08	10.68
Interaction II LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Initial	**7.2**		**0.25**		**6.5**		**226.9**		**33.5**		**316.8**	

Heavy metals accumulation in soil

Irrigation with drain water significantly higher zinc accumulated in soil followed by filtered-II, tube well water and filtered–I, but statistically at par with filtered -II. At 0-10 and 10-20 cm depth, the accumulation of Zn in soils was found to be 1.18, 1.44, 1.68 and 1.79 $mgkg^{-1}$ and 1.07, 1.13, 1.31 and 1.35 $mgkg^{-1}$ under tube well water, filtered water-I, filtered water–II and drain water irrigated plots, respectively. However, at 0-10 and 10-20 cm depth, the significant increased of Zn was observed in plots applied with EDTA resulting 1.61 and 1.32 $mgkg^{-1}$ over the control showing 1.44 and 1.12 $mgkg^{-1}$, respectively. The accumulation of Cu was significantly higher to be 5.82 and 5.11 $mgkg^{-1}$ with EDTA application over the control showing 5.01 and 4.15 $mgkg^{-1}$ in plots at 0-10 and 10-20 cm depth, respectively. The Cu concentration in soils was observed to be 4.81, 4.99, 5.70 and 6.16 $mgkg^{-1}$ and 3.93, 4.36, 4.72 and 5.51 $mgkg^{-1}$ with the application of tube well water, filtered water-I, filtered water–II and drain water irrigated plots at 0-10 and 10-20 cm depth, respectively. The data on Cu content in soil showed that the use of drain water recorded highest amount of Cu (6.16 $mgkg^{-1}$ and 5.51 $mgkg^{-1}$) in soil followed by filtered-II filtered-I and tube well water and was significantly superior over the remaining treatments but at par with filtered-II at both 0-10 and

10-20 cm depth, respectively. At 0-10 and 10-20 cm depth the Mn concentration in soils was 4.18, 3.78, 5.59 and 4.79 $mgkg^{-1}$ and 3.93, 3.53, 2.12 and 4.67 $mgkg^{-1}$ under tube well water, filtered water-I, filtered water–II and drain water irrigated plots, respectively. The increased accumulation of Mn was observed in plots applied with and without EDTA resulting 5.56 and 3.67 $mgkg^{-1}$ over the control showing 3.61 and 3.45 $mgkg^{-1}$ at 0-10 and 10-20 cm depth, respectively but statistically non significant. The accumulation of Pb was significantly higher in plots applied with EDTA resulting 2.92 and 2.49 $mgkg^{-1}$ over the control showing 2.61 and 2.07 $mgkg^{-1}$ at 0-10 and 10-20 cm depth, respectively. At 0-10 and 10-20 cm depth, the Ni concentration in soils was found to be 0.66, 0.67, 0.74 and 0.74 $mgkg^{-1}$ and 0.59, 0.60, 0.50 and 0.58 $mgkg^{-1}$ under tube well water, filtered water-I, filtered water–II and drain water irrigated plots, respectively. The accumulation of Ni was significantly higher under drain water as compared to remaining at 0-10 and 10-20cm depth, but statistically at par with filtered-II. The significant accumulation of Ni was observed in plots applied with EDTA resulting 0.73 and 0.58 $mgkg^{-1}$ over the control showing 0.68 and 0.56 $mgkg^{-1}$at 0-10 and 10-20 cm depth, respectively.

At 0-10 and 10-20 cm depth, the accumulation of Cd in soils was observed to be 0.15, 0.22, 0.24 and 0.30 $mgkg^{-1}$ and 0.12, 0.18, 0.18 and 0.24 $mgkg^{-1}$ under tube well water, filtered water-I, filtered water–II and drain water irrigated plots, respectively. Data showed the application of drain water exhibited the highest accumulation, followed by filtered water II, filtered water I and tube well water. The performance of treatment system, filtered water II and I were at par but statistically significantly over tube well water. The accumulation of Cd in plots applied with and without EDTA was observed to be 0.23 $mgkg^{-1}$ and 0.22 $mgkg^{-1}$ at 0-10 cm but statistically non-significant. However, it was significantly higher 0.19 $mgkg^{-1}$ in plots applied with EDTA over no EDTA (0.17 $mgkg^{-1}$) at 10-20 cm depth. At 0-10 cm and 10-20 cm depth, the Pb accumulation in soils was found to be 2.59, 2.67, 2.71 and 3.08 $mgkg^{-1}$ and 2.02, 2.20, 2.37 and 2.53 $mgkg^{-1}$ under tube well water, filtered water-I, filtered water–II and drain water irrigated plots, respectively. The interaction between wastewater and EDTA application was not significant.

Under drain water irrigation the DTPA extractable Cu, Mn, Pb, Zn, Ni and Cd increased appreciably as compared to the tube well irrigated soils since the wastewater contained higher concentration of these elements. The lower content of heavy metals under filtered water -I and filtered water -II irrigated plots were observed as compared to drain water. Among filtered system, plots under filtered water-I reduced the concentration of heavy metals than filtered-II. This was attributed to the fast growth of *Typha* in this system resulting reduced concentration of heavy metals which was at par with the tube well water. Lower content of Cd, Pb, Ni, Cu, Mn and Zn was observed in sub-surface layer (10-20 cm) as compared to surface layer may be due to higher clay content in soil resulting less downward movement of heavy metals. [8] reported that the Cr and Cu have affinities both to clay and to humic substance quantities. [12] reported the trend of metal accumulation in wastewater-irrigated soil was Fe > Mn> Pb> Cr >Cd. Improvement in bioavailability of heavy metals under EDTA applied soil against its control might be due to chelating agent EDTA [48]. The concentrations of heavy metals may be below the toxic limit due to buffering capacity of the soil. The heavy metal concentrations were, however, below the safe limits of Indian [17] and EU standards [49]. Similar conclusions were also reported by [4, 37-38, 42, 50-51].

Conclusions

Heavy metal accumulation in wastewater-irrigated plot looking to the concern of management of drain water emanated from the human habitation and industrial area containing higher concentration of heavy metals, use of such water for irrigation enhanced the yield of tomato than tube well water. However, at the same time the soil irrigated with such untreated water and the tomato grown on such soil absorbed the heavy metals like cadmium, lead, copper nearly two fold in its shoot than the roots. Although these metals content in fruit part and soil were below the permissible limit, but in long run continuous use of untreated wastewater may pose threat of entry of such metals in food chain through tomato shoot and root. In order to check risk of soil contamination and crop quality, treatment of polluted water showed potential for remediation of heavy metals including cadmium, lead, copper, nickel and manganese from the drain water. Metal tolerant plant and associated microbial species should be evaluated for multi-metals concentrations in soil.

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