Annals of Plant and Soil Research 17(4): 350-355 (2015)

EFFECT OF SEWAGE WATER ON STATUS OF NUTRIENTS AND HEAVY METALS IN SOILS AND VEGETABLE CROPS

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Received: May, 2015; Revised accepted: October, 2015

ABSTRACT

A survey was conducted during 2012-14 to study the effect of sewage water on status of nutrients and heavy metals in vegetables. Study revealed that raw sewage water (RSW) contained elevated concentrations of toxic metals (Cd and Cr) with high BOD, COD, TDS and RSC being rich source of macro and micro nutrients, whereas treated sewage water (TSW) proved to be a good source of plant nutrients and irrigation water. RSW and TSW irrigated fields showed relatively higher concentrations of trace metals but well below the phytotoxicity limits. Raw sewage water irrigated vegetables contained Cd and Cr whereas these metals were absent in TSW irrigated vegetables and soils. Though, the application of raw sewage water and treated sewage water improved chemical properties and plant nutrient status of soils but did result in buildup of Fe, Cu, Mn, Zn, in general, and Cd and Cr in particular. However, a definite toxic cations concentration in crops is apparent looking in to buildup of metallic cations in edible parts due to long term irrigation with RSW as against tube well water.

Key words: Raw sewage water, treated sewage water, soil properties, trace and toxic metals, vegetables.

INTRODUCTION

Indeed, the awareness of need to recycle when possible source contained in waste has become of interest in application of municipal sewage in peri-urban agriculture areas, because, it supplements towards replenishment of already mined nutrients from soil (Bhat *et al.* 2011). Therefore, utilization of sewage water for vegetable production has become common practice as the availability of fresh water for irrigation is getting reduced day by day in semi-arid areas. Therefore, in such situations use of sewage water/ industrial effluents has been advocated to be utilized in irrigation thereby meeting the existing demand of water and plant nutrients, the most limiting factor in agricultural production. Utilization of sewage water in irrigation provides water and nutrients to crops on one hand and paves the means and ways for safe disposal of sewage through land treatment and avoids potential environmental hazards. As the soils are most effective sink having higher metabolic rates to transform waste material in to useful products to plant and soil (Tiwari *et al.* 2003, Saraswat *et al.* 2007). Sewage water is a potential source of irrigation water and plant nutrient. The escalating cost of inorganic fertilizers and limited availability of good quality water, practice of raw sewage irrigation has been accentuated in peri-urban areas (Nyamanagara and Mzezewa 2001, Tiwari *et.al* 2003). Sewage irrigation is expected to carry a substantial amount of macro (NPK) and micro (Fe, Cu, Mn, Zn) nutrients to soils, thereby controlling crop production and fertility level of soils (Meena *et.al.* 2006). But major limitation of municipal sewage/or industrial effluents is the resultant heavy metal accumulation in soils followed by biomagnifications in food chain, posing a potential health hazard for human beings (Sims and Kline 1991). Prolonged use of sewage and industrial effluents may ultimately cause pollution of soils and ground water (Saraswat *et.al* 2005). This needs regular exercise for characterization and monitoring of such soils with respect to health for sustainable productivity of soil resource to mitigate these effects. Peri-urban agriculture is predominantly facing a serious environmental pollution in its agro-ecosystem wherein soils and crops are on the verge of pollution and need some policy interventions with respect to environmental pollution in soil-crop cycle in peri-urban agricultural areas to be followed while using raw sewage, effluents or treated sewage water in irrigation. Keeping all these factors in mind, a study was conducted during 2012-14 in Sanganer Industrial area of Jaipur where a large number of dye, printing, textile and dairy industries are in operation.

MATERIALS AND METHODS

A survey of peri urban areas of Jaipur viz Durgapura, Sanganer, Chandlai, Ramsinghpura, Baxawala, Khetapura, Govindpura and Goner was done in 2012-13 for gathering information and accordingly composite samples (one made up of five samples) of soil, vegetable crops and sewage water were collected and brought to laboratory. Vegetables collected for study were cauliflower (*Brassica oleracea var. botrytis*), cabbage (*Brassica oleracea*

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var. capitata), brinjal (*Solanum melongena*), radish (*Raphanus sativus*), spinach (*Spinacea oleracea*) and tomato (*Lycopersicum esculentum*) in winter and bottle gourd (*Lagenaria siceraria*), sponge gourd (*Lufa cylindrica*), bitter gourd (*Memoradica charantia*) and okra (*Abelmoschus esculentus*) in summer season, respectively. Composite samples of above mentioned vegetable grown in treated sewage water irrigated areas of Banasthali and Haripura village were also collected and brought to laboratory for further analysis. Composite samples of tube well irrigated soil; vegetables and ground water were also collected for making comparative study with raw sewage area. The representative sample (0.5 g) was taken in 125 ml digestion tube and 5 ml of di-acid digestion mixture (HNO_3: $HClO_4$ 9:4) was added to each tube and allowed to react over night. Trace metals and pollutant elements (Fe, Cu, Mn, Zn, Cd and Cr) were estimated by employing filtrate liquid in atomic absorption spectrophotometer (AAS Model No. 4129). The pH, EC, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were estimated immediately after collection of samples. BOD and COD of raw sewage water were estimated by using Wrinkler's method (Trivedy and Goel 1984) and Reflux method (APHA 1985) respectively. Total dissolved solids (TDS), NPK, cations (Ca^{+2}+ Mg^{+2}, Na^{+}), anions (CO_3, HCO_3), trace and pollutant element (Fe, Cu, Mn, Zn, Cd and Cr) were estimated by using standard procedures as outlined by Richards (1954), Tandon (2009) and Trivedy and Goel (1984). Five composite surface soil samples from Durgapura, Sanganer, Chandlai, Ramsinghpura, Baxawala, Khetapura, Govindpura Goner of using raw sewage water, Banasthali and Haripura of using treated sewage water (TSW) and Banasthali using tube well water (TW) were collected and analyzed for their physic-chemical parameter using standard methods and procedures as outlined by Jackson (1973) and Tandon (2009).

RESULTS AND DISCUSSIONS

Irrigation quality of sewage water: Data given in Table 1 reveal that raw sewage water was alkaline in reaction (pH 8.2), whereas treated sewage water (TSW) and TW were slightly sodic in nature. Soluble salts (EC) were higher in raw sewage water (RSW) and TSW as compared to TW. BOD and COD levels in RSW were also very high (89 and 125 mg L^{-1} respectively) as compared to TSW, while TW did not show the presence of suspended matter requiring BOD and COD. Raw sewage water contained relatively higher TDS (912 mg L^{-1}) as compared to treated sewage water (505 mg L^{-1}) and (250 mg L^{-1}), but all these waters had exceeded the prescribed limits of TDS (450 mg L^{-1}) according to FAO (1985). Data reveals that total NPK (68, 18, 11 mg L^{-1} respectively) in RSW were of higher magnitude as compared to TSW (NPK: 38, 9.6, 6.0 mg L^{-1} respectively) and TW (NPK: 1.5, 0.5, 2.0 mg L^{-1} respectively). Similarly total cationic (Ca^{+2}+Mg^{+2}: 9.5; Na^{+}: 16.0 meq L^{-1} respectively) and anionic (CO^{-}_3 and HCO^{-}_3: 15.5 and 21.2 meq L^{-1} respectively) concentrations were also higher in RSW compared to TSW (Ca^{+2}+Mg^{+2}: 8.0; Na^{+}: 11.0 meq L^{-1}; CO^{-}_3 and HCO^{-}_3: 9.6 & 8.6 meq L^{-1} respectively), whereas, these parameters in TW were of very lower magnitude (Table 1).

Table 1: Irrigation quality of RSW, TSW and Tube well used for irrigation in vegetables

Water quality parameters	RSW*	TSW**	TW***
pH	7.9	8.0	8.5
EC (dS m^{-1})	1.8	1.0	1.2
BOD (mg L^{-1})	89	42	ND
COD (mg L^{-1})	125	100	ND
TDS (mg L^{-1})	912	505	250
Total N (mg L^{-1})	68.0	38	1.5
Total P (mg L^{-1})	18.0	9.6	0.5
Total K(mg L^{-1})	11.0	7.0	2.0
Ca^{+2}+Mg^{+2} (meq L^{-1})	9.5	8.0	6.5
Na+ (meq L^{-1})	16.0	11.0	8.8
CO^{-}_3 (meq L^{-1})	15.5	9.6,	6.6
HCO^{-}_3 (meq L^{-1})	21.2	8.8	9.8
RSC(meq L^{-1})	21.2	6.8	9.9
Fe (mg L^{-1})	26.3	18	2.6
Cu (mg L^{-1})	12.4	4	3.1
Mn (mg L^{-1})	23.6	3.0	1.2
Zn (mg L^{-1})	24.3	0.9	2.1
Cd (mg L^{-1})	2.5	ND#	ND#
Cr (mg L^{-1})	5.6	ND	ND
Ni (mg L^{-1})	0.98	ND	ND

**Raw sewage water, **Treated sewage water, ***Tube well water, #Not detectable*

Among the cations, Na^{+} (16.0 meq L^{-1}) in raw sewage, TSW (11 meq L^{-1}) and TW (8.8 meq L^{-1}) was higher than 3.0 meq L^{-1} as per guidelines of FAO (1985). Bicarbonate contents in RSW (21.2 meq L^{-1}), TSW (9.6 meq L^{-1}) and in TW (9.8 meq L^{-1}) were quite high suggesting that these levels are toxic since they exceed 1.5 meq L^{-1} recommended level for such water to be used in irrigation (FAO 1985). Poor quality of RSW might be attributed to higher suspended solids, high BOD and COD values due to organic residues and high RSC due to high salt load in waste water. Concentrations of Fe (26.3 mg L^{-1}), Cu (12.4 mg L^{-1}), Mn (23.6 mg L^{-1}), Zn (24.3 mg L^{-1}), Cd (2.5 mg L^{-1}) and Cr (5.6 mg L^{-1}) were above the standard limits permissible for irrigation in case of raw sewage water containing industrial effluents. Whereas Fe (18.0 mg L^{-1}), Cu (4.0 mg L^{-1}), Mn (3.0 mg L^{-1}) and Zn (0.9 mg L^{-1}) in TSW and TW (Fe 2.6; Cu 3.1; Mn 1.2 and Zn 2.1 mg L^{-1} respectively) were almost found to be in the safe range for the use of such waters in irrigation. Data further show that TSW and TW of Banasthali area did not contain toxic element (Cd and Cr) in addition to BOD and COD. On the basis of macro plant nutrient contents, the RSW and TSW proved to be a good source of these nutrients, but due to higher concentrations of heavy metals, high BOD, COD, RSC and TDS as compared to prescribed limits, these waters are unfit for irrigation.

Chemical properties of sewage irrigated soils: Composite soil samples collected from RSW irrigated area showed pH and EC in the range from 7.6 to 8.5 and 0.65 to 1.34 dS m^{-1} being both lowest in Durgapura (sewage irrigated sol) and highest in TW irrigated (Banasthali) soils respectively. Organic carbon status of soils varied from 5.95- 20.20 g kg^{-1} being highest in Durgapura (sewage irrigated sol) and lowest in TW irrigated (Banasthali) soils. Raw sewage water irrigated soils had low pH and EC and higher organic carbon as compared to TW irrigated soils (Baddesha *et al.* 1997). The decrease in pH of RSW irrigated soils may be attributed primarily to low pH of sewage water. Acidification effects of CO_2 and organic acids produced during bio degradation of higher organic matter might have caused lowering of pH. Application of sewage water for irrigation results in decreasing pH and increasing EC of surface soils (Malla and Totawat 2008). But lowering of EC of sewage water irrigated soils may be attributed to downward movement of salts present in higher concentrations in the form of suspended solids. The higher organic carbon contents of RSW/TSW irrigated soils may be ascribed to addition of organic matter through long term application of sewage effluents. The sewage application to soils is a carbon building / sequestration and soil quality sustaining process (Rattan *et al.* 2002). These results also confirm the findings of Dutta *et al.* (2000) who reported higher organic carbon status of soils receiving long term sewage water irrigation in comparison to adjoining soils irrigated with tube well water. The soils irrigated with RSW contained medium level of available N (280-560 kg ha^{-1}) barring Ramsinghpura (262.0 kg ha^{-1}) soils as compared to TSW irrigated (Banasthali and Haripura) and tube well irrigated (Banasthali) soils. All the soils of RSW irrigated area registered higher level of available phosphorus (> 22.0 kg ha^{-1}) which ranged from 22.3 to 29.5 kg ha^{-1} whereas TSW and TW irrigated soils had available phosphorus of medium level (11.5-19.2 kg ha^{-1}). The soil sampling sites had invariably medium to higher contents of available potassium in surface layer with varied from 217.0 to 293.0 kg ha^{-1} being lowest (217 kg ha^{-1}) in TW irrigated (Banasthali) soils and highest (293.0 kg ha^{-1}) in Durgapura soil samples (Kharche *et al.* 2001; Malla and Totawat 2008).

Table 2: Surface soil chemical properties and plant nutrient contents in sewage/ effluent irrigated soils

Soil Sampling site	Soil properties			Macronutrients (kg/ha)			Micronutrients metals (mg/kg)					
	pH	EC (dSm^{-1})	OC (g/kg)	N	P	K	Fe	Cu	Mn	Zn	Cd	Cr
Durgapura *	7.6	0.65	5.95	380.0	29.5	293.0	25.5	5.9	27.4	11.6	0.97	1.0
Sanganer *	7.8	0.82	4.59	285.5	26.8	284.9	11.7	2.3	31.8	11.9	1.98	1.8
Chandlai *	7.8	0.94	4.55	290.0	29.0	280.5	11.6	5.2	36.9	9.9	1.68	1.5
Ramsinghpura *	7.9	0.89	4.52	262.0	26.2	290.0	12.6	3.2	22.5	9.4	1.86	1.3
Baxawala*	7.8	0.91	4.45	290.5	22.0	285.0	12.7	4.2	26.7	9.3	1.69	1.2
Khetapura*	7.7	0.86	4.98	324.6	22.3	278.5	12.6	3.2	27.7	6.8	0.99	1.2
Govindpura*	7.7	0.85	4.64	314.0	26.0	291.0	11.0	6.6	22.8	5.5	1.98	1.5
Goner *	7.9	0.96	4.58	285.5	23.5	280.0	10.9	3.9	31.5	5.8	1.96	1.5
Mean	.77	0.86	4.78	304	25.7	285.5	13.6	4.3	28.4	8.8	1.6	1.25
Banasthali Village**	8.1	0.83	3.42	260.4	19.0	286.0	6.7	3.7	16.8	4.5	0	0
Haripura Village**	8.5	0.79	2.90	270.2	19.2	257.0	8.6	3.6	16.8	2.5	0	0
Banasthali Village (TW Irrigated)	8.5	1.34	2.20	270.2	11.2	217.0	4.6	2.2	9.8	1.5	0	0

**Raw sewage irrigated area, **TSW irrigated areas*

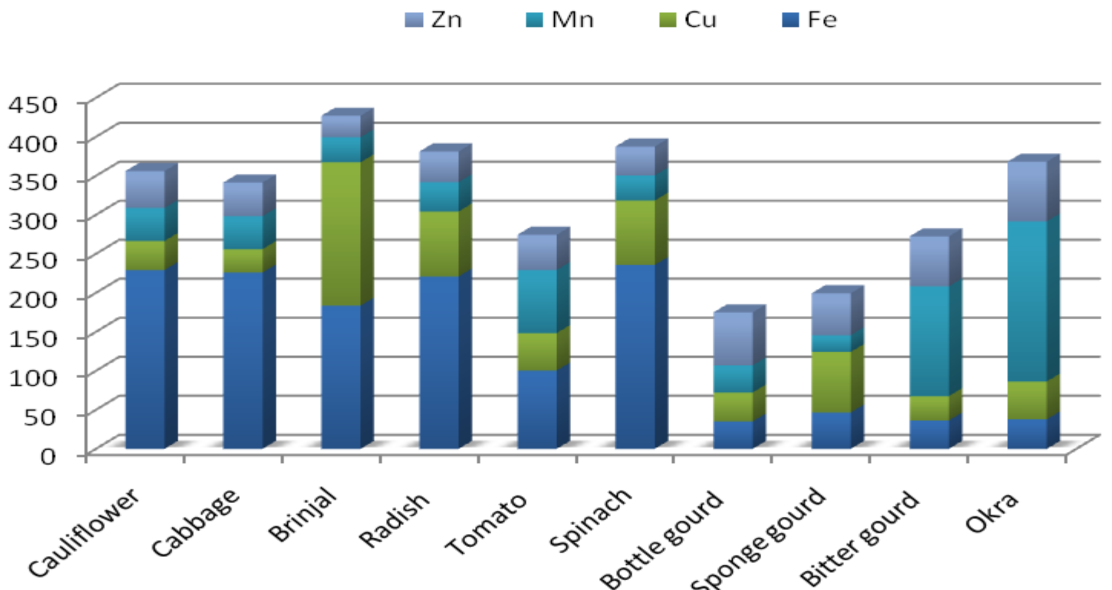

Fig. 1 : Fe, Cu, Mn & Zn contents in RSW & TW irrigated Vegitables

Trace element and heavy metals in soils: Data (Table 2) reveal that available Fe content in surface soils varied from 5.64 to 25.57 mg kg^{-1} being lowest in TW irrigated (Banasthali village) soils and highest in Durgapura (Jaipur) soils. Soils samples of raw sewage irrigated sites (Durgapura, Sanganer, Chandlai, Ramsinghpura, Baxawala, Khetapura, Govindpura and Goner) registered higher amount of available iron as compared to TSW (Banasthali and Haripura) and TW (Banasthali village) irrigated soils. Most of the soil samples contained adequate amount of available Fe. The amounts of Fe, Mn, Cu and Zn were much lower in tube well water irrigated soils (Singh *et al.* 2015). The concentrations of Cd and Cr were higher in raw sewage water irrigated soils as compared to treated sewage water and tube well water irrigated soils. Thus, the results show that raw sewage water irrigation resulted in the increased contents of micro nutrient cations and heavy metals in the soils.

Heavy metal contents in vegetables

Data (Table 3) reveal that sewage irrigated vegetables invariably registered higher amount of these metals as compared to tube well irrigated vegetables. On the basis of mean iron (Fe) content was of higher magnitude (135.25 mg kg^{-1}) in sewage irrigated vegetables than corresponding value (Fe:108.0 mg kg^{-1}) in TW irrigated vegetables. Among all sewage irrigated vegetables cauliflower, cabbage, radish and spinach registered higher amount of Fe as compared to rest vegetables (Table 3 and Fig.1).

Table 3: Range and mean of heavy metal contents (mg kg^{-1}) in vegetables of sewage irrigated area

Vegetables	Fe		Cu		Mn		Zn		Cd		Cr	
	RS*	TW**	RS	TW	RS	TW	RS	TW	RS	TW	RS	TW
Cauliflower	229.3	180.8	37.2	20.5	42.2	30.5	47.3	22.0	1.17	0	1.15	0
Cabbage	226.1	192.6	29.9	25.2	42.3	29.6	43.1	25.5	1.11	0	1.15	0
Brinjal	183.7	180.4	183.7	22.6	32.2	19.4	27.4	19.5	0.44	0	0.17	0
Radish	221.0	205.5	83.3	16.4	37.5	22.2	39.3	21.0	0.16	0	0.77	0
Tomato	100.5	95.3	47.9	18.5	80.9	45.8	45.1	24.2	0.09	0	0.27	0
Spinach	235.8	118.8	82.4	65.6	32.3	21.9	37.0	26.6	1.44	0	1.18	0
Bottle gourd	35.26	28.7	37.0	51.4	34.8	22.5	67.9	29.5	0.15	0	0.19	0
Sponge gourd	46.68	29.6	77.5	58.6	21.5	15.6	53.7	28.7	0.19	0	0.58	0
Bitter gourd	36.35	22.4	31.1	19.5	140.8	85.2	64.1	29.6	0.21	0	0.97	0
Okra	37.9	26.9	48.5	35.4	205.3	108.3	76.5	31.2	0.19	0	0.98	0
Range	135.25	108	65.8	33.37	66.9	40.1	50.1	25.7	0.52	-	0.75	-

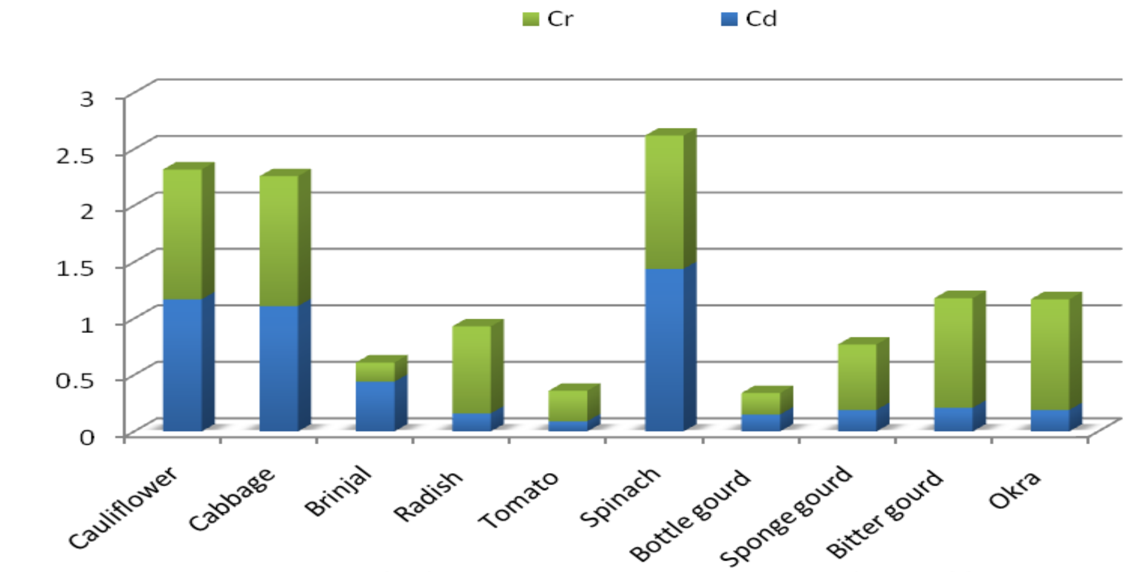

Fig. 2 : Cr and Cd contents in RSW & TW irrigated Vegitables

Copper contents in raw sewage irrigated vegetables were also higher than their corresponding vegetables of TW irrigated areas. Average value of Cu (65.8 mg kg^{-1}) was significantly higher than (33.37 mg kg^{-1}) in TW irrigated vegetables. The relative concentration of copper was higher in brinjal, radish and spinach in particular and was of lower magnitude in rest all vegetables in general (Fig. 5). For most of the vegetable crops the optimum limit of copper considered is 4-15 mg kg^{-1} in dry matter (Alloway 1968) with phytotoxicity range 20-100 mg kg^{-1}. In general plants do not accumulate Cu to levels that are likely to be toxic to human and animals. All raw sewage irrigated vegetables absorbed higher amount of Mn that TW irrigated vegetables and mean content of Mn (66.9 mg kg^{-1}) in raw sewage irrigated vegetables was higher than (40.1 mg kg^{-1}) in TW irrigated vegetables. The relatively higher concentration of Mn was recorded in okra and bitter gourd and lower amount of in all vegetables in general, but these contents were well below the phytotoxicity limits (>500 mg kg^{-1}) Likewise Mn, the Zn did not show higher magnitude of plant absorption in raw sewage irrigated vegetables but still its concentrations were of higher magnitude as compared to corresponding vegetables grown in TW irrigated areas. The mean concentration (50.1 mg kg^{-1}) was relatively higher in sewage irrigated vegetables as compared tents (25.7 mg kg^{-1}) TW irrigated vegetables. The vegetables of raw sewage irrigated absorbed higher amounts of Cd and Cr whereas concentrations of these metals were completely absent in TW irrigated vegetables (Table 3). Data pertaining to Cd and Cr contents reveals that Cr level in vegetables was higher that Cd in raw sewage irrigated vegetables (Fig. 2). Cauliflower, cabbage, spinach, bitter gourd, okra and radish absorbed higher amount of Cd compared to rest of all vegetables. Similarly, Cd contents were also higher in cauliflower, cabbage and spinach. In addition to these, brinjal also registered higher levels of Cd as compared to rest all vegetables collected from sewage irrigated areas (Fig. 2). Elevated metal concentrations in plants due to application of raw sewage and industrial effluents have been reported by Malla and Totawat (2006). Present study revealed that use of raw sewage water and treated sewage water has improved soil chemical properties and plant nutrient status including macro and micronutrients. Soils of raw sewage water irrigated area (Jaipur) showed the presence of toxic metals whereas TSW irrigated soils did not show the presence of toxic metals. Vegetables of RSW and TSW area contained invariably higher amount of trace metals but toxic metals were present only in RSW receiving vegetables. Treated sewage water instead of raw sewage water could be a substitute for nutrient requirement and reduce cost of production which is important factor in agricultural economy. Hence, raw sewage water be diverted to irrigation after proper treatment. Effluent application in irrigation needs to be monitored for sustaining agro-ecosystem in peri-urban areas.

Acknowledgement

First author place on record the award of DST-SERC young scientist project and financial support from Department of Science and Technology (Government of India), Technology Bhawan, New Mehrauli Road, New Delhi for innovative research and successful compilation of this work.

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