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Status of nutrients and heavy metals in soils and vegetable crops irrigated with sewage water

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ABSTRACT

The status of nutrients and heavy metals in soils and crops with sewage water irrigation was assessed at Bichpuri, Agra in alluvial soils. Nutrient and heavy metal status of sewage-irrigated soils and crops was compared with tube well water irrigated soils and vegetable crops. The results revealed that the quality of effluent from the sewage channel and ground water from tube well was found suitable for irrigation purpose but differed widely in their chemical characteristics. Enrichment with organic matter, N, P and K was comparatively higher in sewage- irrigated soils as compared tube well water irrigated soils. The sewage irrigated soils contained 190 to 470, 14.5 to 28.0, 122.0 to 251.0 kg ha^{-1} and 4.6 to 42.0, 3.5 to 21.9, 0.45 to 5.73 and 0.55 to 6.47 mg kg^{-1} available N, P, K, Fe, Mn, Cu and Zn, respectively, whereas adjoining soils irrigated with tube well water contained 145 - 250, 9.0 - 19.0, 100.0- 190.0 kg ha^{-1}, 3.1-14.0, 1.8-5.2, 0.15-0.70, and 0.35-1.2 mg kg^{-1}, respectively. Concentrations of micronutrients and heavy metals in vegetables irrigated with sewage water were higher than those irrigated with tube well water. Spinach had higher amount of Fe, Mn, Ni in its leaves. The higher amounts of Cu were recorded in onion and those of Zn and Pb in cabbage.

Key words: Accumulation, heavy metals soils, vegetables

INTRODUCTION

Efficient utilization of water resource is crucial to agricultural production for meeting the challenge of feeding the ever-increasing human population in India. Industrial and domestic effluents with solid (sludge) and liquid (sewage) components are often used for irrigation purpose due to non availability of fresh water to take advantage of organic matter and plant nutrients. Sewage effluents of municipal origin contain appreciable amount of major essential plant nutrients like N, P, K, S and several micronutrients such as Zn, Cu, Mn and Fe. Accordingly the nutrient levels of the soils are expected to improve considerable with continuous application of sewage effluent. Again sewage effluents contain variable amounts of heavy metals like Pb, Cd, Cr, Ni etc. A limiting factor in the long term application of sewage effluent to agricultural land is the likelihood of accumulation of heavy metals in the soils and their transmission to crops grown. In order to optimize the benefits of waste water as a source of both the water and nutrients, it is inevitable to minimize the negative impacts of its use on human health. Before it is used for irrigation in agricultural lands, it is absolutely necessary to give due consideration towards its environmentally negative and positive aspects. Several reports revealed accumulation of organic matter and soil available nutrients in soils irrigated with sewage waste water. The amounts of organic matter and heavy metals in sewage water irrigated soils were found to be higher compared to ground water irrigated soils (Usha Rani *et al.* 2015). Information is lacking on the effect of sewage water irrigation on accumulation of heavy metals in soils and vegetable crops. The present investigation was, therefore, initiated to evaluate the effect of sewage water irrigation on heavy metals in soil and their content in vegetable crops grown on treated sewage water irrigated command area around sewage treatment plant Dhandhupura, Agra, Uttar Pradesh.

MATERIALS AND METHODS

The sewage water and ground water samples of the tube well were collected in winter season from the sewage water irrigated areas of Dhandhupura sewage treatment plant in Agra district of Uttar Pradesh. The sewage effluent and ground water samples were analysed for pH and EC following the standard methods. For the determination of micronutrients and heavy

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metals, treated sewage water sample (100ml) was digested with 5 ml of HNO_3: $HClO_4$, 4:1 and the mixture was concentrated by drying and made up to 50 ml. Surface (0-15 cm) samples of soils irrigated with sewage water were collected from 50 locations. Soil samples (15) were also collected from an adjoining area where only tube well water was used for irrigation. The samples, thus, collected were brought to the laboratory, dried, processed and analyzed. Organic carbon, available N, P and K were determined by adopting standard procedures (Jackson 1973). DTPA-extractable Fe, Mn, Cu, Zn, Ni, Cd and Pb, were determined by atomic absorption spectrophotometer. Plant samples of vegetable crops collected from the same sites were digested with di-acid mixture (HNO_3: $HClO_4$ 9:4) and analyzed for these trace elements and heavy metals using atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The pH of sewage water was 7.6, whereas that of tube well water it was 7.8. EC was 0.96 dSm^{-1} for sewage water and 0.98 dSm^{-1} for tube well water. The pH and EC of the effluents were within the permissible limits in respect of its use in agriculture. However, the average TSS (total suspended solids) 978 mg L^1 in sewage water was above the permissible limit (100mg L^{-1}, EPR 1993) for effluents (table 1). Heavy metals status of sewage effluent followed the order: Pb (0.77 mg L^{-1})> Cd (0.30 mg L^{-1})> Ni (0.20 mg L^{-1}). As per the safe limit of 5 mg L^{-1} of Pb in irrigation waters (Ayers and Westcot 1985), the value was below the safe limit of Pb. The concentrations of Fe (4.80 mg L^{-1}), Mn (0.66 mg L^{-1}), Cu (0.43 mg L^{-1}), and Zn (0.55 mg L^{-1}) in sewage water were well within the maximum prescribed limits for irrigation quality standard (100 mg L^{-1}, Pratt 1972). Tube well water was a poor source of these micronutrients (Fe 1.0, Mn 0.20, Cu traces and Zn 0.10 mg L^{-1}) in comparison to sewage water. Over all chemical analysis reveals that sewage water had higher amounts of heavy metals than tube well water. Since the concentration of Cd in sewage water was present beyond the permissible limit, use of such water over long period for irrigation without any remedial measures can possibly lead to accumulation of Cd in soils and thus contamination ration of food chain through its uptake by plants (Kumar *et al.* 2011).

Table 1: Chemical characteristics of sewage and tube well water used for irrigation

Parameters	Sewage water	Tube well water
pH	7.6	7.8
EC (dSm^{-1})	0.96	0.98
Total solid (mg L^{-1})	978.0	338
Iron (mg L^{-1})	4.80	1.0
Manganese (mg L^{-1})	0.66	0.20
Copper (mg L^{-1})	0.43	Tr.
Zinc (mg L^{-1})	0.55	0.10
Cadmium (mg L^{-1})	0.30	0.01
Lead (mg L^{-1})	0.77	0.01
Nickel (mg L^{-1})	0.20	0.01

Tr= Trace

The organic carbon content in soil under sewage water irrigated condition varied from 4.5 to 7.8 g kg^{-1} which was higher compared to ground water irrigated soil (2.5-4.9 g kg^{-1}). This may be due to higher content of suspended and soluble organic matter in the sewage water. Similar results were reported by Saraswat *et al.* (2005) and Usha Rani etal. (2015). Available N, P and K status was at higher level in sewage-irrigated soils (Table 2). Average amounts of available N in sewage and tube well water irrigated soils were 286.3 kg ha^{-1} and 183.7 kg ha^{-1}, respectively. Available P content in sewage irrigated soils ranged from 14.5 to 28.0 kg ha^{-1} while in tube well water irrigated soils; it ranged between 9.0 and 19.0 kg ha^{-1}. Available K status was higher in sewage water irrigated soils. The higher content of available nutrients in sewage treated soils was due to continuous addition of higher amounts of organic matter. Higher N, P and K content in sewage-irrigated soil were also reported by Tiwari *et al.* (2003).

Table 2: Soil properties as affected by sewage and tube well water irrigation

Character	Sewage water		Tube well water	
	Range	Mean	Range	Mean
pH	7.1-8.2	7.6	7.3-8.5	8.0
EC(dSm^{-1})	0.09-0.49	0.23	0.10-0.44	0.18
Org.carbon (g kg^{-1})	4.5-7.8	6.2	2.5-4.9	3.4
Avail. N (kg ha^{-1})	190.0-470.0	286.3	145.0-250.0	183.7
Avail. P (kg ha^{-1})	14.5-28.0	23.4	9.0-19.0	12.7
Avail. K (kg ha^{-1})	122.0-251.0	183.2	100.0-190.0	139.3

The content of DTPA-extractable Fe, Mn, Cu and Zn in soils irrigated with sewage water ranged from 4.6 to 42.0, 3.5 to 21.9, 0.45 to 5.73 and 0.55 to 6.47mg kg^{-1} soil, respectably. The comparatively higher concentrations of these micronutrient in comparison to normal soils has resulted from the addition of these elements through the continuous application of sewage water and the maximum concentration was of Fe followed by Mn, Zn and Cu. The amounts of DTPA-extractable Fe, Mn, Cu and Zn were much less in tube well water irrigated soils (Fe 3.1-14.0, Mn 1.8-5.2, Cu 0.15-0.70 and Zn 0.35-1.21 mg kg^{-1}). The higher amounts of these micronutrients in sewage water treated soil might be due to sufficient amounts of these micronutrients in sewage water. On the basis of the limit given by Alloway (1968), concentration of Cu and Zn were above the normal range as found in agricultural soils. DTPA-extractable Fe was maximum in sewage irrigated soil and minimum in tube well water irrigated soil. The concentrations of DTPA-extractable Cu and Zn were more or less 5 and 4 times higher in the sewage irrigated soil as compared to tube well water irrigated soil. These results show that sewage irrigation resulted in the increased content of DTPA-extractable micronutrients. Saraswat *et al.* (2005) have reported accumulation of DTPA-extractable micronutrients in soils through long term irrigation by treated or untreated sewage effluents.

Table 3: Concentration of heavy metals (mg kg^{-1}) in soil irrigated with sewage and tube well water

Character	Sewage water		Tube well water	
	Range	Mean	Range	Mean
Iron	4.6-42.0	16.1	3.1-14.0	6.9
Manganese	3.5-21.9	8.1	1.8-5.2	2.5
Copper	0.45-5.73	2.2	0.15-0.70	0.38
Zinc	0.55-6.47	2.3	0.35-1.21	0.62
Cadmium	0.07-0.37	0.21	Tr-0.07	0.03
Lead	0.30-3.25	1.20	0.15-0.46	0.32
Nickel	0.32-3.45	2.15	0.14-0.85	0.65

The concentration of DTPA-extractable Cd varied from 0.07 to 0.37 mg kg^{-1} at sewage irrigated site and from traces to 0.07 mg kg^{-1} at tube well water irrigated site. The mean DTPA-extractable Pb and Ni were 1.20 and 2.15 mg kg^{-1} respectively for sewage irrigated soil. In general, sewage water soils contained greater amounts of heavy metals followed by ground water irrigated soils. Since, the soils are formed from the same parent material, considerable higher concentrations of Cd, Ni and Pb detected in sewage water treated soils have resulted from external addition of these metals. Thus, continuous application of sewage water could be considered the only source responsible for their enrichment. The results are in consistent with the findings of Bhat *et al.* (2011). The content of Fe and Zn in different vegetables ranged from 34.1 to 205.0 mg kg^{-1} and 13.5 to 75.7 mg kg^{-1}, respectively. The concentration of Zn of the order of 50 mg kg-1 in the dry matter of plant tissue is considered as toxic. The maximum concentration of Fe and Zn were recorded in spinach and cabbage, respectively. The distribution of copper in different vegetables varied from 8.3 to 14.8 mg kg^{-1} and for most plant species, the optimum limit of this element is considered in the range of 4.0 to 15 mg kg^{-1} in the dry matter (Alloway 1968). Onion contained relatively higher amount of copper as comparted to other vegetable crops. The sewage irrigated vegetables showed higher contents of Fe, Mn, Cu and Zn than the tube well irrigated ones but were within the range of safe limits. Kim *et al.* (1988) compared the metal accumulation behavior of some crops and reported that potato was excellent non-accumulator whereas lettuce (*Lactica-sativa* L.) was good accumulator of trace elements. Lead and cadmium were also present in the vegetables. The content of lead was found higher in cabbage followed by spinach. All the vegetable crops contained Pb above the permissible limit of 2 mg kg^{-1} as proposed by Asaolu (1995). Singh et al (2015) also reported accumulation of Pb by plants to hazardous levels. Cadmium was detected in vegetable crops (0.17 to 0.32 mg kg^{-1}) but the concentration was below the toxicity thresholds of 0.8 mg kg^{-1} (Alloway 1968). The ranges of nickel in vegetable crops irrigated with sewage water and ground water were from 1.07 to 1.76 mg kg^{-1} and from 0.30 to 0.61 mg kg^{-1}, respectively. The concentration of Mn in these vegetable crops ranged from 18.2 to 42.5 mg kg^{-1} and was less in some crops than the critical Mn deficiency level of 20 mg kg^{-1} dry weight. Findings indicated that the contents of heavy metals in sewage irrigated vegetables was comparatively higher than the tube well water irrigated vegetables and that was definitely due to larger availability of metals in sewage irrigated soil.

Table 3: Heavy metals (mg kg^{-1}) in vegetable crops irrigated with sewage water (SW) and tube well (TW)

Vegetables	Iron		Manganese		Copper		Zinc		Cadmium		Nickel		Lead	
	SW	TW	SW	TW	SW	TW	SW	TW	SW	TW	SW	TW	SW	TW
Cabbage	49.0	29.7	26.5	10.3	8.3	3.3	75.7	22.0	0.32	0.18	1.08	0.54	41.4	1.90
Cauliflower	43.6	36.6	29.6	14.0	9.2	4.9	49.1	35.8	0.19	0.15	1.07	0.50	39.0	1.80
Coriander	34.1	22.4	18.2	13.0	8.7	3.5	13.5	4.3	0.17	0.09	1.37	0.32	28.0	2.0
Garlic	89.6	53.4	35.8	19.0	14.7	10.4	18.4	5.0	0.19	0.11	1.35	0.36	24.0	1.5
Onion	86.5	57.2	21.7	12.5	14.8	11.6	19.2	5.6	0.17	0.12	1.36	0.33	14.1	1.6
Potato	64.0	51.3	19.1	15.9	8.3	5.1	28.0	24.8	0.27	0.11	1.35	0.30	18.7	1.3
Spinach	205.0	104.0	42.5	28.6	14.5	10.6	48.4	28.5	0.18	0.13	1.76	0.61	39.0	2.2

Although, sewage is a good source of plant nutrients but the effect of its long-term application for irrigation on soil properties needs to be periodically monitored. The study on long term irrigation with treated sewage water confirms that treated sewage water could be used for long-term irrigation with better management practices and these soils are still not contaminated with heavy metals. By and large, concentration of these metals in crops was below the generalized toxic limits except that of lead.

From this study, it may be concluded that accumulation of heavy metals in soils and vegetables irrigated with sewage water was higher than ground water irrigation. It should not be ignored as this can adversely affect the viability of sewage water irrigation scheme in agriculture.

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