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Changes in soil chemical properties as affected by application of wastewater spiked with heavy metals

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ABSTRACT

Wastewater was spiked with cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb) at various concentrations and applied in soil under gladiolus crop at research farm of Water Technology Center, ICAR-IARI, New Delhi during 2017. Changes in soil parameters were determined as per the standard methods. Results indicated that soil properties in-terms of *p*H, organic carbon, phosphorous, potassium and micronutrients (Cu, Fe, Mn, Zn) was not changed significantly, whereas significantly higher salt (EC 0.41 dS/m), nitrogen (161.50 kg/ha) as well as Ni (0.75 mg/kg), Cr (1.64 mg/kg), Cd (0.17 mg/kg) and Pb (2.75 mg/kg) in T5 treated soils were recorded, where highest concentration of metals, i.e. Cd (0.5 mg/L), Cr (5.0 mg/ L), Ni (10 mg/L), Pb (50 mg/L) were spiked in wastewater. It may be concluded that application of metals spiked wastewater irrigation may alter soil functioning by way of elevated levels of metal in soils under pot experiment.

Keywords: Gladiolus, Heavy metal, Irrigation, Micronutrient, Wastewater

Agriculture is the most sensitive sector to water scarcity as compared to all other sectors of economy. Globally agricultural activity consumes 69% of total fresh water, but in India 83% is diverted to agriculture followed by industry and domestic activities. Hence, a larger amount of wastewater is being generated from domestic and industrial sectors. Wastewater is a potential source of essential plant nutrients along with toxic metals. It is estimated that more than 15000 million liters of sewage water is produced every day in India (Paul *et al*. 2010). However, improper discharge of wastewater may result in bioaccumulation of toxic metals with impaired crop growth and soil quality. Build-up of heavy metals in soil irrigated with wastewater was reported earlier by Rattan *et al.* (2005), Golui *et al.* (2019) and Meena *et al.* (2016). Long-term use of sewage irrigation may lead to change in important soil chemical properties (Meena *et al.* 2016). The toxicity of heavy metal is one of the major problems of the environment and remains a serious health issue today across the globe.

As an ornamental plant species, the gladiolus (*Gladiolus grandiflorus* L.), popularly called "queen of bulbous" belongs to the family Irridaceae and sub family Ixoideae, having its elegant flower spikes which have rich variation of colors and long vase life is commercially grown for its fascinating flowers, which are used as the most preferred line flowers in floral arrangements worldwide. In India, gladiolus occupied an area of 10.90 thousand ha with the production of 24.76 thousand million tonnes and productivity of 5922.10 lakh numbers (www.indiastat.com). These species possess high metal tolerance characteristic and high Cd content in its saleable part holds potential to clean up the moderately contaminated soils (Mani *et al.* 2016). The use of non-edible type ornamental plants like gladiolus has been promising for its application on large scale contaminated soils, which possess lower risk of contamination of the food-chain with heavy metals (Mani *et al.* 2016). With this background present investigation was carried out to study the impact of wastewater irrigation spiked with different concentration of metals on soil properties.

MATERIALS AND METHODS

One bulk surface soil sample (0-15 cm) was collected from research farm of Water Technology Center, ICAR-IARI, New Delhi during 2017. The collected soil sample was air dried, ground in wooden mortar and pestle and sieved through 2 mm sieve. The processed soil samples were mixed thoroughly for ensuring homogenization. Processed and homogenized soil was used for pot experiment.

Pot experiment: The bottom holed light colored plastic pots (Size: Upper Diameter-25 cm, Lower Diameter: 12.5 cm and Height: 26 cm) with a capacity of 10 L were used for pot experiment. Four replicates of 10 L capacity pots

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were filled with processed soil (8 kg) to grow the corms of gladiolus. Recommended dose of urea (1.60 g/pot), single super phosphate (3.07 g/pot) and muriate of potash (1.14 g/pot) were mixed thoroughly in soil before filling the pots. Compost was also mixed @ 250 g in each pot before planting of gladiolus corms. The uniform size of corms (Diameter: 4.0-5.0 cm) of gladiolus variety Pusa Vidhushi were planted in each pot on 10 October 2017. Eight treatments, viz. T-1: wastewater irrigation spiked with Cd (0.005 mg/L), Cr (0.05 mg/L), Ni (0.1 mg/L) and Pb (2.5 mg/L), T-2: wastewater irrigation spiked with Cd (0.01 mg/L), Cr (0.1 mg/L), Ni (0.2 mg/L) and Pb (5.0 mg/L), T-3: wastewater irrigation spiked with Cd (0.1 mg/L), Cr (1.0 mg/L), Ni (2 mg/L) and Pb (10 mg/L), T-4: wastewater irrigation spiked with Cd (0.25 mg/L), Cr (2.5 mg/L), Ni (5 mg/L) and Pb (30 mg/L), T-5: wastewater irrigation spiked with Cd (0.5 mg/L), Cr (5.0 mg/L), Ni (10 mg/L) and Pb (50 mg/L), T-6: sole wastewater irrigation without spiking of heavy metals, T-7: wastewater irrigation without spiking and no plant and T-8: sole groundwater irrigation without spiking of heavy metals were laid out in the pots under completely randomized design (CRD). Wastewater was collected from drainage channel of Central Delhi, which carries both domestic and industrial sewage water. Irrigation was given at 10 days interval, where water was added @ 1 L/pot and it was withdrawn 4 weeks before lifting of corms. In all, 6 L water was added per pot during the entire plant growth (Table 1). Gladiolus was harvested at 90 days after planting on maturity.

Table 1 Quantities of metal addition through 6 L irrigation water in soil under pot experiment

Treatment	Cd (mg/L)	Cr (mg/L)	Ni (mg/L)	Pb (mg/L)
T-1	0.03	0.30	0.60	15.0
T-2	0.06	0.60	1.20	30.0
T-3	0.60	6.00	12.0	60.0
T-4	1.50	15.0	30.0	180
T-5	3.00	30.0	60.0	300
T-6	–	–	–	–
T-7	–	–	–	–
T-8	–	–	–	–

Analysis of post-harvest soil: Soil samples were collected from each pot after harvesting the spike and digging the corms of gladiolus. About 500 g of soil was collected from each pot after proper mixing of whole soil. The processed soil samples were used for analysis of physico-chemical properties. The *p*H was measured in 1:2 (soil: water) suspension by digital *p*H meter (Model: Systronics-802) using glass electrode assembly (Jackson 1973). The electrical conductivity (EC) of the soil sample was measured in 1:2 soil:water extract after shaking the soil water suspension for half an hour and filtrating it with Whatman No. 1 filter paper (Jackson 1973). The EC of the filtrate was measured using digital conductivity meter (Model: Systronics-304) and expressed as dS/m. For determination of oxidizable organic carbon, soil samples were sieved to pass through 0.2 mm sieve. Soil samples were further ground and sieved through 0.2 mm sieve before analyzing organic carbon. Organic carbon content in soil was determined by wet oxidation method using $K_2Cr_2O_7$ as outlined by Walkley and Black (1934). Available nitrogen in soil was determined by alkaline potassium permanganate ($KMnO_4$) method as described by Subbiah and Asija (1956). For estimation of available phosphorus (P), soil was extracted with 0.5*M* $NaHCO_3$ (Olsen *et al.* 1954). Phosphorus content in the extract was determined by ascorbic acid blue colour method (Watanabe and Olsen 1965). Available potassium (K) was determined by extracting the soil with 1*N* ammonium acetate (*p*H 7.0) and K content in the extract was measured by flame photometer (Jackson 1973). For determination of available Zn, Cu, Fe, Mn, Ni, Pb, Cd and Cr, DTPA soil test method as described by Lindsay and Norvell (1978) was followed. Concentration of metals in DTPA extract was determined with the help of Atomic Absorption Spectrophotometer (AAS) Model: LABINDIA AA 8000.

Table 2 Effect of metal spiked wastewater irrigation on soil reaction (*p*H), soil salinity (EC), organic carbon, available nitrogen, phosphorous, potassium, micronutrients and heavy metals content in soil under pot experiment

Treatment	*p*H (1:2)	EC (1:2) (dS/m)	Organic carbon (%)	Avail. N (kg/ha)	Avail. P (kg/ha)	Avail. K (kg/ha)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)
T-1	7.18	0.32	0.52	130	42.2	330	1.22	6.02	12.4	1.75	0.20	0.89	0.07	1.88
T-2	7.26	0.34	0.49	137	42.9	347	1.19	6.05	14.2	2.14	0.26	1.05	0.09	2.06
T-3	7.33	0.36	0.55	145	42.0	350	1.12	7.56	11.6	2.43	0.45	1.17	0.12	2.31
T-4	7.33	0.38	0.46	153	42.7	350	1.14	7.11	11.6	2.06	0.60	1.28	0.15	2.43
T-5	7.23	0.41	0.50	161	41.8	350	1.28	6.55	13.4	1.81	0.75	1.64	0.17	2.75
T-6	7.27	0.29	0.49	130	42.2	344	1.26	7.43	13.6	1.96	0.12	1.02	0.05	1.60
T-7	7.63	0.29	0.47	136	42.9	352	1.32	8.06	14.8	2.37	0.15	1.10	0.06	1.74
T-8	7.22	0.23	0.39	114	38.6	305	1.11	6.88	10.0	1.52	0.09	0.60	0.03	0.75
SE(m)	0.12	0.01	0.05	3.10	1.62	23.3	0.15	0.86	1.76	0.23	0.07	0.18	0.01	0.12
CD (P=0.05)	NS	0.04	NS	9.11	NS	NS	NS	NS	NS	NS	0.20	0.54	0.02	0.35

Statistical analysis: Analysis of variance method was followed to assess the effect of wastewater irrigation spiked with different concentration of metal on soil chemical properties including metal build-up using the SPSS statistical package (IBM SPSS statistics). To determine the significance of the difference between the means of the two treatments, least significant differences (LSD) were estimated at 5% probability level.

RESULTS AND DISCUSSION

pH, EC and organic carbon of soil: Effect of metal spiked wastewater irrigation on soil *p*H was non-significant (Table 2). The *p*H was slightly alkaline throughout the treated soil and it ranged from 7.18–7.63 across the irrigated soils.The EC of irrigated soil varied from 0.23–0.41 dS/m across the treatment. Significantly higher values of EC were recorded in soils receiving irrigation either through sole wastewater or metal spiked wastewater as compared to groundwater irrigated soil (T8). This may be due to presence of salts of metals in spiked wastewater or sole wastewater, which leads to buildup of more salt in the irrigated soil (Golui *et al.* 2019). Organic carbon content in the soil ranged from 0.39–0.55% across the treatment. Higher organic carbon content in soil was observed in the treated pots, where wastewater irrigation was applied as compared to groundwater irrigated soil. This is may be due presence of dissolved organic carbon in wastewater as compared to groundwater (Meena *et al.* 2016). However, effect of metal addition in wastewater on changes of soil organic carbon was non-significant. Rattan *et al.* (2005) reported an increment of 59% in organic carbon 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, Bansal *et al.* (1992) have reported that 47.9% increase in organic carbon content of topsoil receiving industrial wastewater for irrigation as compared to the soil irrigated with tube well water at Jamalpur, Punjab.

Macro-nutrient content in soil: Over all, effect of wastewater irrigation on content of available N is statistically significant (Table 2). Higher value of available N (161 kg/ha) was recorded under T-5, where highest level of all metals were added in wastewater for irrigation. On the other hand, lowest value of available N (114 kg/ha) was recorded in soil receiving groundwater irrigation. This may be due to addition of nitrate salts of all metals for the purpose of spiking wastewater. Saha *et al*. (2010) reported 11.4% more available N content in sewage-irrigated soils compared to groundwater-irrigated soils. Across the experimental soil, phosphorous content varied from 38.6–42.9 kg/ha, whereas potassium content ranged from 305–350 kg/ha. The differences in the content of P and K in the irrigated soil under different treatment of metal spiked wastewater were not significant. This may be due to low concentration of P and K in the wastewater and groundwater.

Micro nutrient content in soil: Effect of metal spiked wastewater irrigation on content of micronutrients in soil under pot experiment was found to be non significant (Table 2). Extractable Cu in soil varied from 1.11–1.32 mg/kg across the treatments. Soil receiving irrigation through wastewater (without spiking) showed highest value of extractable Cu (1.32 mg/kg), where crop was not grown. Similar results were noticed for extractable Fe and Mn. Extractable Fe and Mn in the experimental soil ranged from 6.02–8.06 and 10.0–14.8 mg/kg, respectively. In case of Zn, highest value was observed in T3 treated soil. Extractable Zn in experimental soil varied from 1.52–2.43 mg/kg. Earlier studies showed that content of micronutrients in wastewater are generally higher as compared to that in groundwater (Rattan *et al.* 2005, Meena *et al.* 2016). Higher values of micronutrient in T7 treated soil may be due to absence of test crop, which results in least removal of micronutrients from soil via crop uptake.

Heavy metal content in soil: Effect of metal spiked wastewater irrigation on metal content in soil under pot experiment was found to be significant (Table 2). Content of extractable Ni in the experimental soil ranged from 0.09 to 0.75 mg/kg. Soil receiving wastewater irrigation spiked with highest level of all metals showed 0.75 mg/kg of extractable Ni. Similar results were also noticed for Cr, Cd and Pb. Extractable Cr in experimental soil ranged from 0.60 to 1.64 mg/kg. Elevated level of Cr in soil was recorded at all wastewater treatment combination compared to groundwater treated soil, which signifies the supply of Cr through spiking as well from natural sources. Extractable Cd content in soil ranged from 0.03 to 0.17 mg/kg across the treatments, whereas Pb content in soil varied from 0.75 to 2.75 mg/kg. Several researchers reported the elevated levels of heavy metal in sewage irrigated soils earlier (Datta *et al.* 2000, Rattan *et al.* 2002, 2005, Kharche *et al.* 2011, Belaid *et al.* 2012, Golui *et al.* 2019). Heavy metals present in the municipal wastewater used for irrigation tend to accumulate in the soils, become bio-available and eventually get translocated to plants (Toze 2006).

Soil health parameters like *p*H, oxidizable organic carbon, available phosphorous, potassium and micronutrients (Cu, Fe, Mn, Zn) were not altered due to application of metal spiked wastewater, whereas higher salinity, available nitrogen and heavy metals (Ni, Cr, Cd, Pb) in soil were noticed due to addition of wastewater loaded with metals. Therefore, build up of metals in wastewater treated soils needs to be monitored periodically, in view of their significant accumulation in available pool.

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