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Impact of three years continuous wastewater irrigations on the soil chemical properties under turfgrass (*Cynodon dactylon*)

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ABSTRACT

An investigation was carried out to assess short-term (2013–16) impact of wastewater irrigations on the chemical properties of the soil under turfgrass *(Cynodon dactylon* L. var. Selection-1), planted with and without sub-soil porous plastic mulch, in the experimental field of the Water Technology Centre of ICAR-IARI, New Delhi. The investigation comprised 3-replicates of 2 –groundwater irrigation scheduling treatments (each of 50 mm depth) at 100% ET_c and 6- treatments of wastewater irrigation scheduling (also of 50 mm depth each) at 75%, 100% and 125% ET_c, under with and without sub-soil porous plastic mulch planting. The investigation revealed a non-significant change in the rhizosphere soil *p*H and EC under all wastewater irrigation treatments. However, a significant (14 to 25%) increase in the soil organic carbon, particularly under the more frequently (i.e. at 75% ET_c) wastewater irrigated plots, was observed. These were also found to be associated with increased soil major (N: 8.5 to 15.2%; P: 45.7 to 62.8%; K: 12 to 34.7%) and micro nutrients (Zn: 22.4 to 29.5%; Mn: 16.9 to 27.1 %; Cu: 21.9 to 19.2% and Fe: 15.6 to 24.8%). However, there was no heavy metal built-up in such wastewater irrigated soils probably due to their presence in within permissible levels in the applied irrigation waters. The investigations thus indicated a great potential of improved soil health, with no heavy metal threats, under short-term wastewater irrigation applications in urban turfgrass based landscapes.

Key words: Bermuda grass, Impact assessment, Irrigation scheduling, Poor quality water

Rapid population growth due to increased urbanization, industrialization and enhanced economic living standards has resulted in fresh water diversion to the non-farm sectors and thereby, increased wastewater generation (Qian and Mecham 2005). This has concomitantly observed to result in an enormous interest in wastewater reuse and recycling particularly for turfgrass based urban landscaping in common parks, roadsides, golf courses, cemeteries, athletic fields, etc. for conserving/protecting freshwater resource and urban environment (Castro *et al.* 2011, Manas *et al*. 2012 and Harivandi 2012). Turfgrass in particular is known for its capacity to absorb relatively large amounts of nitrogen and other nutrients, often found in elevated quantities in wastewaters (Gurjar and Kaur 2018). However, despite several benefits associated with effective wastewater disposal in the turfgrass based urban landscapes, presence of undesirable levels of one or more chemical constituents/ pathogens in such waters often poses threats to the health of the so irrigated soils, underlaying aquifers and the humans/ livestock enjoying these landscapes (Anderson *et al.* 1981, Pepper and Mancino 1993). In fact, wastewater use in turfgrass based systems is usually dictated by certain guidelines/ local laws (Jalali *et al.* 2008). In view of this, the present investigation was thus primarily aimed at assessing the comparative short-term impact of continuous wastewater irrigations, at different irrigation schedules, on the chemical properties of the soil under turfgrass (*Cynodon dactylon* L. var. Selection-1), planted with and without sub-soil porous plastic mulch, in comparison to the normal ground water irrigated systems.

MATERIALS AND METHODS

The experimental study was carried out in the Field No. 1 of Water Technology Centre research farm, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India during the year 2013-16. The GPS coordinates of experimental field (mid part) are as Latitude 28° 38’ 05” N, Longitude 77° 09’ 38’’E and Altitude 225 m above mean sea level. The study area being a part of the 6th Agro-Climatic Region/Zone (Trans-Gangetic Plains Region) and 4th Agro-Ecological Region (Hot semi-arid eco-region with alluvium derived soil) of India has subtropical and semi-arid climate with hot dry summer and cold winter. The long-term (past 30 years) average annual rainfall was 710 mm. The experiment was laid out in Randomized Block Design with three replications. Treatments included T1: Groundwater irrigation at 100% ET_c without sub-soil porous

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plastic mulch, T2: Groundwater irrigation at 100% ET_c with sub-soil plastic mulch, T3: Wastewater irrigation at 100% ET_c without sub-soil porous plastic mulch, T4: Wastewater irrigation at 100% ET_c with sub-soil plastic mulch, T5: Wastewater irrigation at 125% ET_c without sub-soil porous plastic mulch, T6: Wastewater irrigation at 125% ET_c with sub-soil porous plastic mulch, T7: Wastewater irrigation at 75% ET_c without sub-soil porous plastic mulch, T8: Wastewater irrigation at 75% ET_c with sub-soil porous plastic mulch. The ET_c (i.e. crop evapotranspiration), was computed as a product of reference evapotranspiration (ET_0) and crop coefficient (K_c). Thus, to compute ET_c (=ET_0* K_c), ET_0 values were estimated on daily basis using CROPWAT 8.0 model (FAO 1992, Allen *et al*. 1998) while crop coefficient (Kc) value was assumed as 0.85 as per FAO 1998; FAO 2002 data on turfgrass at mid growth stage. The turfgrass (var. Selection-1) cuttings were planted in the month of May during the year 2013 by dibbling method at a spacing of 10 × 10 cm along with a basal fertilizer dose of 200:200:100 kg NPK/ha. For regular maintenance of turfgrass, manual weeding, mowing and sweeping operations were followed as per the standard package of practices. During each irrigation cycle, groundwater and wastewater samples were collected and analyzed. Acidity/alkalinity (i.e. *p*H) and salinity as electrical conductivity (i.e. EC) were determined though the *p*H and electrical conductivity meters, respectively (Jackson 1973). Sodium, calcium, magnesium (Jackson 1973), carbonate, bicarbonate (Richards 1954) were also analysed in triplicate, as per the standard procedures. The concentrations of sodium, calcium, magnesium, carbonate and bicarbonate so determined were transformed to sodium absorption ratio (SAR) and residual sodium carbonate (RSC) concentrations (Ayers and Westcot 1985). Bio-chemical oxygen demand (BOD: Winkler 1988), chemical oxygen demand (COD: Singh *et al*. 2005) of water samples were measured as per standard methods. Micronutrients and heavy metals in water samples were measured by inductively coupled plasma mass spectrometry (ICP-MS) method as given in APHA (2005). Faecal coliforms analysis in water samples was done using most probable number (MPN) index method (Oblinger and Koburger 1975, WHO 1989, APHA 2005). Besides this, random soil samples (at 0-15 cm and 15-30 cm depth) from each experimental plot were also collected and analyzed for their quality characteristics (as per the standard procedures), during both beginning (i.e. in year 2013) and end of the study period (i.e. in year 2016). Soil reaction (i.e. $pH_{1:2}$) and electrical conductivity (i.e. $EC_{1:2}$) were determined though the *p*H and electrical conductivity meters, respectively (Jackson 1973). While the soil organic carbon (SOC) and available nitrogen (N) contents, respectively were determined through the dichromate oxidation (Walkley and Black 1934) and alkaline potassium permanganate distillation methods (Subbiah and Asija 1956) using a (Pelicon make) nitrogen analyzer. Soil available phosphorus (P) and potassium (K) on the other hand were determined through a UV visible spectrophotometer (Model: HACH DR-5000; Olsen *et al.* 1954 method) and a flame photometer (Jackson 1973 method), respectively. DTPA extractable soil micro-nutrients (viz. Cu, Fe, Mn, Zn) and heavy metal (viz. Cr, Ni, Pb and Cd) contents (Lindsay and Norvell 1978; APHA 2005) on the other hand were estimated through an Inductively Coupled Plasma Spectrophotometer, as per the standard procedures. The analysis of variation (ANOVA) technique was carried out on the data for each parameter as applicable to randomized block design (Gomez and Gomez 1983). The significance of the treatment effect was determined using F-test, and to determine the significance of the difference between the means of the two treatments, least significant differences (LSD) was estimated at 5% probability level, and Duncan's multiple range test was used for comparing three or more means at the same probability level.

RESULTS AND DISCUSSION

Impact on soil chemical properties

Soil acidity, conductivity and organic carbon

Short-term impact of wastewater *vs.* ground water irrigations on the *p*H, EC and SOC are illustrated in Table 1. It could be observed from Table 1 that the irrigating with wastewaters (having groundwater comparable *p*H and EC values) seems to be having non-significant impacts on the soil *p*H at either of the soil depths. This was also observed to be the case w.r.t the soil electrical conductivity (EC) of the top-soil (0-15 cm) layer. However, as observed from Table 2, there was a significant (30 to 35%) decrease in sub-soil (15-30 cm) electrical conductivity in both ground and wastewater irrigated plots (with or without sub-soil porous plastic mulch) due to the constant leaching of salts to the deeper soil layers. Thus, the investigation revealed non-significant changes in the soil *p*H and EC levels under wastewater irrigations, in comparison to the groundwater irrigations in both with and without sub-soil porous plastic mulch based turfgrass planted treatments. However, the investigation revealed a significant (14 to 25%) increase in the soil organic carbon particularly under the more frequently (i.e. at 75% ET_c; 2) wastewater irrigated plots due to greater leaching of mobile carbon fractions to the deeper soil layers associated with relatively lower SOC mineralization and hence relatively higher SOC sequestration than the frequently tilled top- soil layers. However, like ground water irrigations, short-term applications of less frequent wastewater irrigations (at 125% ET_c; Table 2), on the contrary, were observed to be associated with non-significant SOC built-up in both top and sub-soil layers. These findings were found to be in close conformity with the other similar investigations (Saha *et al.* 2010) on short/ long-term impacts of wastewater irrigations.

Major soil available nutrients

Comparative impacts of ground and wastewater irrigations on the soil available - N, P and K contents are illustrated in Table 2. Short term impact of wastewaters scheduled at 75%, 100% and 125% ET_c revealed a significant

Table 1 Comparative impact of wastewater and ground water irrigations on the soil chemical properties under turfgrass

Treatment	*p*H		EC (dS/m)		Organic carbon (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T1	7.62	7.70	0.23 (NS)	0.18 (-30.8)	0.35 (NS)	0.25 (NS)
T2	7.70	7.71	0.21 (NS)	0.18 (-30.8)	0.35 (NS)	0.25 (NS)
T3	7.61	7.70	0.21 (NS)	0.17 (-34.6)	0.38 (+8.6)	0.30 (NS)
T4	7.69	7.45	0.23 (NS)	0.17 (-34.6)	0.38 (+8.6)	0.31 (+10.7)
T5	7.60	7.61	0.22 (NS)	0.17 (-34.6)	0.36 (NS)	0.27 (NS)
T6	7.61	7.80	0.24 (NS)	0.16 (-38.5)	0.37 (NS)	0.27 (NS)
T7	7.70	7.76	0.29 (NS)	0.17 (-34.6)	0.40 (+14.3)	0.33 (+17.9)
T8	7.64	7.72	0.28 (NS)	0.17 (-34.6)	0.41 (+17.1)	0.35 (+25.0)
SEm±	0.07	0.08	0.04	0.02	0.01	0.01
LSD (P=0.05)	NS	NS	0.13	0.06	0.02	0.04

Note: Percentage significant increase (+) or decrease (-) over initial value is shown in bracket.

Table 2 Impact of wastewater irrigations on soil available nutrients (NPK) under turfgrass

Treatment	Available nitrogen (kg/ha)		Available phosphorous (kg/ha)		Available potassium (kg/ha)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T1	164.0 (+3.5)	148.6 (+4.2)	32.5 (NS)	17.2 (NS)	220.3 (NS)	124.0 (NS)
T2	164.0 (+3.5)	149.4 (+4.8)	32.5 (NS)	17.2 (NS)	219.8 (NS)	123.5 (NS)
T3	168.7 (+6.4)	157.2 (+10.2)	39.2 (+30.7)	19.4 (NS)	241.6 (+7.5)	145.3 (+14.6)
T4	169.5 (+6.9)	158.0 (+10.8)	40.3 (+34.3)	20.9 (NS)	245.2 (+9.1)	148.9 (+17.4)
T5	166.4 (+5.0)	152.5 (+6.9)	35.8 (+19.3)	23.1 (+22.9)	230.7 (NS)	134.4 (NS)
T6	167.2 (+5.5)	151.7 (+6.4)	37.0 (+23.3)	25.4 (+35.1)	238.3 (+6.1)	142.0 (+12.0)
T7	171.9 (+8.5)	161.9 (+13.5)	43.7 (+45.7)	28.4 (+51.1)	256.2 (+14.0)	159.9 (+26.1)
T8	174.2 (+9.9)	164.3 (+15.2)	47.0 (+56.7)	30.6 (+62.8)	267.1 (+18.9)	170.8 (+34.7)
SEm±	0.96	1.78	1.37	1.15	4.02	4.01
LSD (P=0.05)	2.98	5.53	4.27	3.57	12.52	12.50

Note: Percentage significant increase (+) or decrease (-) over initial value is shown in bracket.

increase in soil -N, P and K contents in both top (0-15 cm) and sub-soil (15-30 cm) layers under turfgrass. In general, the soils receiving more frequent wastewater irrigations (i.e. at 75% ET_c), were observed to be associated with higher soil available - N, P and K built-up. While those receiving ground water irrigations were observed to be associated with non-significant soil available N, P and K built-up. This was primarily attributed to relatively higher levels of N, P and K contents in the applied wastewaters. Similar observations have also been reported by Siebe (1998), Ryan *et al.* (2006) and Kalavrouziotis *et al.* (2008) during long-term sewage irrigations.

Soil available micro-nutrients

Application of wastewater irrigations was also found to be associated with significantly improved soil available micronutrient (viz. Cu, Fe, Mn, Zn) contents in both top and sub-soil layers of soil under turfgrass (Table 3). In general, the turfgrass (with/ without sub-soil porous plastic mulch) receiving more frequent wastewater irrigation was observed to be associated with the highest available micro-nutrient built up in both top and sub-soil layers (Table 3). In contrast to these treatments, the ones receiving groundwater irrigations were observed to be associated with non-significant soil micro-nutrient built up. This could also be primarily attributed to relatively (3 to 21 times) higher levels of Cu, Fe, Mn and Zn contents in the applied wastewaters than the ground waters. Similar observations have also been reported by Saha *et al.* (2010).

Heavy metal built-up

It expected that long-term application of wastewater irrigation can result into soil heavy metal accumulation. However, no such pattern of soil heavy metal accumulation (Cr, Cd, Ni, Pb) was observed in the present investigation, with differentially applied wastewater irrigations. This could primarily be due to either the precipitation/ transformation of heavy metals into their non bio-available forms (Rusan *et al.* 2007) in soil and/ or its uptake by turfgrass (Toze 2006).

Thus, the investigations clearly indicated a great potential of improved soil health, particularly in terms of the available major and micro-nutrients under short-term wastewater irrigation applications in urban turfgrass based landscapes. Besides this, the investigation also clearly ruled out a significant soil heavy metal build up and the inter-connected human and livestock threats under such wastewater irrigated landscapes, at least short-term scales. However, due to a definite built-up of both major and micro-nutrients during the investigation period, a regular monitoring of soil quality under such landscapes exposed to wastewater irrigations seems imperative for reducing any future environmental threats.

Table 3 Impact of wastewater irrigations on soil micro-nutrient content under turfgrass

Treatment	Zn (mg/kg)		Mn (mg/kg)		Cu (mg/kg)		Fe (mg/kg)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T1	0.61 (NS)	0.47 (+6.8)	6.01 (NS)	4.67 (NS)	0.33 (NS)	0.24 (NS)	6.44 (NS)	5.27 (NS)
T2	0.61 (NS)	0.47 (+6.8)	6.00 (NS)	4.66 (NS)	0.33 (NS)	0.24 (NS)	6.43 (NS)	5.25 (NS)
T3	0.67 (+15.5)	0.52 (+18.2)	6.60 (+10.4)	5.25 (+12.2)	0.37 (+15.6)	0.27 (NS)	7.07 (+9.1)	5.89 (+10.7)
T4	0.68 (+17.2)	0.53 (+20.5)	6.69 (+11.9)	5.35 (+14.3)	0.37 (+15.6)	0.28 (NS)	7.17 (+10.6)	6.00 (+12.8)
T5	0.64 (+10.3)	0.49 (+11.4)	6.30 (+5.4)	4.95 (NS)	0.35 (+9.4)	0.25 (NS)	6.75 (NS)	5.57 (NS)
T6	0.66 (+13.8)	0.51 (+15.9)	6.51 (+8.9)	5.16 (+10.3)	0.36 (+12.5)	0.27 (NS)	6.97 (+7.6)	5.79 (+8.8)
T7	0.71 (+22.4)	0.55 (+25.0)	6.99 (+16.9)	5.65 (+20.7)	0.39 (+21.9)	0.29 (+11.5)	7.49 (+15.6)	6.32 (+18.8)
T8	0.74 (+27.6)	0.57 (+29.5)	7.29 (+21.9)	5.95 (+27.1)	0.41 (+28.1)	0.31 (+19.2)	7.81 (+20.5)	6.64 (+24.8)
SEm±	0.01	0.01	0.11	0.10	0.01	0.01	0.11	0.12
LSD (P=0.05)	0.03	0.02	0.34	0.33	0.02	0.02	0.37	0.36

Note: Percentage significant increase (+) or decrease (-) over initial value is shown in bracket.

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