www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(2): 211-217

www.thepharmajournal.com
Received: 25-11-2022
Accepted: 24-01-2023

Diana Dhayal
ICAR-Indian Agricultural Research Institute, New Delhi, India

Khajanchi Lal
ICAR-Indian Agricultural Research Institute, New Delhi, India

Corresponding Author:
Diana Dhayal
ICAR-Indian Agricultural Research Institute, New Delhi, India

Nutritional status of wastewater irrigated soil under lemongrass (*Cymbopogon flexuosus*)

Diana Dhayal and Khajanchi Lal

DOI: https://doi.org/10.22271/tpi.2023.v12.i2c.19148

Abstract

A field experiment was conducted in a split plot design at ICAR-Indian Agricultural Research Institute (IARI) to evaluate the effects of groundwater (GW), untreated wastewater (WW), constructed wetland treated wastewater (TWW) and groundwater in conjunction with untreated wastewater in cyclic mode (CW) in the main plots and three levels of fertilizers in subplots *viz.* control (no NPK fertilizer application) (N_0), recommended dose of NPK fertilizers – the amount of NPK added through irrigation water (N_1) and recommended dose of NPK fertilizers (N_2) during 2018-2019 on the soil chemical properties. The N, P, K, RSC, Zn, Cu, Mn, Fe, Ni, Pb and Cr contents in untreated wastewater were significantly higher and 2.3, 3.7, 2.7, 1.6, 3.1, 2.0, 2.1, 2.9, 2.3, 7.2 and 2.3 times more than the constructed wetland treated water respectively. The initial soils were normal in reaction having pH 7.34, electrical conductivity 0.29 dSm^{-1}, organic carbon 0.68% and available N, P and K contents were 238, 24.6 and 227 kg ha^{-1}. Similarly, DTPA extractable Zn, Cu, Mn and Fe were well above the deficiency critical limit but below the permissible threshold limit for toxicity. The available Ni, Pb and Cr contents were 0.22, 2.54 and 0.25 mg kg^{-1}. The organic carbon, macro nutrients (N, P, and K) and micronutrients (Zn, Mn, Cu and Fe) content of soil got improved with sewage irrigation followed by soil irrigated alternatively with sewage and ground water. The results demonstrated that raising lemongrass with wastewater improved the nutritional quality of soil.

Keywords: Aromatic plant, conjunctive use, constructed wetland, heavy metal, wastewater

Introduction

Wastewater is found to be rich in essential plant nutrients. Irrigation usage of wastewater will also reduce addition of nutrients from fertilizers. The concentration of nutrients in wastewater irrigation by 1,000 m^3 per hectare was found varying considerably: 4– 24 kg phosphorus, 16–62 kg total nitrogen, 2–69 kg potassium, 27–182 kg sodium, 9–110 kg magnesium and 18–208 kg calcium (Qadir, 2011) [21]. The use of municipal wastewater for irrigation has various benefits including the safe and low-cost treatment and disposal of wastewater, the conservation of water and recharge of groundwater reserves; and the use of nutrients in the wastewater for productive purposes. Application of treated domestic sewage effluents improves soil fertility and physical properties, causing an increase in crop yield (Lopez *et al.*, 2006 and Weber *et al.*, 2006) [16, 29].

Decentralized treatment systems like constructed wetlands have been considered as a viable option for treatment of waste water over conventional sewage treatment system because of low cost, easy in operation and using natural processes with high pollutant removal efficiency. Nutrient and pollutant removal efficiency of wetlands is further improved if they are vegetated (Juwarkar, 1991). Use of wastewater in crops with non-edible economic parts is being considered a remunerative and viable option.

India is the largest producer (300-350 tonnes annum−1) of lemongrass oil exports 80% of it (National Horticulture Board, Govt. of India, 2005) [18]. The lemongrass plant is hardy and flourishes in a wide variety of soil ranging from rich loam type of soils to poor laterite. There has been a growing gap in the global production and demand of the lemongrass oil (3900 metric tonnes; Barbosa *et al.*, 2008) [2]. Hence, to meet the demand of this industrial crop, expansion of its production to the wastewater irrigated lands seems to be a sustainable option. The yield of lemongrass may also be affected by nutrients, salts, pathogens, heavy metals and other pollutants present in wastewater. The information on wastewater irrigated soil with lemongrass is not adequate. In order to assess the impacts of re-using wastewater on soil health, present study was carried out with lemongrass.

Materials and Methods

Study site characteristics

The study was carried out in the experimental field having latitude of 28°38'21.3" N and longitude of 77°08'56.5" E near to a sewage drain covering an area of 150 m^2 inside the ICAR-Indian Agricultural Research Institute (IARI). The site comprises of sandy loam soil with a bulk density of 1.54 g cm^{-3}.

Experimental wastewater treatment framework

The treatment system consisted of wetland in form of 18 mesocosms using 500 litres syntax tanks with hydraulic retention time (HRT) of 8.5±3.1 hrs and an effective pore space of 36.5%. The untreated wastewater collected in a sump (2.36 x 0.68 x 0.762 m^3) was connected to the mesocosms at a water head of 16.3 cm. The whole process of waste water flow from open sewage channel to sump was gravity-driven whereas electric motor was used to pump it from the sump to the individual mesocosms. Only 12-mesocosms were used for planting four replicates of three emergent macrophytes *viz*. *Typha latifolia* (Cattail), *Phragmites karka* (Reed), *Acorus calamus* (Vachh). The remaining 6-mesocosms were left un-vegetated. Intermittent flooding was done in all mesocosms up to a maximum depth of 16.3 cm with the wastewater during the experimental period (August 2018 to April 2019), thrice in a month. The treated effluent from each mesocosm was collected and stored treatment wise in 500 litre capacity tanks.

The experimental field consisted of 36 micro-plots, each of size 1.8 × 1.5 m. The crop was established for first year (September 2017) with uniform inputs and using groundwater for irrigation. From September 2018 onwards the crop was fertilized and irrigated as per treatment. Split plot design was used for experiment with three replications. A total number of 12 treatments were given which consisted of combinations of; (A) Different types of irrigation water in main-plots, *viz* (i) groundwater (GW), (ii) untreated wastewater (WW), (iii) constructed wetland treated wastewater (TWW) and (iv) groundwater in conjunction with untreated wastewater in cyclic mode (CW) (B) three levels of fertilizers in subplots *viz*. (i) control (no NPK fertilizer application)(N_0), (ii) recommended dose of NPK fertilizers – amount of NPK added through irrigation water (N_1) and (iii) recommended dose of NPK fertilizers (N_2). The fertilizers N, P_2O_5 and K_2O had recommended doses of 150, 60 and 60 kg ha^{-1}. One fourth of N and total P and K were applied as basal dose while the rest of N was top-dressed in three equal splits at 30 and 60 and 90 days after imposition of the treatments. Considering the irrigation frequency of once in 20 days, total 10 irrigations were applied from September to April.

The depth of irrigation was kept 5 cm which required 135 litres of water per irrigation in each subplot. For application of treated wastewater (TWW), 34 litres of treated wastewater obtained separately from mesocosms planted with *Typha latifolia* (Cattail), *Phragmites karka* (Reed), *Acorus calamus* (Vachh) and without vegetation were collected, mixed, and applied with the help of 20 litre capacity buckets. In case of conjunctive wastewater irrigation, groundwater and untreated wastewater were applied alternately in a cyclic mode beginning with groundwater irrigation.

Water and soil analysis

In order to access the impact of treated and untreated wastewater irrigation on soil properties, water and soil samples from each treatment were collected as per requirement.

Water

The groundwater, untreated wastewater and treated wastewater samples from each mesocosm used for micro-plot irrigation were collected for analysis. For all the water samples, the pH value and electrical conductivity (EC) was determined at the site. Then the water samples were immediately transferred from the site to the laboratory for the further chemical analysis. They were stored at 4°C in refrigerator in laboratory. Each water sample was collected separately in high density polyethylene (HDPE) bottles of 500 mL and 100 mL capacity. The 100 mL water sample bottles were then immediately acidified with 1N HNO_3 before subjecting to heavy metal analysis. Whereas the water samples collected in the 500 mL bottles were analysed for pH, EC, sodium (Na), potassium (K), phosphate (P), carbonate and bicarbonate, calcium and magnesium (Ca and Mg), micronutrient and heavy metals using standard methods and procedures. Prior to sample collection, the plastic bottles were rinse with respective water and closed air tight after collection to avoid contamination.

The pH of filtered water samples was determined directly using combined electrode (glass and calomel electrodes) by digital pH meter. The electrical conductivity (EC) was determined in the same sample with the help of Conductivity Bridge and expressed in dS m^{-1} at 25 °C (Jackson, 1973) [11]. Carbonate and bicarbonates content of the water samples were analyzed using H_2SO_4 titration method. For determining the calcium and magnesium content in the collected water samples, Versenate titration method was followed as outlined by Richards (1954) [24]. Sodium and potassium contents in the filtered samples were directly measured by flame photometer after calibrating with standards (Richards, 1954) [24].

Content of Zn, Fe, Mn, Cr, Cu, Ni, Cd, and Pb in the filtered aliquot were determined directly with the help of Atomic Absorption Spectrophotometer (AAS). The total contents of micronutrients and heavy metals were determined by digesting a known volume of wastewater both treated and untreated in di acid (HNO_3:$HClO_4$:9:4). The digested samples were filtered using Whatman No. 42 with 3-4 washings with double distilled water in 50 mL volumetric flask. Zn, Cu, Fe, Mn, Co, Ni, Pb and Cd were determined in the extracts using atomic absorption.

Soil

Soil samples were collected from a depth of 0 to 15 cm from each plot twice -one at the beginning (before treatment) and then again at end (after three cuttings) of the experiment. These were air dried, ground and passed through 2 mm sieve. The processed soil samples were used for determination of pH, EC, organic carbon, nitrogen, phosphorus, potassium, micronutrients and heavy metals.

Soil electrical conductivity (EC) and pH

For the determination of pH of soil, the pH meter was used in 1:2 (soil: water) suspension after shaking it as per method given by Jackson (1973) [11]. Then the supernatant of same suspension was used to determine the electrical conductivity ($EC_{1:2}$) with the help of Conductivity Bridge and was expressed as dS m^{-1} at 25 °C (Jackson, 1973) [11].

Organic carbon

In order to determine oxidizable organic carbon, soil samples were made to pass through 0.2 mm sieve and then the wet oxidation method using $K_2Cr_2O_7$ was used to determine organic carbon content, as outlined by Walkley and Black (1934) [27].

Available nitrogen

Estimation of available nitrogen was made using alkaline $KMnO_4$ which oxidizes and hydrolyses the organic matter present in soil as per the procedure given by Subbiah and Asija (1956) [25]. The liberated ammonia is condensed and absorbed in boric acid, which was titrated against standard 0.01N H_2SO_4.

Available phosphorus

In order to determine the available phosphorous, the soil samples were extracted with 0.5 M $NaHCO_3$; pH 8.5. And then the ascorbic acid method was used to determine the phosphorus content in the extracts (Watanabe and Olsen, 1965) [28].

Available potassium

For determination of available potassium content the soil was extracted with 1N ammonium acetate (pH 7.0) and then the flame photometer was used to measure the K content in the extract by following Hanway and Heidel (1952) [10] method as given by (Jackson, 1973) [11].

Extractable heavy metals and micronutrients

To determine the available Zn, Fe, Mn, Cr, Cu, Ni, Cd and Pb, the soil was extracted with DTPA solution. This extractant contains 0.1 M triethanolamine (TEA), 0.005 M DTPA and 0.01 M $CaCl_2.H_2O$. The dilute HCI (1:1) was used to adjust the its pH of the solution to 7.3. For extraction process, 10 g of air-dried soil and 20 mL of extractant were added and the contents were shaken for two hours on reciprocating shaker. After filtration through filter paper Whatman No.42, the extracts were analyzed for Zn, Fe, Mn, Cr, Cu, Ni, Cd, and Pb using atomic absorption spectrophotometer (AAS).

For estimating the total contents of micronutrients and heavy metals, soil samples (0.5 g) were weighed and transferred to 50 mL conical flask. The samples were predigested with 15 mL di-acid mixture (HNO_3:$HClO_4$:9:4) and then digested on hot plate. The digested solutions were allowed to cool and filtered using Whatman No. 42 with 3-4 washings with double distilled water in 50 mL volumetric flask. Zn, Cu, Fe, Mn, Co, Ni, Pb and Cd were determined in the extracts using AAS.

Statistical analysis

Each parameter data was subjected to a two-way ANOVA analysis (Gomez and Gomez, 1984) [9] with separation of means. All tests of significance were performed at the level of 5% probability.

Results and Discussion

Characterization of water samples

From the experimental site the water samples were collected during the study period and were analyzed for various chemical properties such as: pH, electrical conductivity (EC), organic carbon (OC), nitrogen, phosphorus, potassium, sodium absorption ratio (SAR), residual sodium carbonate (RSC), heavy metals (Fe, Cu, Zn, Mn, Ni, Co, Cr and Cd) using standard methods (Table.1).

Groundwater used for study on an average had pH 7.5, EC 2.19 dSm^{-1}, RSC 1.20 meq L^{-1} and SAR was 7.37. The concentration of N, P and K was 2.1, 0.24 and 3.3 mgL^{-1} respectively. These parameters were nearly within the range for irrigation usage. The concentrations of Zn 0.02 mgL^{-1}, Cu 0.01 mgL^{-1}, Mn 0.02 mgL^{-1} and Fe 0.27 mgL^{-1} were within the safe limits (2.0, 0.2, 0.2 and 5 mgL^{-1} respectively for Zn, Cu, Mn and Fe) given by FAO (1985) [8]. Cr content was found to be 0.05 mgL^{-1}. However, the concentrations of Pb, Ni and Cd were in traces. Untreated wastewater used for the study had pH 7.13, EC 2.58 dSm^{-1}, N 17.5 mgL^{-1}, P 3.97 mgL^{-1} and K 14.8 mgL^{-1}. Similarly, the contents of Zn, Cu, Mn and Fe were 0.58, 0.06, 0.76 and 4.04 mgL^{-1}. As indicated by the analytical data, the untreated wastewater was found to be a rich source of plant nutrients. It was marginally saline sodic as shown by EC 2.58±0.28 dSm^{-1}, SAR 7.72±0.32 and RSC 2.3±0.62 $meqL^{-1}$. However, Cd, Cr, Ni and Pb contents were observed to be 0.01, 0.07, 0.09 and 1.43 mgL^{-1}, which were well within their respective permissible limits (0.01, 0.1, 0.2 and 5 mgL^{-1}) given by FAO (1985) [8].

Table 1: Characteristics of treated and untreated wastewater used for irrigation

Water	pH	EC (dSm^{-1})	N (mgl^{-1})	P (mgl^{-1})	K (mgl^{-1})	RSC ($meql^{-1}$)	SAR	Ni (mgl^{-1})	Cd (mgl^{-1})	Cr (mgl^{-1})	Pb (mgl^{-1})	Cu (mgl^{-1})	Mn (mgl^{-1})	Zn (mgl^{-1})	Fe (mgl^{-1})
GW	7.5	2.1	2.1	0.24	3.30	1.20	7.37	ND	ND	0.05	ND	0.01	0.02	0.02	0.27
SW	7.1	2.5	17.5	3.97	14.80	2.30	7.72	0.09	0.01	0.07	1.43	0.06	0.76	0.58	4.04
TWW	7.1	2.3	7.5	1.06	5.45	1.39	6.30	0.04	ND	0.03	0.20	0.03	0.35	0.19	1.38
CD (5%)	NS	0.2		0.67	0.80	0.62	0.32	0.01	NS	0.01	0.05	0.01	0.08	0.07	0.18
Safe limit	6.5-8.4	0.7-3.0		0 – 2	0 – 2	<1.25	<10	0.2	0.01	0.1	1.5	0.2	0.2	2	5

Wastewater treated through low-cost wetland mesocosm had pH 7.10, EC 2.34 dSm^{-1}, SAR 6.30 and RSC 1.39 $meqL^{-1}$. The concentration of N, P and K was 7.5, 1.06 and 5.45 mgL^{-1} respectively. Similarly, the contents of Ni, Cr, Pb, Cu, Mn, Zn and Fe were 0.04, 0.03, 0.20, 0.03, 0.35, 0.19 and 1.38 mgL^{-1} respectively and found within their respective permissible limits (0.2, 0.1, 1.5, 0.2, 0.2, 2 and 5 mgL^{-1}). Cd was found in traces. Overall, in general the quality of wastewater treated through constructed wetland technology was significantly improved and was at par with the groundwater.

The pH had no significant difference among all the treatments. The pH is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system. An increase in carbon dioxide lowers pH, whereas a decrease will cause it to rise (WHO, 1996) [30]. Slightly reduced pH of the treated wastewater than those of untreated wastewater could mainly be due to release of carbon dioxide, organic acid released by root and plant metabolites and wetland bacteria. Similar observations were made by Chen *et al.* (2017) [6] from a Jhouzai Constructed Wetland system in Taiwan. The pH values of all the treatments were within the permissible limit of irrigation water (6.5-8.4) given by FAO (1985) [8]. Untreated wastewater had the higher electrical conductivity (2.58 dS m^{-1}) compared to treated wastewater (2.34 dS m^{-1}) or groundwater (2.19 dS m^{-1}). Higher electrical conductivity in untreated wastewater may be due to the presence of more amounts of soluble salts such as sodium, potassium, chloride or sulphate, carbonate or bicarbonate released from households or other sources (Nazir *et al*, 2015) [19]. Lower EC values in treated wastewater could be due to trapping of suspended sediments and ion uptake by the vegetation planted in the constructed wetland treatment system. The EC of all the treatments were > 2 dS m^{-1} which indicated that the water samples were slightly towards saline but they were well within the safe limit for irrigation (< 3 dSm^{-1}) given by FAO (1985) [8].

Similar and higher contents of N, P and K in untreated sewage were also found by Rattan *et al*. (2005) [23] and Lone *et al*. (1996). Untreated wastewater had residual sodium carbonate 2.30 meq L^{-1} which was categorized marginal as per USSL staff (1954). Treated wastewater had RSC 1.39 $meqL^{-1}$ whereas in groundwater it was 1.20 meq L^{-1}. Higher residual sodium carbonate of untreated wastewater could mainly be due to disposal of detergent used for washing. However, sodium adsorption ratio of groundwater, treated or untreated wastewater did not vary much and were within the safe limit (< 10) given by FAO (1985) [8].

Contents of Zn, Cu, Mn and Fe were 29, 6, 38 and 15 times higher in the untreated wastewater compared to the groundwater. Treated wastewater had contents of Zn, Cu, Mn and Fe 3.1, 2.0, 2.2 and 2.9 time lower compared to untreated sewage showing that constructed wetland system effectively removed these cations from wastewater. On an average, contents of Cr, Ni and Pb in treated wastewater were 2.2, 2. 3 and 7.2 times lower compared to untreated sewage. According to Pescod (1992) [20], threshold limits of metal concentration in irrigation water leading to crop damage are: Cd 10, Cr 100, Cu 200, Fe 5000, Mn 200, for Ni 200, Pb 5000 and Zn 2000 µg L^{-1}. Similar heavy metal concentrations (mg L^{-1}) ranging from 0.249 to 0.257 for Fe, 0.049 to 0.056 for Zn, 0.028 to 0.036 for Cd, 0.015 to 0.019 for Cu, 0.035 to 0.042 for Pb and 0.031 to 0.038 for Ni were recorded in effluent used for irrigation in Allahabad (Yadav *et al*., 2013) [31].

Initial soil properties

To analyse the initial soil properties before the application of treatments, soil samples were collected from 0-15 cm depth from all the 36 experimental plots and mixed to obtain a composite sample by quartering method. Soil samples were dried, processed and analyzed for pH, electrical conductivity, organic carbon, available N, P and K contents and DTPA extractable contents of Mn, Zn, Cu, Fe, Pb, Cd, Cr and Ni and the results are presented in Tables 2. Electrical conductivity ($EC_{1:2}$), $pH_{(1:2)}$ and organic carbon of 0-15 cm soil layer was 0.29 dSm^{-1}, 7.34 and 0.68 (%) respectively. Available N, P and K contents were 238, 24.6 and 226.56 kg ha^{-1} respectively. Similarly, Fe, Zn, Cu, Mn, Pb, Ni and Cr were found to be 25.1, 5.95, 4.25, 2.67, 2.54, 0.22 and 0.25 mg kg^{-1} respectively. Cd was found in traces and could not be detected.

Table 2: Initial soil properties

Parameters	Value
pH	7.34
Electrical Conductivity (dSm^{-1})	0.29
Organic Carbon (%)	0.68
Available N (kg ha^{-1})	238
Available P (kg ha^{-1})	24.6
Available K (kg ha^{-1})	226.5
Fe (mg kg^{-1})	25.1
Cu (mg kg^{-1})	4.25
Zn (mg kg^{-1})	5.95
Mn (mg kg^{-1})	2.67
Ni (mg kg^{-1})	0.22
Pb (mg kg^{-1})	2.54
Cr (mg kg^{-1})	0.255

Table 3: Soil properties after harvesting of lemongrass

Initial soil	pH	EC (dSm^{-1})	OC (%)	N ($kgha^{-1}$)	P ($kgha^{-1}$)	K ($kgha^{-1}$)	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Fe (mg kg^{-1})	Ni (mg kg^{-1})	Pb (mg kg^{-1})	Cr (mg kg^{-1})
GW	7.3	0.37	0.64	234	25.6	248	5.5	3.9	2.7	24.3	0.20	2.70	0.32
WW	7.4	0.38	0.75	257	29.5	251	7.0	4.7	3.3	29.2	0.27	4.20	0.38
TWW	7.23	0.35	0.70	244	26.5	248	6.6	4.4	3.0	28.6	0.27	3.00	0.31
CW	7.45	0.33	0.70	249	26.5	253	6.2	4.0	2.6	26.4	0.25	3.50	0.35
CD 5%	NS	NS	0.08	19	3	NS	1.5	NS	0.5	NS	0.05	0.30	NS
Nutrient Doses													
N0	7.48	0.33	0.62	229	24.6	243	4.9	4.4	2.7	28.0	0.24	3.00	0.35
N1	4.29	0.36	0.72	249	27	250	6.6	4.3	3.2	27.0	0.27	3.30	0.33
N2	7.26	0.38	0.76	260	29.5	257	7.5	4.0	2.7	26.3	0.24	3.80	0.34
CD 5%	NS	NS	0.06	17	2.8	NS	1.3	NS	NS	NS	NS	NS	NS

Changes in soil properties

After the third harvest of lemongrass, soil samples were collected with tube auger from 0-15 cm depth from all the experimental plots. The collected soil samples were dried, processed and analysed for EC, pH, OC, N, P, K, Zn, Fe, Mn, Cu, Ni, Pb, Cr and Cd and the values of which are represented in Table 3.

EC, pH and OC

Electrical conductivity ($EC_{1:2}$) of surface 15 cm soil layer of differently irrigated plots ranged from 0.29 to 0.44 dSm^{-1} with mean values varying from 0.33 to 0.38 dSm^{-1}. Amongst different treatments, untreated wastewater irrigated plots had the maximum EC (0.38 dSm^{-1}) and minimum (0.33 dSm^{-1}) was found in case of plots irrigated alternatively with wastewater and groundwater. The electrical conductivity of plots irrigated with groundwater was 0.37 dSm^{-1}. Electrical conductivity of soil was not influenced by quality of irrigation water and nutrient doses. Similarly, mean values of soil pH irrigated with groundwater, untreated wastewater, treated wastewater and conjunctive water use varied from 7.23 to 7.48 in surface 15 cm soil layer. Soil pH was also not influenced by quality of irrigation water and nutrient doses. Different nutrient doses had no significant effect on soil pH and electrical conductivity. Deliback *et al*. (2009) [7] also reported that there were no significant changes with wastewater or sewage sludge applications on soil pH.

Organic carbon (OC) content of surface 15 cm soil layer of differently irrigated plots ranged from 0.64 to 0.76%. The mean organic carbon content in soil irrigated with untreated wastewater was 0.75% The mean organic carbon content in the treated wastewater and conjunctively irrigated plots was 0.73%, which was significantly higher (16%) compared to the organic carbon in groundwater irrigated soil (0.64%). The increase in soil organic carbon content may be due to the appreciable amount of organic matter present in wastewater both as particulate and dissolved forms. The increase in organic carbon content due to sewage irrigation was also reported earlier by Al Omron *et al*. (2012) [1] and Belaid *et al*. (2012) [3]. The differences in organic carbon content were found non-significant in the soil which has been irrigated with untreated wastewater, treated wastewater and conjunctively irrigated. Application of recommended or adjusted doses of N, P and K led to significantly higher build of soil organic carbon compared to control (no nutrient application). However, the differences in soil organic carbon content obtained with recommended and adjusted nutrient doses were not significant.

Available N, P and K

After taking three cuttings of the crop, available Nitrogen (N) content in surface 15 cm soil layer ranged from 229 to 260 kg ha^{-1}. Available N content was the maximum (260 kg ha^{-1}) in the plots irrigated with untreated wastewater which was significantly higher than that recorded in groundwater irrigated plots (229 kg ha^{-1}). The differences in N content values of soils irrigated with untreated wastewater, treated wastewater and conjunctively water use were not significant. Nitrogen content of groundwater, treated wastewater and conjunctively irrigated soil were also found statistically equal. Application of recommended or adjusted doses of N, P and K led to significantly higher build of soil nitrogen compared to control (no nutrient application). However, the differences in soil nitrogen content obtained with recommended and adjusted nutrient doses were not significant.

Olsen's Phosphorus (P) in surface 15 cm soil layer irrigated with groundwater, untreated and treated wastewater varied from 22.9 to 30.7 kg ha^{-1}. The mean P content was the highest in untreated wastewater irrigated plots (29.5 kg ha^{-1}) which was significantly higher compared to groundwater irrigated plots (24.6 kg ha^{-1}) but at par with soil irrigated with treated wastewater and conjunctively water use. Similarly, P contents in soil irrigated with, groundwater, treated wastewater and conjunctively water use were statistically equal. Soil P content obtained with the application of recommended or adjusted doses of N, P and K was significantly higher compared to control (no nutrient application). But the differences in soil P content obtained with recommended and adjusted nutrient doses were not significant.

Mean values of available potassium (K) content in surface 15 cm soil layer of differently irrigated plots ranged from 243 to 257 kg ha^{-1}. Available K contents analyzed in soil after the three crop harvests were not influenced by different quality of irrigation water and nutrient doses of N, P and K applied. Several researchers also reported a substantial build-up of N, P and K in sewage irrigated soils (Priyanie *et al*., 2008; Kharche *et al*., 2011; Belaid *et al*., 2012) [21, 3, 13]. Retention of a significant amount of N, P and K bound and contained in the soil particles during treatment in wetland system and utilization of plant nutrients by wetland vegetation resulted in lesser amount of nutrients in treated effluents compared to untreated sewage. As a result, soil fertility build up was less in plots receiving treated wastewater compared to untreated wastewater. Application of recommended doses also resulted in higher organic carbon content. Long term application of recommended doses of fertilizers led to rhizo-depositions, additions of root biomass and the above ground stubbles *etc* which resulted in improvements in the soil organic carbon and available NPK status (Brar *et al*., 2000) [5].

Available contents of Zn, Cu, Mn, Fe, Cd, Cr, Ni and Pb

With the use of different quality of irrigation waters, mean values of DTPA extractable soil Zn, Cu, Mn and Fe in surface 0-15 cm layer varied from 4.9 to 7.5, 3.9 – 4.7, 2.6 – 3.3 and 24.3 – 29.2 mg kg^{-1}, respectively. The numerical values of above micronutrients in surface layer were found to be the lowest in groundwater irrigated plots and the highest in untreated wastewater irrigated soil. But the impacts of irrigation water quality were found non-significant on DTPA extractable Cu and Fe. However, soil Zn and Mn contents in soil irrigated with untreated wastewater were significantly higher than in the groundwater irrigated soils. Soil Zn content obtained with the application of recommended or adjusted doses of N, P and K was significantly higher compared to control (no nutrient application). The differences in soil Zn content obtained with recommended and adjusted nutrient doses were not significant. However, impacts of application of recommended and adjusted nutrient doses were found ineffective on contents of Cu, Mn and Fe in soil.

Surface 15 cm soil layer of differently irrigated soil had nickel (Ni) content in range of 0.20 to 0.27 mg kg^{-1}. Groundwater irrigated plots had the lowest Ni content (0.20 mg kg^{-1}). Ni content in the soil which has been irrigated with the treated sewage water was found 0.27 mg kg^{-1} (maximum) which was 35% higher than that in case of groundwater irrigated plots. The differences in Ni contents of soil irrigated with untreated wastewater, treated wastewater and conjunctively water use were not significant. Similarly, soil Ni contents were not affected by variable nutrient doses. DTPA extractable soil lead (Pb) mean values varied from 2.7 to 4.2 mg kg^{-1}. Amongst different treatments, wastewater irrigated plots had the highest and significantly higher Pb content (4.2 mg kg^{-1})

compared to groundwater, treated wastewater and conjunctively irrigated soil. Similar to Ni, the Pb content of soil was not affected by variable nutrient doses. Mean values of chromium (Cr) content of surface 15 cm soil layer of differently irrigated plots ranged from 0.31 to 0.38 mg kg^{-1}. Contents of soil Cr were not affected both by the quality of irrigation water and application of nutrient doses. Soil cadmium (Cd) content in surface soil was found in traces and could not be detected by using atomic absorption spectrophotometer.

Low solubility and limited plant uptake caused heavy metals to accumulate in surface soil (Manpanda *et al*., 2005) [17]. Similar observations were also made by Nazir *et al*. (2015) [19] and Rattan *et al*. (2005) [23]. Soils irrigated with groundwater and wastewater treated through vegetated wetlands had similar contents of available micronutrients and heavy metals. Compared to untreated wastewater, treated sewage effluents did not contain appreciable quantities of heavy metals, making use of treated wastewater for irrigation safe compared to its direct disposal. Belmont *et al*. (2004) [4] also found that municipal wastewater treated with wetland technologies suitable for crop irrigation, meeting specific national guidelines. Though there was increase in the metals content, all the values for metals in all the treatments were well within the maximum permissible threshold limit given by WHO (1996) [30].

Conclusions

The overall experimental evidences show the potential of cultivating the aromatic lemongrass with untreated wastewater improving the soil chemical properties. The macro nutrients (N, P, and K) and organic carbon content of soil got improved with sewage irrigation followed by soil irrigated alternatively with sewage and ground water. Contents of micronutrients (Zn, Mn, Cu and Fe) were also the maximum in sewage water irrigated soils followed by soil irrigated alternatively with sewage and ground water. Application of treated wastewater led to a significant reduction in soil Pb accumulation compared to untreated wastewater. Organic carbon, available N, P, K and Zn contents were improved with the application of recommended or adjusted nutrient doses compared to control.

References

1. Al Omron AM, El-Maghraby SE, Nadeem MEA, Al-Eter AM, Al-Mohani H. Long term effect of irrigation with the treated sewage effluent on some soil properties of Al-Hassa Governorate, Saudi Arabia. Journal of the Saudi Society of Agricultural Sciences. 2012;11(1):15-18.
2. Barbosa LCA, Pereira UA, Martinazzo AP, Maltha CRA, Teixeira RR, De Catro Mello E. Evaluation of the chemical composition of Brazilian commercial Cymbopogon citrates (DC.) Staph. Samples. Molecules. 2008;13(8):1864-1874.
3. Belaid N, Neel C, Lenain JF, Buzier R, Kallel M, Ayoub T, Baudu M. Assessment of metal accumulation in calcareous soil and forage crops subjected to long-term irrigation using treated wastewater: Case of El Hajeb-S fax, Tunisia. Agriculture, ecosystems & environment. 2012;158:83-93.
4. Belmont MA, Cantellano E, Thompson S, Williamson M, Sanchez A, Metcalfe CD. Treatment of domestic wastewater in a pilot-scale natural treatment system in central Mexico. Ecological Engineering. 2004;23(4-5):299–311.
5. Brar MS, Mahli SS, Singh AP, Arora CL, Gill KS. Sewer water irrigation effects on some potentially toxic trace elements in soil and potato plants in north western India. Canadian Journal of Soil Science. 2000;80(3):465-471.
6. Chen SC, Ming-Young Jan, Kuo-Liang Lin, Sung-Lin Chao, Chien-Sen Liao. Sustainability of Constructed Wetland under the Impact of Aquatic Organisms Overloading. Sustainability. 2017;9(863):532-538.
7. Delibacack S, Okur B, Ongun AR. Effect of sewage sludge levels on temporal variation of some soil properties of Typic Xerofluent soil in Menemen Plain, Western Anatolia, Turkey. Environment Monitoring Assessment. 2009;148:85-95.
8. FAO. Water Quality for Agriculture, Irrigation and Drainage Paper; c1985. p. 29.
9. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd Edition, John Wiley and Sons, New York; c1984. p. 680.
10. Hanway JJ, Heidal H. Soil analysis methods as used in Iowa State College Soil Testing Laboratory. Iowa State College of Agriculture Bulletin. 1952;57:1-31.
11. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi; c1973. p. 106-203.
12. Juwarkar AS. Proceedings of Internal Conference on Environment. NEERI, Nagpur India; c1991.
13. Kharche VK, Desai VN, Pharande AL. Effect of sewage irrigation on soil properties, essential nutrient and pollutant element status of soils and plants in a vegetable growing area around Ahmednagar city in Maharashtra. Journal of the Indian Society of Soil Science. 2011;59(2):177-184.
14. Lal K, Minhas PS, Chaturvedi RK, Yadav RK. Cadmium uptake and tolerance of three aromatic grasses on Cd-rich soils. Journal of the Indian Society of Soil Science. 2008b;56(3):290-294.
15. Lal K, Minhas PS, Shipra Chaturvedi RK, Yadav RK. Extraction of cadmium and tolerance of three annual cut flowers on Cd-contaminated soils. Bioresource Technology. 2008a;99(5):1006-1011.
16. Lopez A, Pollice A, Lonigro A, Masi S, Palese AM, Cirelli GL, *et al*. Agricultural wastewater reuse in southern Italy. Desalination. 2006;187(1-3):323-334.
17. Mapanda F, Mangwayana EN, Nyamangara J, Giller KE. The effect of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. Agriculture, Ecosystems & Environment. 2005;107(2-3):151-165.
18. National Horticulture Board. Lemongrass, Model Project Reports. National Horticulture Board, Ministry of Agriculture, Government of India, Gurgaon 122015, Haryana, India. http://nhb.gov.in (Retrieved 18.08.12); c2005.
19. Nazir R, Khan M, Masab M, Rehman HU, Rauf NU, Shahab S, *et al*. Accumulation of heavy metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water collected from Tanda Dam Kohat. Journal of Pharmaceutical Sciences and Research. 2015;7(3):89.
20. Pescod M. Wastewater treatment and use in agriculture. Bull, FAO 47 (125), (Rome); c1992.
21. Priyanie A, Philipp W, Robert S, Sreedhar A, Axel D. An

atlas of water quality, health and agronomic risks and benefits associated with wastewater irrigated agriculture- A study from the banks of the Musiriver, India; c2008.
22. Qadir M. Agricultural use of marginal-quality water: Opportunities and challenges IWMI Part 4 Ch8-16 final.indd 425 IWMI Part 4 Ch8-16 final.indd 425; c2011.
23. Rattan RK, Datta SP, Chhonkar PK, Suribabu K, Singh AK. Longterm impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater: A case study. Agriculture, Ecosystems and Environment. 2005;109(3-4):310-322.
24. Richards LA. Diagnosis and improvement of saline and alkali soils. Agriculture Handbook 60, Department of Agricultural, Washington DC: US; c1954.
25. Subbiah BV, Asija GL. A Rapid Procedure for the Estimation of Available Nitrogen in Soils. Current Science. 1956;25:259-260.
26. USDA/US Salinity Laboratory Staff. Salinity Management in Agriculture; c1954.
27. Walkley AJ, Black IA. Estimation of soil organic carbon by the chromic acid titration method. Soil science. 1934;37(1):29-38.
28. Watanabe FS, Olsen SR. Test of an Ascorbic Acid Method for Determining Phosphorus in Water and NaHCO3 Extracts from the Soil. Soil Science Society of America Journal. 1965;29(6):677-678.
29. Weber S, Khan S, Hollende J. Human risk assessment of organic contaminants in reclaimed wastewater used for irrigation. Desalination. 2006;187(1-3):53-64.
30. World Health Organization WHO. WHO Guidelines for Drinking Water Quality 2nd Edition; c1996.
31. Yadav A, Yadav PK, Shukla DN. Investigation of heavy metal status in soil and vegetables grown in urban area of Allahabad, Uttar Pradesh, India. International Journal of Scientific and Research Publications. 2013;3(9):1-7.