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Research Article

Impact of treated sewage water on nutrient status of alfisols and vegetable crops

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Abstract

This study was conducted to determine the impact on the nutrient status of soil and vegetable crops irrigated with the treated sewage water. Three samples of water and five samples of soil and five commonly grown vegetables viz. radish, carrot, spinach, cauliflower, and potato were collected from Ganjia, Arail and Dandi located in Naini, Allahabad (India). The water samples were analysed for pH, EC, and heavy metals (Pb^{2+}, Cr^{3+}, Cd^{2+} and Ni^{2+}) concentration. Water samples from all the sites were alkaline with EC below the safe limits. The soil and plant samples from all the three sites showed that Gangia recorded the highest value of EC (dS m^{-1}), organic carbon (OC) (%), available NPK (kg ha^{-1}), and micronutrients concentration (Mn^{2+}, Zn^{2+} and Fe^{2+}) (mg kg^{-1}) whereas, the lowest concentration was recorded at Dandi followed by Arail. The soil samples collected from all three sites were alkaline. The nutrient status (N, P and K) showed the highest value in potato in the three sites, whereas manganese and zinc showed the highest value in spinach and iron in carrot. The study concludes that treated sewage water used for irrigation has a positive impact on nutrient status in soils and as well as in vegetable crops.

Keywords: alfisols; nitrogen; organic carbon; treated sewage; vegetables

Introduction

Approximately 20 million ha in 50 countries are irrigated with wastewater (Verma *et al.*, 2015; Khalid *et al.*, 2017). The wastewater is frequently used for crop irrigation, without any prior treatment in peri-urban

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areas of many countries in Asia (Murtaza *et al.*, 2010; Farid *et al.*, 2014; Khan *et al.*, 2015; Qureshi *et al.*, 2016; Khalid *et al.*, 2017).

Nearly 80 percent of the water used for household purposes and in the industry is discharged back as wastewater in many countries. According to the report published in 2007, the total urban wastewater generated in India alone is around 38.000 million liters per day (MLD), and overexploitation of groundwater use is increasing (Verma *et al.*, 2015). The class-I, class-II cities, and towns represent 72 percent of the urban population in India. These areas produce nearly 98 liters per capita per day (LPCD) of wastewater. On the other hand, the capital city Delhi alone discharges 3.663 MLD of wastewater, which is over 220 LPCD, but approximately 61 percent of this is treated (CPCB, 2007). The sewage generation in Varanasi is 230.17 MLD, and only 44 percent is treated (CPCB, 2007). CPCB estimates are that total wastewater generation from Class I cities (498) and Class II (410) towns in the country is around 35.558 and 2.696 MLD respectively; but, the installed sewage treatment capacity for these is just 11.553 and 233 MLD. This leads to a gap of 26.468 MLD in sewage treatment capacity (CPCB, 2007).

In India, the major contributions to the wastewater in Delhi and several other States (63%; CPCB, 2007). The projections given for 2050 are that nearly 132 billion liters per day of wastewater will be generated, this amount has the potential to meet about 5 percent of the total irrigation water demand (Kaur *et al.*, 2012). The future analysis of water resources indicates that due to population overload and industrialization the public will face a twin-edged problem with reduced freshwater availability and increased wastewater generation (Kaur *et al.*, 2012).

The waters of marginal quality like sewage and others are used to supplement irrigation needs in many countries where good quality of water is limited (Ozturk *et al.*, 2005, 2011; Sharma *et al.*, 2012; Maya *et al.*, 2016). Nitrogen, phosphorus, and potassium content of sewage generally range from 1 to 1.5%, 1 to 12%, and 0.35 to 0.8%, respectively.

The sewage water evaluation in agriculture is an age-old practice (Mani *et al.*, 2013). The use of wastewater for crop irrigation has certain advantages, such as the supply of essential plant nutrients and organic matter to the soil, saving water, and nutrients and reducing water pollution (Murtaza *et al.*, 2010; Mani *et al.*, 2013; Akınbile *et al.*, 2016; Khalid *et al.*, 2017). Moreover, irrigation with sewage water increases soil electrical conductivity and organic carbon, contributes to the supply of macro and micronutrients for plant growth, regulates soil buffer capacity, as well as soil cation exchange capacity (CEC), but at the same time decreases soil pH. However, it can also result in the accumulation of heavy metals in the plow layer of agricultural soils when applied for a long term with indiscriminate use and without pre-control that may prove hazardous to human health (Ghosh *et al.*, 2012; Amin *et al.*, 2012). Despite this, the use of sewage effluents for irrigating agricultural lands is increasing in many industrializing countries due to a lack of enough fresh water supplies (Verma *et al.*, 2015).

During the last few decades, numerous studies have focused on the cultivation of vegetables on wastewater-irrigated soils and the associated health risks (Pourrut *et al.*, 2011; Mahmood and Malik, 2014; Xiong *et al.*, 2016; Zia *et al.*, 2016). It is reported that vegetables may accumulate metals in concentrations greater than the maximum permissible limits with serious public health implications (Shaheen *et al.*, 2016). Keeping this in view, it is highly practical to monitor and reduce health risks associated with the cultivation of vegetables on contaminated soils (Khalid *et al.*, 2017). Because of the increasing vulnerability related to the consumption of vegetables with heavy metal accumulation, it is of practical significance to determine the heavy metal accumulations in the soil as well as the vegetables irrigated with wastewater (Chang *et al.*, 2013; Verma *et al.*, 2015), the current study was therefore planned with this aim.

Materials and Methods

Study area

The experimental work was done on the selected sites in Naini, Allahabad (India), where farmers usually irrigate their fields with sewage water. The climate of the study area is sub-tropical with summer temperatures reaching up to 48 °C, whereas the winter temperatures may be as low as 1.8 °C, with occasional frost in winter and extreme dry hot strong wind (loo) in summer. The average annual rainfall of the study area is about 50 cm.

A survey of the area using treated sewage water for irrigation was carried out at selected locations. Several vegetables like radish, carrot, spinach, cauliflower, and potato are grown extensively on these soils therefore these species were chosen for analytical evaluation. Three sampling sites namely Ganjia, Arail, and Dandi were selected keeping in view the increase in distance from the disposal site.

Data analyses

Three samples of sewage water used for irrigation of vegetables were collected and analyzed for pH, electrical conductivity (EC), and heavy metals (Pb^{2+}, Cd^{2+}, Cr^{3+}, and Ni^{2+}). EC and pH of water were determined according to APHA (1998). Heavy metals (Pb^{2+}, Cd^{2+}, Cr^{3+}, and Ni^{2+}) concentrations were determined by atomic absorption spectrophotometer (Perveen *et al.*, 2012). Soil samples at the depths (0-15 and 15-30 cm) were collected from each site, bypassed through a 2 mm sieve and analyzed for pH, electrical conductivity (1:2.5 soil water suspension), organic carbon, available nitrogen (alkaline permanganate method), available phosphorus (calorimetric method), available potassium (flame photometric method) and available micronutrients (Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+}) in DTPA extraction atomic absorption spectrophotometer as adopted by Kıran *et al.* (2012).

The plant samples (radish, carrot, spinach, cauliflower, and potato) were also collected from the fields irrigated with the sewage water. These were washed with the tap water followed by acidified water, distilled water, and double-distilled water (Lone *et al.*, 2013). Plant samples were digested and analyzed for nitrogen (modified macro-Kjeldahl method), phosphorus (vanadomolibdate method), potassium (flame photometry), and micronutrients like Fe^{2+}, Mn^{2+} and Zn^{2+} were determined by (Di-acid Digestion (HNO_3:HC_1O_4, 3:1) method described by Rapheal and Adebayo (2011).

Results

The sewage water of the three sites viz. Gangia, Arail, and Dandi were slightly alkaline with mean pH ranging between 7.24 to 7.81, and the highest pH value (7.90) was observed at Dandi. The irrigation water of these sites had EC values ranging from 0.91 to 1.18 dS m^{-1}. Among the heavy metals, Pb^{2+} was the highest (1.04-2.16 mg/L) followed by Cr^{3+} (0.94-1.94 mg/L), Ni^{2+} (0.10-1.34 mg/L) and lowest was Cd^{2+} (0.01-0.07 mg/L) at all the three sites (Table 1). The levels of heavy metal contamination in the water samples showed marked variation. Water samples from Gangia showed the highest level of Pb^{2+} (2.16 mg/L), Cr^{3+} (1.94 mg/L) and Cd^{2+} (0.05 mg/L). Samples from Arail had the highest levels of Ni^{2+} (1.28 mg/L), whereas the lowest level of Cd^{2+} (0.01 mg/L) was observed at Dandi.

Comparing our data with the findings reported by several authors from other countries in Asia, we observed that relatively high values of Pb^{2+} were observed (Chandra *et al.*, 2009; Kashif *et al.*, 2009; Sing *et al.*, 2010; Khan *et al.*, 2013; Mahmood and Malik, 2014; Randhawa *et al.*, 2014; Iqbal *et al.*, 2015; Khanum *et al.*, 2017). On the other hand, the values of Cd were lower than those given by Tiwari *et al.* (2011), Akhtar *et al.* (2014), and Wantong *et al.* (2014). The concentration of Pb^{2+} (1.08-2.10 mg/L) was very high in our studies, above the maximum permissible limit set by WWF (2007) (the max. permissible limit for Pb^{2+} in irrigation water is 0.1 mg/L). Relatively higher values of Cr^{3+} have been recorded here as compared to the values given by Chandra *et al.* (2009), Kashif *et al.* (2009), Sing et al. (2010), Khan *et al.* (2013), Mahmood and Malik **(2014),** Randhawa *et al.* (2014), Wantong *et al.* (2014), Iqbal *et al.* (2015), and Khanum *et al.* (2017). However, the values of Cr^{3+} were lower than those given by Tiwari et al. (2011). The concentration of Cr^{3+} (1.00-1.86 mg/L) was very high in our samples, above the maximum permissible limit set by FAO/WHO (2011) (the max. permissible limit for Cr^{3+} in irrigation water is 0.1 mg/L). The concentration of Ni^{2+} (0.64-1.29 mg/L) too was very high above the maximum permissible limit set by WWF (2007) (the max. permissible limit for Ni^{2+} in irrigation water is 0.20 mg/L).

Table 1. Chemical characteristics of the sewage water from different sites

Sites	Parameters	Sample-I	Sample-II	Sample-III	Mean
Site-I (Ganjia)	pH	7.20	7.50	7.02	7.24
	EC dS m^{-1}	1.30	1.21	1.03	1.18
	Pb (mg/L)	2.06	2.16	2.10	2.10
	Cd (mg/L)	0.05	0.05	0.07	0.06
	Ni (mg/L)	1.25	1.25	1.34	1.29
	Cr (mg/L)	1.94	1.86	1.79	1.86
Site-II (Arail)	pH	7.60	7.82	7.58	7.56
	EC dS m^{-1}	0.97	1.20	1.05	1.07
	Pb (mg/L)	1.96	1.89	1.86	1.90
	Cd (mg/L)	0.05	0.03	0.04	0.04
	Ni (mg/L)	1.28	1.04	1.09	1.13
	Cr (mg/L)	1.82	1.67	1.54	1.67
Site-III (Dandi)	pH	7.79	7.85	7.90	7.81
	EC dS m^{-1}	1.01	0.92	0.82	0.91
	Pb (mg/L)	1.04	1.09	1.11	1.08
	Cd (mg/L)	0.04	0.01	0.02	0.02
	Ni (mg/L)	0.98	0.86	0.10	0.64
	Cr (mg/L)	1.12	0.96	0.94	1.00

The values of Cd^{2+} were relatively lower than the values published by several authors from other Asian countries (Chandra *et al.*, 2009; Kashif *et al.*, 2009; Tiwari *et al.*, 2011; Khan *et al.*, 2013; Akhtar *et al.*, 2014; Mahmood and Malik, 2014; Randhawa *et al.*, 2014; Iqbal *et al.*, 2015; Khanum *et al.*, 2017). However, the value of Cd^{2+} in our investigation was higher than those given by Sing *et al.* (2010). The Cd^{2+} concentration in the sewage water recorded by Wantong *et al.* (2014) was in agreement with our results. In general, the concentrations of Cd^{2+} (0.02-0.06 mg/L) in our samples were slightly above the maximum permissible limit set by WWF (2007) (the max. permissible limit for Cd^{2+} in irrigation water is 0.01 mg/L).

The sewage waters used in this study have shown the trends of heavy metals as; $Pb^{2+}>Cr^{3+}>Ni^{2+}>Cd^{2+}$. The differences in the levels of heavy metals in water can be associated with the use of different quantity and quality of sewage and sludge, level and type of industrial plant near the sampling area, the proximity of field from the source, presence of thermal power plants, and use of different types of agrochemicals containing heavy metals (Singh and Kumar, 2006; Perveen *et al.*, 2012).

The mean pH value recorded at 0-15 and 15-30 cm depth at all the sites was alkaline with the highest pH observed at Dandi (7.84 and 7.34) followed by Arail (7.46 and 7.09) whereas, the lowest pH was recorded at Gangia (7.36 and 7.08), as shown in Table 2. The maximum EC at 0-15 and 15-30 cm depth (dS m^{-1}) was recorded at Ganjia (0.34 and 0.30) and the minimum was observed at Dandi (0.28 and 0.24) followed by Arail (0.33 and 0.30) as shown in Table 3. The mean percentage (%) of organic carbon was observed to be significantly greater in Gangia (1.90 and 1.59%), but the lowest was observed at Dandi (0.74 and 0.55) (Table 4). This may be attributed to the fact that Gangia probably received sewage water for irrigation for a long time and is also located nearer to the sewage discharge point compared to Arail and Dandi. The mean organic carbon was found to decrease abruptly with the increase in soil depth, which can be due to anaerobic reactions in the soil with increasing soil depth. Similar findings have also been reported by Singh and Verloo (1996), and

Saraswat *et al.* (2005). Morugan-Coronado *et al.* (2011) have found that electrical conductivity and sodium content of soil increase but no remarkable change in soil organic carbon and microbial biomass carbon is observed due to the low organic carbon content of the water used for irrigation in the Mediterranean countries. On the contrary, Xue *et al.* (2012) have reported that there was an increase in the values of organic matter in the soil irrigated with sewage water compared to the soil irrigated with fresh water.

Table 2. Depth wise pH of soil water suspension 1:2.5 (w/v) in the soils from different sites

		0-15 cm						15-30 cm					
Soil samples		S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
Site-I (Ganjia)		7.32	7.38	7.40	7.39	7.31	7.36	7.16	7.05	7.12	7.04	7.04	7.08
Site-II (Arail)		7.37	7.54	7.38	7.51	7.48	7.46	7.02	7.13	7.10	7.08	7.12	7.09
Site-III (Dandi)		7.80	7.74	7.85	7.91	7.89	7.84	7.20	7.30	7.15	7.61	7.43	7.34
Mean		7.50	7.55	7.54	7.60	7.56		7.13	7.16	7.12	7.24	7.20	
p<0.05	Soil samples	NS						NS					
	Sites	0.08						0.17					

Table 3. Depth wise electrical conductivity (dS m^{-1}) of soil water suspension 1:2.5 (w/v) in the soils from different sites

		0-15 cm						15-30 cm					
Soil samples		S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
Site-I (Ganjia)		0.35	0.34	0.35	0.34	0.33	0.34	0.30	0.31	0.30	0.31	0.30	0.30
Site-II (Arail)		0.34	0.33	0.32	0.33	0.33	0.33	0.31	0.30	0.29	0.30	0.32	0.30
Site-III (Dandi)		0.28	0.27	0.28	0.27	0.28	0.28	0.21	0.26	0.26	0.23	0.24	0.24
Mean		0.32	0.32	0.32	0.32	0.31		0.27	0.29	0.29	0.28	0.28	
p<0.05	Soil samples	NS						NS					
	Sites	0.01						1.128					

Table 4. Depth wise percent organic carbon in the soils from different sites

		0-15 cm						15-30 cm					
Soil samples		S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
Site-I (Ganjia)		1.92	1.87	1.89	1.95	1.89	1.90	1.73	1.44	1.48	1.64	1.68	1.59
Site-II (Arail)		0.89	0.93	0.99	0.89	0.90	0.92	0.74	0.67	0.78	0.69	0.71	0.71
Site-III (Dandi)		0.77	0.74	0.78	0.75	0.69	0.74	0.58	0.61	0.54	0.53	0.51	0.55
Mean		1.19	1.18	1.22	1.19	1.16		1.01	0.90	0.93	0.95	0.96	
p<0.05	Soil samples	NS						NS					
	Sites	0.05						0.112					

The maximum N, P, and K of sewage irrigated soils at 0-15 and 15-30 cm was observed at Ganjia followed by Arail whereas the minimum value was observed at Dandi (Tables 5-7). The mean N, P, and K kg ha^{-1} of sewage irrigated soils were found to decrease abruptly with the increase in soil depth. This fact can be associated with the presence of Gangia closer to the discharge point with high concentrations of nitrogen, phosphorus, and potassium; therefore, it brings a significant increase in the available N, P, and K of soils as well. Similar findings have been reported by Mitra and Gupta (1999), Yadav *et al.* (2002), Malla and Totawat (2006), Rojas-Valencia *et al.* (2011), and Xue *et al.* (2012).

Table 5. Available nitrogen (kg ha^{-1}) in soils of different sites at different depths (cm)

		0-15 cm						15-30 cm					
Soil samples		S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
Site-T (Ganjia)		360.00	350.30	328.60	338.30	320.00	339.40	352.60	348.60	320.00	330.60	311.60	332.70
Site-II (Arail)		305.00	280.00	276.66	275.00	278.33	283.00	296.60	273.33	272.30	270.00	272.30	276.90
Site-III (Dandi)		259.60	252.40	260.30	251.56	249.50	254.60	250.40	248.00	256.00	250.00	242.30	249.30
Mean		308.20	294.20	288.50	288.30	282.60		299.10	290.00	282.70	283.50	275.40	
p<0.05	Soil samples	NS						NS					
	Sites	11.47						13.45					

Table 6. Available phosphorus (kg ha^{-1}) in soils of different sites at different depths (cm)

		0-15 cm						15-30 cm					
Soil samples		S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S5	Mean
Site-I (Ganjia)		36.50	34.03	32.61	31.62	32.00	33.35	35.10	32.43	31.03	30.60	30.40	31.91
Site-II (Arail)		28.92	29.03	30.10	27.80	28.15	28.80	27.03	26.13	29.10	24.63	27.14	26.81
Site-III (Dandi)		23.56	24.83	25.47	24.03	24.11	24.40	22.51	22.61	23.10	22.43	22.23	22.58
Mean		29.66	29.30	29.39	27.82	28.09		28.21	27.06	27.74	25.89	26.59	
p<0.05	Soil samples	NS						NS					
	Sites	1.66						1.86					

Table 7. Available potassium (kg ha^{-1}) in soils of different sites at different depths (cm)

		0-15 cm						15-30 cm					
Soil samples		S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
Site-I (Ganjia)		269.00	258.66	249.00	251.33	248.63	255.32	266.66	254.66	243.00	232.66	236.03	246.60
Site-II (Arail)		241.43	239.33	242.61	238.13	239.40	240.18	238.11	229.43	230.13	228.03	229.56	231.05
Site-III (Dandi)		220.10	219.56	215.43	219.96	212.63	217.54	214.61	210.63	209.96	212.90	210.03	211.63
Mean		243.51	239.18	235.68	236.47	233.55		239.79	231.57	227.70	224.53	225.21	
p<0.05	Soil samples	NS						NS					
	Sites	6.24						9.26					

The maximum concentration of micronutrients i.e., Mn^{2+}, Zn^{2+}, and Fe^{2+} (mg kg^{-1}) of sewage water irrigated soils at 0-15 and 15-30 was recorded in Ganjia whereas, minimum content was observed at Dandi as shown in Tables 8, 9 and 10. Mean value of Mn^{2+}, Zn^{2+} and Fe^{2+} (mg kg^{-1}) recorded at Ganjia at 0-15 cm and 15-30 cm depth was found to be 31.97 and 30.79 mg kg^{-1}, 114.47 and 111.96 mg kg^{-1} and 96.93 and 96.49 mg kg^{-1}, whereas, Mn^{2+}, Zn^{2+} and Fe^{2+} (mg kg^{-1}) recorded at Arail at 0-15 and 15-30 cm depth was 26.24 and 25.83 mg kg^{-1}, 96.72 and 96.01 mg kg^{-1} and 85.78 and 85.13 mg kg^{-1}. The minimum concentration of Mn^{2+}, Zn^{2+}, and Fe^{2+} (mg kg^{-1}) recorded at Dandi at 0-15 and 15-30 cm depth was 22.67 and 21.74 mg kg^{-1}, 93.47 and 93.02 mg kg^{-1} and 79.06 and 77.60 mg kg^{-1}, respectively. The maximum concentration of Mn^{2+}, Zn^{2+} and Fe^{2+} in soils of Ganjia may be due to the continuous use of sewage water for irrigation purposes during the long periods and also due to its near location to the sewage discharge point. The sewage water contains an appreciably high amount of Mn^{2+}, Zn^{2+}, and Fe^{2+} and gradually decreases with the increase with distance from the discharge point. These findings are in accordance with the findings reported by Singh and Singh (1994), and Saraswat *et al.* (2005).

Table 8. Manganese (mg kg^{-1}) in soils different sites at different depths (cm)

		0-15 cm						15-30 cm					
Soil samples		S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
Site-I (Ganjia)		31.96	30.56	33.66	31.76	31.90	31.97	30.50	29.66	33.10	30.23	30.46	30.79
Site-II (Arail)		29.13	27.66	26.06	25.30	23.06	26.24	28.56	27.30	25.70	24.83	22.76	25.83
Site-III (Dandi)		24.60	23.46	22.53	21.83	20.93	22.67	23.00	22.73	21.93	21.20	19.86	21.74
Mean		28.56	27.23	27.42	26.30	25.30		27.35	26.56	26.91	25.42	24.36	
p<0.05	Soil samples	NS						NS					
	Sites	1.87						1.84					

Table 9. Zinc (mg kg^{-1}) in soils different sites at different depths (cm)

		0-15 cm						15-30 cm					
Soil samples		S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
Site-I (Ganjia)		114.70	118.23	114.20	110.00	115.23	114.47	110.36	116.76	113.20	109.23	110.26	111.96
Site-II (Arail)		99.40	98.50	96.60	95.33	93.76	96.72	98.93	97.03	95.96	94.90	93.23	96.01
Site-III (Dandi)		95.23	94.23	93.36	92.66	91.86	93.47	94.86	93.63	93.10	92.20	91.33	93.02
Mean		103.11	103.65	101.39	99.33	100.28		101.38	102.47	100.75	98.78	98.27	
p<0.05	Soil samples	NS						NS					
	Sites	2.20						2.35					

Table 10. Iron (mg kg^{-1}) in soils of different sites at different depths (cm)

		0-15 cm						15-30 cm					
Soil samples		S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
Site-I (Ganjia)		98.63	95.90	96.90	97.00	96.20	96.93	97.23	96.26	96.53	96.63	95.80	96.49
Site-II (Arail)		88.40	86.73	85.66	84.60	83.53	85.78	88.06	85.26	85.26	84.10	82.96	85.13
Site-III (Dandi)		86.63	81.66	77.30	75.50	74.20	79.06	84.80	80.06	75.83	74.20	73.10	77.60
Mean		91.22	88.10	86.62	85.70	84.64		90.03	87.19	85.87	84.98	83.95	
p<0.05	Soil samples	NS						NS					
	Sites	3.08						3.01					

The concentration of Fe, Mn, and Zn were not affected under short-term wastewater irrigation in the soil. The selected metals maintained the order of Zn-Fe-Mn for wastewater irrigation in the soil in the study area. In the wastewater irrigated soil, Zn and Fe were found in high concentration, while Mn had low value in comparison with soil irrigated with groundwater. The normal concentration range of these metals in soils is as follows: Fe 30-500 mg kg^{-1}, Mn 300-1000 mg kg^{-1}, and Zn 10-300 mg kg^{-1} (Blum *et al.*, 2012; Ozturk *et al.*, 2015, 2017). In the light of these evaluations, Fe and Zn are found within the permissible ranges, while Mn is below normal values in the wastewater irrigated soil in the study area.

The mean percentage values for N, P and K recorded in carrot, radish, spinach, cauliflower, and potato showed the highest value in potato and the lowest in carrot. The vegetables grown in Ganjia soils showed the highest content of N, P and K followed by Arail and Dandi. The mean N content of carrot, radish, spinach, cauliflower, and potato was 4.03, 4.43, 4.56, 4.40 and 4.96 percent at Ganjia, 3.16, 3.83, 3.96, 3.73 and 4.13 percent at Arail, and 2.90, 2.53, 3.46, 3.07 and 3.56 percent, respectively at Dandi. Phosphorus content recorded in carrot, radish, spinach, cauliflower and potato was 0.31, 0.55, 0.73, 0.51 and 0.83 per cent at Ganjia, 0.24, 0.40, 0.61, 0.37 and 0.67 per cent at Arail, and 0.22, 0.32, 0.51, 0.30 and 0.55 per cent, respectively at Dandi. A similar trend was observed with percentage potassium with 3.10, 3.33, 3.80, 3.10 and 4.33 percent recorded at Ganjia, 2.50, 2.70, 3.20, 2.53 and 3.76 percent at Arail, and 2.03, 2.20, 2.70, 2.03 and 3.03 percent at Dandi in carrot, radish, spinach, cauliflower, and potato, respectively (Table 11).

Table 11. Percentage of macronutrient content in the vegetables from different sites

Sites		Carrot	Radish	Spinach	Cauliflower	Potato	Mean
Nitrogen							
Site-I (Ganjia)		4.03	4.43	4.56	4.40	4.96	4.48
Site-II (Arail)		3.16	3.83	3.96	3.73	4.13	3.76
Site-III (Dandi)		2.90	2.53	3.46	3.07	3.56	3.10
Mean		3.36	3.60	3.99	3.73	4.22	
$p<0.05$	Vegetables sites	0.28 0.28					
Phosphorus							
Site-I (Ganjia)		0.31	0.55	0.73	0.51	0.83	0.59
Site-II (Arail)		0.24	0.40	0.61.	0.37	0.67	0.46
Site-III (Dandi)		0.22	0.32	0.51	0.30	0.55	0.38
Mean		0.26	0.42	0.62	0.39	0.68	
$p<0.05$	Vegetables sites	0.05 0.05					
Potassium							
Site-I (Ganjia)		3.10	3.33	3.80	3.10	4.33	3.53
Site-II (Arail)		2.50	2.70	3.20	2.53	3.76	2.94
Site-III (Dandi)		2.03	2.20	2.70	2.03	3.03	2.40
Mean		2.54	2.74	3.23	2.55	3.71	
$p<0.05$	Vegetables sites	0.08 0.08					

The normal limits for NPK in the plants are reported to lie in the range of 4-5 percent for N, 0.30-0.70 percent for P, and 3.00-4.50 percent for K (Jones *et al.*, 1991). An assessment made in terms of N has revealed that for potatoes the range of values is normal, while in all other vegetables, N values are below normal. In the case of P, only carrot shows values below the normal level, while all other vegetables are within the normal range. When an assessment for K is made the values for spinach and potato are at a normal level, but all other vegetables show values below the normal levels.

An overall assessment of our findings points to the fact that this may be due to the fact that soils at Ganjia receive continuous sewage water for irrigation for longer durations and are located next to the sewage discharge point followed Arail and Dandi. As sewage water contains higher amount of N, P, K, and other nutrients, it brings a significant increase in the percentages of N, P, and K in vegetable crops. Similar findings have been reported by Mitra and Gupta (1999), and Reddy *et al.* (1998).

Sewage waters have significant effect on vegetables like carrot, radish, spinach, cauliflower and potato grown at different sites. The mean values for Mn^{2+} (mg kg^{-1}) are in the following order; spinach > carrot > radish > cauliflower > potato; for Zn^{2+} (mg kg^{-1}) as spinach > radish > carrot > potato > cauliflower; and for Fe^{2+} (mg kg^{-1}) as carrot > spinach > radish > potato > cauliflower in all three sites. The mean Mn^{2+} content of carrot, radish, spinach, cauliflower and potato was 25.76, 23.70, 32.40, 18.80 and 15.10 mg kg^{-1} at Ganjia, 18.36, 16.96, 28.26, 12.83 and 13.00 mg kg^{-1} at Arail, and 11.23, 10.16, 20.43, 9.63 and 8.66 mg kg^{-1}, respectively at Dandi. Zn^{2+} concentration recorded in carrot, radish, spinach, cauliflower and potato was 249.40, 282.30, 296.80, 179.30 and 170.03 mg kg^{-1} at Ganjia, 210.76, 230.33, 251.08, 120.30 and 141.33 mg kg^{-1} at Arail, and 185.33, 200.70, 220.90, 105.70 and 100.13 mg kg^{-1} at Dandi, respectively. The mean value of

Fe^{2+} observed in carrot, radish, spinach, cauliflower and potato was 316.20, 221.03, 213.80, 153.30 and 140.63 mg kg^{-1} at Ganjia, 299.36, 180.80, 151.30, 110.46 and 114.70 mg kg^{-1} at Arail, and 249.90, 110.23, 100.50, 70.30 and 81.20 mg kg^{-1} at Dandi, respectively (Table 12).

Table 12. Micronutrient content (mg kg^{-1}) in the vegetables cultivated at different sites

Sites		Carrot	Radish	Spinach	Cauliflower	Potato	Mean
Manganese							
Site-I (Ganjia)		25.36	23.70	32.40	18.80	15.10	23.07
Site-II (Arail)		18.36	16.96	28.26	12.83	13.00	17.88
Site-III (Dandi)		11.23	10.16	20.43	9.63	8.66	12.02
Mean		18.32	16.94	27.03	13.75	12.25	
p<0.05	Vegetables	2.30					
	Sites	2.30					
Zinc							
Site-I (Ganjia)		249.90	282.30	296.80	179.30	170.03	235.67
Site-II (Arail)		210.76	230.33	251.08	120.30	141.33	190.76
Site-III (Dandi)		185.33	200.70	220.90	105.70	100.13	162.55
Mean		215.33	237.78	256.26	135.10	137.16	
p<0.05	Vegetables	8.78					
	Sites	8.78					
Iron							
Site-I (Ganjia)		316.20	221.03	213.80	153.30	140.63	208.99
Site-II (Arail)		299.36	180.80	151.30	110.46	114.70	171.32
Site-III (Dandi)		249.90	110.23	100.50	70.30	81.20	102.43
Mean		288.49	137.35	155.20	111.35	112.18	
p<0.05	Vegetables	17.90					
	Sites	17.90					

Generally, crop plants make use of many essential nutrients and trace elements in a short time, therefore, the safety of vegetables is a concern for human health and it has attracted more attention (Khan *et al.*, 2015). Some of the vegetables, such as spinach, radish, and carrot can easily take up heavy metals like copper, cadmium, lead, zinc and manganese in their tissue. Their uptake by plants generally increases when they are grown on contaminated soils (Yang *et al.*, 2011; Khan *et al.*, 2015). The normal limits for manganese and zinc concentrations in plants are reported to lie in the range of 20-400 ppm and 20-100 ppm respectively (Blum *et al.*, 2012). According to Ozturk *et al.* (2015, 2017), the normal limits of iron should be 220-1200 ppm. In the light of these reports, manganese is found within the permissible ranges in spinach, while in all other vegetables the values are below the normal ones in our samples. Iron has been found within the permissible ranges in carrot, but in all other vegetables, the values are below the normal level. The zinc has been found far above the normal values in all vegetables.

The maximum accumulation of Mn^{2+}, Zn^{2+}, and Fe^{2+} in vegetables of Ganjia may be due to the fact that it receives continuous sewage water for irrigation and is also located near to the sewage discharge point followed by Arail and Dandi. As sewage water contains a higher amount of micronutrients it brings a significant increase in Mn^{2+}, Zn^{2+}, and Fe^{2+} in the vegetables grown. Similar findings have also been reported by Lone *et al.* (2003), Saraswat *et al.* (2005), and Gupta *et al.* (2008). Sewage-amended plants usually result in elevated micronutrient levels, these may accumulate such nutrients to a degree that would be toxic to living beings. Patel *et al.* (2004)

have also confirmed that different vegetable crops accumulate invariably high amounts of micronutrients irrespective of the type of effluents/water used for irrigation indicating variable uptake as a function of crop species, cultivar, and selectivity for different elements.

A significant part of the wastewater is already used for crop production in response to the limited availability of fresh water for agriculture by the majority of urban farmers in India, who use wastewater rich in heavy metals like cadmium, chromium, iron, nickel, manganese, lead and zinc (Kumar *et al.*, 2015). In view of this, increasing volumes of wastewater will become the major source of additional irrigation water supplies for farming in water-scarce countries like India (Parashar and Prasad, 2013; Kumar *et al.*, 2015).

Conclusions

Our studies have revealed that the soils of Ganjia showed the highest value of EC, organic carbon, available NPK, and micronutrients (Mn^{2+}, Zn^{2+}, and Fe^{2+}); whereas, the soils of Dandi contained lower concentrations of available nutrients. The vegetables grown on the soils of Ganjia showed higher NPK content and micronutrients (Mn^{2+}, Zn^{2+}, and Fe^{2+}). Among the vegetables analysed during this study, the potato showed the highest NPK, whereas spinach had higher levels of manganese and zinc. The highest values of iron were recorded in the carrots. In general, the sewage water used for irrigation had a positive impact on nutrient status in soils and vegetable crops. However, it may increase the concentration of toxic metals if used continuously without being subjected to a pre-treatment.

Authors' Contributions

Conceptualization: SH, RB and RAB; Investigation: SH, RB, RAB, AAB and MAD; Methodology: SH, RB and RAB; Formal analysis: SH, RB and RAB; Writing-original draft: SH, RB, RAB, MO, VA and KRH; and Writing-review and editing: MO and VA. All authors read and approved the final manuscript.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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