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Long term effect of sewage water irrigation on soil chemical properties and heavy metals contents in soil of peri urban areas of Nagpur district

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Abstract
The present investigation in relation to "Long term effect of sewage water irrigation on chemical properties and heavy metals contents of soil in peri urban areas of Nagpur district." The field experiment was carried out in farmers field of Narsara, Bahadura and Vihirgaon villages of Nagpur district which are in the close vicinity of Nag river during 2022-2023. The sewage water irrigated through direct pipeline showed slightly lower soil reaction (pH 6.95) with higher EC (0.85 dS m^{-1}) and high organic carbon (8.5 g kg^{-1}) content. The available N, P, K status of sewage water irrigated soils through direct pipeline was appreciably higher as compared to other treatments. The concentration of micronutrients *viz*. Fe, Mn, Zn, Cu and heavy metals like Cd, Cr, Pb and Co were found comparatively higher in sewage water irrigated soils applied through direct pipeline. The concentration of these elements was observed to be greater than their critical concentration and lead to soil contamination.

Keywords: Sewage water, micronutrients and heavy metals contamination

Introduction
Sewage water is a household and industrial wastewater known as grey water or black water. The raw sewage water contains both beneficial as well as toxic metals. Sewage water mainly composed of more than 95 per cent water, pathogen, organic particles, soluble organic materials etc. Sewage water and industrial waters are rich sources of beneficial and harmful elements. Most of the untreated as well as contaminated sewage water and industrial wastewater may have higher concentrations of heavy metals like Cd, Pb, Ni and Cr. Their continuous accumulation in soils has resulted the soil sickness and deposition of some toxic metals in agricultural soil (Kharche *et al.*, 2011) [10] which may cause serious animal and human health hazard. Wastewater from municipal sewage treatment plants often contains higher levels of nutrients, particularly N and P which are essential to plant growth. Agricultural use of sewage water provides water and nutrients for vegetables production and the nutrient rich wastewater could gradually reduce the use of chemical fertilizers (Chambers *et al.*, 2002) [3].

Materials and Methods
The study was conducted in Nagpur district of Maharashtra (India) during the years 202223 to study the properties of sewage water, to assess the chemical properties of soils and to evaluate the contamination of heavy metals. The field survey was undertaken in three selected villages of the Nagpur district *viz.*, Narsara, Bahadura and Vihirgaon, where sewage water being used to irrigate fields since 25-30 years and accordingly five farmers are selected. Total twenty soil and twenty water samples were collected as per the treatment details. The experiment was conducted in Randomized Block Design with four treatments each were replicated five times. The treatment consists of T1 (Sewage water irrigation through drain with natural vegetative barrier 0200 m distance from source), T_2 (Sewage water irrigation through drain with natural vegetative barrier 200-400 m distance from source), T_3 (Sewage water irrigation through direct pipeline), T_4 (Well water irrigation in the vicinity of Nag River).

The result was analysed and interpreted in accordance with the methods outlined in Statistical Methods for Agricultural Workers by Gomez and Gomez (1984) [7].

Water samples were collected as per the treatments. All samples were collected in sterilized one-liter polythene bottle. The sample bottles were labelled carefully as per the location of each village and brought to the laboratory and filtered through Whatman's filter paper No. 1. Immediately pH and EC of water samples were determined. Then water samples were acidified with 2 ml of 10% nitric acid and stored in polythene bottles for further analysis. Then samples were further analyzed for different water parameters *viz.* CO_3^{2-} HCO_3^-, Cl^-, SO_4^{2-}, Mg^{2+}, Na^+, K^+, micronutrients (Fe, Mn, Cu and Zn) and heavy metals (Cd, Cr, Pb and Co). The chemical properties *viz.*, pH was determined using a glass electrode (Electrometric Method) pH meter, EC were determined by using conductivity meter, Carbonate and Bicarbonate was determined by titrating against standard sulphuric acid (H_2SO_4), Chloride was determined by titrating with standard silver nitrate, Sodium and potassium were determined directly by flame photometer method, Calcium and Magnesium were determined directly by Versenate titration method Micronutrients and heavy metals were analyzed on atomic absorption spectrophotometer as given by (APHA, 1975) [1].

Soil samples were collected as per treatment at the depth of 0-20 cm using auger and placed in labelled plastic bags as per the location of each village. The chemical properties *viz.*, pH was determined in 1:2.5 soil water suspension with the help of glass electrode using pH meter (Jackson, 1973) [9], Electrical conductivity (EC) of the soil was determined in 1:2.5 soil water suspension using conductivity bridge (Jackson, 1973) [9], Organic carbon was estimated by Walkley and Black's (1934) [18] Wet Oxidation method and. Nitrogen content was determined as alkaline permagnate method described by Subbiah and Asija (1956) [16], While phosphorus was estimated by using Olsen's method reagent (Olsen and Sommer 1982) [14] and potassium was extracted by 1N ammonium acetate of pH 7.0 and determined by using flame photometer as described by Jackson (1973) [9] and sulphur determined by turbidity method given by Chesnin and Yien (1951) [4]. DTPA (0.005 M) Extractable Fe, Mn, Zn, Cu, Cd, Cr, Pb and Co was determined as the procedure outlined by Lindsay and Norwell (1978) [11] using atomic absorption spectrophotometer.

Table 1: Characteristics of sewage water (me L^{-1})

Treatments	pH	EC	CO_3-	HCO3-	Cl-	SO_4-	Ca2+	Mg2+	Na+	K+
T_1 : Sewage irrigation through drain with natural vegetative barrier (0-200 m distance from source)	7.10	0.89	0.30	2.90	5.80	5.15	3.36	1.26	3.49	0.52
T_2 : Sewage irrigation through drain with natural vegetative barrier (200-400 m distance from source)	7.25	0.85	0.26	2.59	5.13	4.20	3.35	1.19	3.16	0.31
T_3 : Sewage water irrigation through direct pipeline	6.83	0.98	0.34	3.15	6.27	5.99	3.95	1.58	3.61	0.63
T_4 : Well water irrigation in the vicinity of Nag river	7.52	0.54	0.22	2.84	4.57	2.78	3.16	1.12	1.35	0.15
SE (m) ±	0.038	0.013	0.010	0.012	0.017	0.017	0.010	0.014	0.021	0.012
CD at 5%	0.114	0.040	0.030	0.038	0.05	0.054	0.030	0.042	0.060	0.036
Safe limits (FAO, 1985)	<8.5	<3	<1.00	<1.50	<4.00	<5.00	<6.00	<4.50	<3.00	<1.00

Table 2: Characteristics of sewage water (mg L^{-1})

Treatments	Fe	Mn	Zn	Cu	Cd	Cr	Pb	Co
T_1 : Sewage irrigation through drain with natural vegetative barrier (0-200 m distance from source)	1.87	0.33	0.84	0.28	0.022	0.16	0.021	0.058
T_2 : Sewage irrigation through drain with natural vegetative barrier (200-400 m distance from source)	1.47	0.28	0.41	0.21	0.017	0.11	0.016	0.054
T_3 : Sewage water irrigation through direct pipeline	2.42	0.41	1.31	0.35	0.026	0.21	0.024	0.061
T_4 : Well water irrigation in the vicinity of Nag river	1.24	0.22	0.30	0.15	0.012	0.08	0.007	0.030
SE (m) ±	0.020	0.013	0.010	0.010	0.001	0.007	0.001	0.001
CD at 5%	0.060	0.041	0.030	0.032	0.003	0.021	0.003	0.003
Safe limits (FAO, 1985)	<5.00	<0.20	<2.00	<0.20	<0.01	<0.10	0.02	<0.05

Table 3: Effect of sewage water irrigation on chemical properties of soil.

Treatments	pH	EC (dS m^{-1})	OC (g kg^{-1})	Avail N (kg ha^{-1})	Avail P (kg ha^{-1})	Avail K (kg ha^{-1})	Avail S (kg ha^{-1})
T_1 : Sewage irrigation through drain with natural vegetative barrier (0-200 m distance from source)	7.05	0.77	7.6	312.4	19.56	354.4	24.43
T_2 : Sewage irrigation through drain with natural vegetative barrier (200-400 m distance from source)	7.27	0.69	6.4	265.5	17.98	339.9	22.26
T_3 : Sewage water irrigation through direct pipeline	6.95	0.85	8.5	342.4	20.58	362.4	26.40
T_4 : Well water irrigation in the vicinity of Nag river	7.36	0.48	5.1	243.3	16.41	327.0	19.33
SE (m) ±	0.032	0.016	0.030	3.57	0.35	2.43	0.29
CD at 5%	0.090	0.050	0.089	11.0	0.92	7.47	0.89

Table 4: Effect of sewage water irrigation on micronutrients heavy metals contents in soil (mg kg^{-1})

Treatments	Fe	Mn	Zn	Cu	Cd	Cr	Pb	Co
T_1 : Sewage irrigation through drain with natural vegetative barrier (0200 m distance from source)	8.34	7.19	0.67	1.17	0.27	0.22	1.7	1.12
T_2 : Sewage irrigation through drain with natural vegetative barrier (200-400 m distance from source)	7.28	6.66	0.65	1.06	0.16	0.15	1.5	1.07
T_3 : Sewage water irrigation through direct pipeline	9.22	9.01	0.73	1.21	0.39	0.28	1.8	1.17
T_4 : Well water irrigation in the vicinity of Nag river	6.33	5.85	0.51	1.00	0.08	0.09	1.17	1.02

SE (m) ±	0.020	0.012	0.023	0.016	0.02	0.010	0.02	0.01
CD at 5%	0.060	0.038	0.070	0.034	0.05	0.030	0.061	0.03
limits	<4.5*	<2.0*	<0.6*	<0.2*	<0.10**	<0.05**	<1.00**	<0.5**

*Critical limits: AICRP on micronutrients, PDKV

** Safe limits: FAO. 1985

Results and Discussion

Characteristics of sewage water

Data regarding characteristics of sewage water are presented in Table 1 and Table 2.

The pH of sewage water was slightly lower than well water and was found neutral to slightly alkaline in reaction (6.83-7.52). Electrical conductivity was higher in sewage water through direct pipeline (0.98 dS m^{-1}) and lower in well water (0.54 dS m^{-1}). Similar result were also reported by (kharche *et al.*, 2011) [10]. All the treatments indicating that they were within the safe limits given by FAO, 1985. The cations and anions $Ca^{2+,}$ Mg^{2+}, Na^{+}, K^{+}, CO_3-, HCO_3- SO_4^{2-} and Cl^{-} content in sewage water found significantly higher with sewage water irrigation through direct pipeline i.e. 3.95, 1.58, 3.61, 0.63, 0.34, 3.15, 5.99 and 6.27 me L^{-1} respectively, similar observations were also obtained by (Singh *et al.*, 2012 and Mhaske *et al.*, 2021) [15, 13] Concentration of micronutrients mainly Fe, Mn, Zn and Cu in sewage water were found significantly superior in sewage water irrigation through direct pipeline i.e. 2.42, 0.41, 1.31 0.35 mg L^{-1} all the micronutrients found within the safe limit given by FAO, 1985 except manganese. (Singh *et al.*, 2012) [15] reported similar results. Sewage water irrigation through direct pipeline has significantly higher heavy metals contents i.e. Cd, Cr, Pb and Co in the range of 0.026, 0.21, 0.024 and 0.061 mg L^{-1} respectively. Similar results also given by (Kharche *et al.*, 2011 and Mhaske *et al.*, 2021) [10, 13].

Effect of sewage water irrigation on chemical properties of soil

The chemical properties of soil are as influenced by application of sewage water presented in Table 3 and Table 4. Data revealed that pH was found higher (7.36) in well water than sewage water irrigated soil (6.83-7.27) it might be due to acidic components present in sewage water. EC (0.85 dS m^{-1}) of soil irrigated with sewage water was significantly higher, indicating dissolution of soluble salts this results are conformity with the (kharche *et al.*, 2011 and Gurjar *et al.*, 2017) [10, 8]. Organic carbon significantly highest (8.5 mg kg^{-1}) in sewage water irrigation through direct pipeline. It might be due to addition of suspended organic matter through hydraulic loading directly from drain in application of long term. The findings are in conformity with the earlier studies by (Masto *et al.*, 2009 and Mhaske *et al.*, 2021) [12, 13] reported that soil irrigated with sewage water had high organic carbon. The available nitrogen, phosphorus, potassium and sulphur were significantly higher in sewage water irrigation applied through direct pipeline i.e. 342.4, 20.58, 362.4 and 26.40 kg ha^{-1} respectively. Aswal *et al.* (2022) [2] also reported that sewage water increases the soil available major nutrients than well water this might be attributed to the addition of organic matter through sewage water irrigation.

The concentrations of micronutrients *Viz.* Fe, Zn, Mn and Cu in sewage water irrigated soil found significantly higher i.e. 9.22, 9.01, 0.73 and 1.21 mg kg^{-1} respectively. Similarly, heavy metals i.e. Cd, Cr, Pb and Co in sewage water irrigated soil were found significantly higher 0.39, 0.28, 1.8 and 1.17 respectively, all treatments were found above the safe limits given by FAO, 1985 [5]. Similar results were obtained by (Taywade and prasad 2008 and Mhaske *et al.*, 2021) [17, 13].

Conclusion

An application of sewage water for irrigation increases the soil fertility but, it also increased the heavy metals content in soil. More concentrations of bicarbonates, chlorides, sodium, potassium, and heavy metals like Cd, Cr, Pb, and Co in sewage water were responsible for contamination of soil. The long-term use of sewage water for irrigating agricultural crops was beneficial in improving soil properties *viz.*, organic carbon, available N, P, and K status, and can help to partially reduce the expenditure on fertilizers but contaminates the soil and crop by adding heavy metals.

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