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IMPACT OF SEWAGE WATER IRRIGATION ON BLACK SOIL

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ABSTRACT

The sewage irrigated soil and plant samples were collected from farmers' field in village Ghusar near Akola city. The sewage water was alkaline in reaction (pH 8.25 -7.91) with high EC *i.e.* 2.60-2.85 dSm^{-1},COD was 840 and 820 mgL^{-1}, BOD was 160 and 180 mg L^{-1} and TDS was 1664 and 1824 mg L^{-1} which was higher than the permissible limit. The concentration of calcium was 280 and 320 mg L^{-1}, Mg^{2+} (96 and 72 mg L^{-1}), Na^{+} (230 and 322 mg L^{-1}), K (54.99 and 39 mg L^{-1}), HCO_3^-(976 and 1280 mg L^{-1}),Cl^-(140 and 280 mg L^{-1}),NH_4-N (27.7 and 66.8 mg L^{-1}) and NO_3-N (5.6 and 8.6 mg L^{-1}) during year 2011 and 2012, respectively which exceeds permissible limit. The concentration of Fe (2.12 and2.66 mg L^{-1})Mn(1.22 and 2.94 mg L^{-1}),Zn (2.24 and 7.88 mg L^{-1}), Cu (0.44 and 0.56mg L^{-1}) and B (4.0 and 6.2 mg L^{-1}) was higher than critical limit whereas concentration of Cd (0.15 and 0.12 mg L^{-1}),Cr(0.20 and 0.30 mg L^{-1}),Pb (3.6 and 1.6 mg L^{-1}) and Co (0.38 and 0.51 mg L^{-1}) was higher during the year 2011 and 2012 respectively. The bulk density of sewage irrigated soil was 1.28 and 1.2 Mg m^{-3} during year 2011 and2012, respectively. The B.D. of sewage free soil was 1.30 Mg m^{-3} which was higher than sewage irrigated soils while hydraulic conductivity and aggregate stability was increased as compared to sewage free soil. The sewage treated soil was alkaline in reaction with increasing trend of EC than sewage free soil. This soil contains more organic carbon, available N,P and K than sewage free soil. The concentration of Fe,Mn,Zn,Cu,B and Mo was considerably higher in sewage irrigated soil than normal soil which may reach the maximum permissible limit in future. The concentration of Cd, Cr, Pb and Co was more in this soil which indicates future toxicity of these elements. The soil microbial count of bacteria,fungi and actinomycetes was higher than the sewage free soil. The long-term use of sewage water for irrigation was found beneficial in improving soil physical properties like bulk density, aggregate stability, hydraulic conductivity, organic carbon, macro and micro nutrients status of soil but the higher concentration of heavy metal become phytotoxic and enter the food chain suggesting the use of sewage water in agriculture with caution.

(Key words: Sewage, TDS, actinomycetes, bacteria, BOD, fungi)

INTRODUCTION

The share of fresh water available for agriculture is estimated to decrease in India from present level of 85 per cent to 74 per cent in 2025 due to increasing demand for water from other user sectors.

Since resources are limited and large gap exists between available water supply and amount required. Appropriate use of waste water of domestic origin can help in meeting a part of increased demand of water for crop production. Industrial and domestic effluents with solid and liquid sewage components are being used partially for irrigation which contains higher concentration of trace metals.

The city sewage water is being largely used for irrigation in the adjoining village Ghusar, near Akola is being largely used for irrigation.

The present investigation will give the fair idea about the distribution pattern of nutrients and heavy metals in soil as well as in plants and also its impact on soil physical and chemical properties.

MATERIALS AND METHODS

The study was undertaken at farmer's field at village Ghusar, Dist.Akola. The soil samples were collected from the farmer's field at Ghusar village where the sewage water was continuously used for irrigating the crops. The sewage water samples were also collected during January – February. 2012 and analyzed for important characteristics. pH of water samples was measured by using glass electrode pH meter (Jackson, 1973).EC of water sample was measured by using ELICO Conductivity Bridge as given by Jackson (1973). Total Dissolved Solids (TDS) were estimated by gravimetric method, TDS (mg L^-) = ECw (dSm^{-1}) x 640. The Calcium and Magnesium were determined by Versenate titration method as given by Richards (1954).Sodium and potassium were determined by flame photometer as

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described by Page *et al.* (1989).The carbonates and bicarbonates were determined by rapid titration method as outlined by Richards (1954).Chlorides were determined by titration with standard $AgNO_3$ as described by Richards (1954).Sulphates were determined by Turbedimetric method as outlined by (Jackson, 1973).In the water nitrate nitrogen was obtained by reducing Devardas alloy followed by distillation. Phosphorus were determined by Calorimetric (ammonium molybdate - ascorbic acid) method.DTPA extractable micronutrients (Zn, Fe, Mn, Cu) were determined by using AAS (Atomic absorption spectrophotometer) by Lindsay and Norvell (1978).The standard methods suggested for sewage water analysis as per APHA (1985) have been used.

RESULTS AND DISCUSSION

A- Characteristics of Sewage Water :

pH

The pH of sewage water was 8.25 and 7.91 in the year 2011 and 2012, respectively which was slightly higher than the safe limit which might be due to the dissolved salts in sewage (Table 1). Maiti *et al.*(1992) also reported the similar results, who reported that continuous application of sewage effluents makes the soil alkaline and increase in salt content.

Electrical conductivity

The electrical conductivity of sewage water was 2.60 dSm^{-1} in the year 2011 and increased upto 2.85 dSm^{-1}after one year,which was higher than the recommended water quality guidelines for waste water use in agriculture i.e. <0.7 dSm^{-1}. The higher EC of sewage water indicates the chances of development of salinity under continuous utilization of sewage water for irrigation (Reddy and Rao,2000).

Biochemical Oxygen Demand(BOD)

BOD of sewage water was 160 and 180 mg L^{-1}in the year 2011 and 2012, respectively which was more than the permissible limit of 100 mg L^{-1}. This might be due to the presence of higher suspended organic solids in effluents. These results are in accordance with the findings of Chandrashekharan and Rajkannan (2003) and Deshmukh and Urkude (2014) where they reported the BOD in between 30-80 mg L^{-1}.

Chemical Oxygen Demand (COD)

COD of sewage water was 840 mgL^{-1} in 2011 and 820 mg L^{-1} in 2012, which might be due to the enrichment of sewage with domestic and industrial waste. Adhikari *et al.*,1997 reported that the COD of sewage water varied from 14-18 mg L^{-1}

Total Dissolved Solids

The TDS in sewage water (i.e. 1664 and 1824 mgL^{-1} during 2011 and 2012 respectively) was higher than the permissible limit of 400 (450)mg L^{-1}as per Anonymous,1985 and recommended not to use for irrigation, indicating very high total dissolved solids due to domestic use of detergents.

Cations

The concentration of calcium was 280 mg L^{-1}(2011) and 320 mg L^{-1}(2012). The concentration of magnesium was 96 mg L^{-1}(2011) and 72 mg L^{-1}(2012) which was higher than the recommended guidelines i.e. 60 mg L^{-1}. The sodium concentration was also high in sewage water i.e. 230 and 322 mg L^{-1} during the year 2011and 2012, respectively which exceeds the permissible limit of 69 mg L^{-1}.This might be due to the higher concentration of detergents in domestic sewage. The potassium concentration was 54.99 and 39 mg L^{-1} during 2011 and 2012 respectively, (Tiwari *et al.*, 2003) where they recorded the concentration of Ca^{2+} was ranged 2.5-13, Mg^{2+} 0.6-8.0,Na^{+}5.4-34.2 and K^{+} was 0.03-0.66 mgL^{-1}.

Anions

The concentration of sulphate in sewage water was 268.8 (2011) and 331(2012) mg L^{-1}. The bicarbonate concentration was 976 mgL^{-1} (2011) and 1281 mg L^{-1} (2012) which was higher than the maximum recommended concentration of 91.5 mgL^{-1}. The chloride content in sewage water was higher than the permissible limit of 140 mg L^{-1} and recorded 140 and 280 mg L^{-1} during year 2011 and 2012, respectively. This might be due to the contamination of domestic and city waste (Renukaprasanna *et al.*, 2002).

Ammonical and nitrate nitrogen

The Ammoniacal nitrogen was 57.7 and 66.8 mgL^{-1} in 2011 and 2012, respectively which was higher than the maximum limit of 50 mg L^{-1} and the nitrate nitrogen was 5.6 and 8.6 mg L^{-1} during 2011 and 2012, respectively which exceeds the safe limit of 5 mg L^{-1}. This was due to high COD and BOD containing considerable amount of suspended solid which undergo decomposition anaerobically resulting in more accumulation of NH_4^+-N than NO_3—N. These results are in conformity with the findings of Dash (2010), who reported that the sewage is a rich source of nitrogen.

Phosphorus

The phosphorus content in sewage water was 21.0 (2011) and 29.0 (2012) mg L^{-1},which was more than recommended value of 10 mg L^{-1}.Chandrashekharan and Rajkannan (2003) also recorded the higher concentration i.e. 20-30 mg L^{-1} of P in sewage water.

Micro nutrient

The content of micronutrient in sewage water (Table 2) was as; Fe 2.12 and 2.66 mg L^{-1}, Mn1.22 and 2.94 mg L^{-1}in year 2011 and 2012 respectively. The concentration of Mn was higher than recommended maximum concentration of 0.2 mg L^{-1}. The Zn concentration was 2.24 and 7.88 mg L^{-1}during year 2011 and 2012 respectively which was more than the recommended concentration of 2.0 mg L^{-1}. The Cu concentration was 0.44 and 0.56 mg L^{-1} during 2011 and 2012 respectively which exceeds the limit of 0.2 mg L^{-1}recommended concentration. The Boron concentration i.e., 4.00 and 6.20 mg L^{-1} was also more than the limit of 2.0 mg L^{-1} indicating the city waste water is a good source of micronutrients (Kansal and Singh, 1983).

Heavy Metal

The concentration of Cadmium in sewage water (Table 2) was 0.15 and 0.12 mg L^{-1},Chromium 0.20 and 0.30 mg L^{-1}, Lead 3.6 and1.6mg L^{-1} and Cobalt 0.38 and 0.51mg L^{-1} in the year 2011 and 2012 respectively which exceeds the maximum limits of these metals *i.e.* 0.01 mg L^{-1} for Cd,0.1 mg $L^{-1}$for Cr, 0.1 mg $L^{-1}$for Pb and 0.05 mg L^{-1} for Co. Jalan and Pandy (1989) and Azad *et al.* (1986) also reported that the content of total Cd,Ni,Co was ranged from 0.53-1.05 ppm,18.0-30.0 ppm and 11.0-21.0 ppm, respectively.

B. Soil properties

The physical, chemical and biological properties of sewage irrigated soil and sewage free soil are presented in table 3, 4 and 5, respectively.

Bulk Density

Bulk density of sewage irrigated soil was 1.28 and 1.20 Mg m^{-3} during year 2011 and 2012, respectively. The B.D. of sewage free soil was 1.30 Mg m^{-3} which was higher than sewage irrigated soils indicates that the long term use of sewage water lower the B.D. due to addition of organic carbon through sewage and improve the structural stability and increase the porosity. Renukaprasanna *et al.*(2002) also reported the better aggregation in surface layer due to high organic matter status.

Hydraulic conductivity

The hydraulic conductivity of sewage irrigated soil was 2.85 (2011) and 2.96 (2012) cm hr^{-1} and sewage free soil was 1.80 cm hr^{-1}.The hydraulic conductivity in sewage fed soil was more because of addition of organic matter through sewage which increases porosity.

Texture

Sand, silt and clay per cent of sewage irrigated soil was 12.25, 49.65 and 38.01, respectively indicating clay loam textural class, whereas sewage free soil content 20.23 per cent sand,43.50 per cent silt and 36.20 per cent clay indicating clay loam textural class.Reddy and Rao (2000) also reported the similar textural class.

Aggregate stability

The aggregate stability of sewage irrigated soil was 50 and 52 per cent during 2011 and 2012 respectively, where as it was 46 per cent in sewage free soil because sewage improves soil physical condition by increasing water stable aggregates. Aggregate stability is positively correlated with soil organic carbon.Similar type of result was reported by Hall and Coker (1983).

pH

The pH of sewage irrigated soil was 8.25 and 8.38 (2011 and 2012, respectively) indicating alkaline reaction, whereas the pH of sewage free soil was 7.92 indicating moderate alkaline reaction. Prasad and Gajbhiye (2005) reported in their research that, the increase in pH in sewage irrigated soil was due to exchangeable Na in sewage water.

Electrical conductivity

Electrical conductivity of sewage irrigated soil was 0.79 and 0.83 dSm^{-1}during the year 2011 and 2012, respectively and in sewage free soil it was 0.33 dSm^{-1}.The higher electrical conductivity of sewage treated soil was because of presence of salt in sewage. These findings are in conformity with the findings of Narval *et al.* (1993), who also showed increase in EC after the use of sewage water.

Calcium carbonate

The calcium carbonate content in sewage irrigated soil was 5.25 per cent and 5.60 per cent (during 2011 and 2012, respectively) and that of sewage free soil contain 6.80 per cent. This lowering in calcium carbonate content in sewage fed soil because of acidic component of domestic waste. The results are in agreement with Rattan *et al.* (2001), who reported that the sewage water is responsible for development of soil calcareousness.

Organic carbon

The organic carbon content in sewage irrigated soil was 8.70 (2011) and 10.0 (2012) g kg^{-1} and in that of sewage free soil it was 6.20 g kg^{-1}.This might be due to suspended organic material from city waste. The results are in agreement with Tiwari *et al.*(1996) where he observed that the long term sewage irrigation is found carbon building.

Microbial count

In sewage irrigated soil the population of fungi was $7x10^4$ and $11x10^4$, Actinomycetes104 $x10^5$ and $96x10^5$, Bacteria $22x10^7$ and $80x10^7$ $gram^{-1}$ and in sewage free soil the population of fungi $8x10^4$, Actinomycetes13 $x10^5$, Bacteria $18x10^7$$gram^{-1}$which was lower than the sewage fed soil due to addition of organic matter.In sewage treated soil it was higher due to presence of suspended organic material which serves as a source of energy for developing microbial population. The higher contamination with coliform bacteria and other pathogenic microbes in water of faecal, domestic sewage and industrial origin was also reported by Mishra *et al.* (2012).

Nutrient concentration in soil

The data regarding major nutrient concentration and micronutrient and heavy metal composition are presented in table 6 and 7, respectively.

Available nitrogen

In sewage irrigated soil available nitrogen was 313.6 kg ha^{-1} in year 2011 and increased up to 380.46 kg ha^{-1} one year after sewage water irrigation which was more than sewage free soil *i.e.*277.76 kg ha^{-1} because sewage increases available nitrogen because of addition of organic matter (Jayabaskaran and Sree Ramula,1996 and Tiwari *et al.*,1996).

Available phosphorus (P_2O_5)

The available phosphorus in sewage irrigated soil was 63.98 and 72.88 kg ha^{-1} in 2011 and 2012, respectively and in sewage free soil it was 41.54 kg ha^{-1}. This might be due to organic matter content in sewage which dissolves native phosphorus and increase its availability (Jayabaskaran and Sree Ramula,1996).

Available potassium (K_2O)

The available potassium in sewage irrigated soil

Table 1. Characteristics of sewage water

Sr. No.	Parameter, Unit	Observed values 2011	Observed values 2012	Permissible limit	Remarks
1	pH	8.25	7.91	6.5-8.5	High
2	Electrical conductivity (EC) dSm^{-1}	2.60	2.85	<0.7	High
3	Biochemical Oxygen Demand (BOD) mg L^{-1}	160	180	100	High
4	Chemical Oxygen Demand (COD) mg L^{-1}	840	820	100	High
5	Total Dissolved solids (TDS) mg L^{-1}	1664	1824	<400	High
6	Calcium mg L^{-1}	280	320	400	Low
7	Magnesium mg L^{-1}	96	72	60	High
8	Sodium mg L^{-1}	230	322	69	High
9	Potassium mg L^{-1}	54.99	39.00		
10	Sulphate mg L^{-1}	268.80	331	1000	Low
11	Carbonates mg L^{-1}	Trace	Trace		
12	Bicarbonates mg L^{-1}	976	1281	91.5	High
13	Chlorides mg L^{-1}	140	280	140	Low
14	Ammonical nitrogen mg L^{-1}	57.70	66.80	50	High
15	Nitrate nitrogen mg L^{-1}	5.60	8.60	5	High
16	Phosphorus mg L^{-1}	21.00	29.00	10	High

Table 2. Micronutrient and heavy metal composition of sewage water

Sr.No.	Parameter, Unit	Observed values 2011	Observed values 2012	Permissible limit	Remarks
1	Iron , mg L^{-1}	2.12	2.66	5.00	Low
2	Manganese , mg L^{-1}	1.22	2.94	0.20	High
3	Zinc , mg L^{-1}	2.24	7.88	2.00	High
4	Copper , mg L^{-1}	0.44	0. 56	0.20	High
5	Boron , mg L^{-1}	4.00	6.20	2.00	High
6	Cadmium , mg L^{-1}	0.15	0. 12	0.01	High
7	Chromium, mg L^{-1}	0.20	0. 30	0.10	High
8	Lead, mg L^{-1}	3.60	1.60	0.10	High
9	Cobalt, mg L^{-1}	0.38	0.51	0.05	High

Table 3. Physical characteristics of sewage irrigated soil and sewage free soil

Sr.No.	Parameter, Unit	Observed values of sewage irrigated soil		Observed values of sewage free soil
		2011	2012	
1	Bulk Density Mg m^{-3}	1.28	1.20	1.30
2	Hydraulic conductivity cm h^{-1}	2.85	2.96	1.80
3	Sand, %	12.25	—	20.23
4	Silt,%	49.65	—	43.50
5	Clay,%	38.01	—	36.20
6	Textural class	Clay loam	—	Clay loam
7	Aggregate stability,%	50	52	46

Table 4. Chemical properties of sewage irrigated and sewage free soil

Sr. No.	Parameter, Unit	Observed values of sewage irrigated soil		Observed values of sewage free soil
		2011	2012	
1	pH	8.25	8.38	7.92
2	Electrical conductivity dSm^{-1}	0.79	0. 83	0.33
3	Calcium carbonate, %	5.25	5.60	6.80
4	Organic carbon, g kg^{-1}	8.70	10.0	6.20

Table 5. Biological properties of sewage irrigated and sewage free soil

Sr.No.	Parameter, Unit	Observed values of sewage irrigated soil		Observed values of sewage free soil
		2011	2012	
1	Fungi, g^{-1}	$7x10^4$	$11x10^4$	$8x10^4$
2	Actinomycetes, g^{-1}	$104 x10^5$	$96x10^5$	$13x10^5$
3	Bacteria, g^{-1}	$22x10^7$	$80x10^7$	$18x10^7$

Table 6. Nutrient concentration of sewage irrigated and sewage free soil

Sr.No.	Parameter, Unit	Observed values of sewage irrigated soil		Observed values of sewage free soil	Critical limit
		2011	2012		
1	Available nitrogen, kg ha^{-1}	313.6	380.46	277.76	>700
2	Available phosphorus (P_2O_5), kg ha^{-1}	63.98	72.88	41.54	>80
3	Available potassium (K_2O), kg ha^{-1}	840	780	345	>360

Table 7. Micronutrient and heavy metal composition of sewage irrigated and sewage free soil

Sr.No.	Parameter, Unit	Observed values		Observed values of sewage free soil
		2011	2012	
1	Iron , mg kg^{-1}	19.50	5.44	4.42
2	Manganese , mg kg^{-1}	50.34	11.27	10.18
3	Zinc , mg kg^{-1}	1.17	3.40	1.57
4	Copper , mg kg^{-1}	3.68	13.75	4.66
5	Molybdenum mg kg^{-1}	0.20	0.18	0.13
6	Boron , mg kg^{-1}	3.02	4.30	0.52
7	Cadmium , mg kg^{-1}	0.09	0.10	0.012
8	Chromium, mg kg^{-1}	1.74	1.86	0.86
9	Lead, mg kg^{-1}	3.60	2.16	0.96
10	Cobalt, mg kg^{-1}	0.38	0.23	0.09

was 840 kg ha^{-1} in 2011 and 780 kg ha^{-1} in 2012. In sewage free soil it was 345 kg ha^{-1}. It was higher in sewage irrigated soil than sewage free soil because of long term use of sewage irrigation which contains nutrients reported by Azad *et al.* (1986) and Tiwari *et al.* (1996).

The available micronutrient concentration in sewage irrigated soil was as; Fe 19.25 and 15.44 mg kg^{-1},Mn 50.34 and 11.27 mg kg^{-1},Zn 1.17 and 3.40 mg kg^{-1},Cu 3.68 and 13.75 mg kg^{-1}, Mo 0.20 and 0.18 mg kg^{-1}, B 3.02 and 4.3 mg kg^{-1} whereas sewage free soil content was as; Fe 4.42 mg kg^{-1},Mn 10.18 mg kg^{-1}, Zn 1.57 mg kg^{-1},Cu 4.66 mg kg^{-1},Mo 0.13 mg kg^{-1}, B 0.52 mg kg^{-1} during year 2011and 2012 respectively which was higher in sewage treated soil than the sewage free soil .

The heavy metal content in sewage treated soil during 2011 and 2012 was Cadmium 0.09 and 0. 10, mg kg^{-1}, Chromium 1.74 and 1.86 mg kg^{-1}, Lead 3.6 and 2.16 mg kg^{-1} and Cobalt 0.38 and 0.23 mg kg^{-1} and in sewage free soil Cadmium 0.012 mg kg^{-1}, Chromium 0.86 mg kg^{-1}, Lead 0.96 mg kg^{-1}, and Cobalt 0.09 mg kg^{-1}. It was higher in sewage treated soil than sewage free soil.

The sewage water was alkaline in reaction with high EC,COD,BOD and TDS than the permissible limit. The concentration of calcium was below permissible limit whereas the concentration of Mg^{2+}, Na^{+}, P,HCO_3^-,Cl^-,NH_4-N and NO_3-N exceeds permissible limit. The concentration of Mn,Zn,Cu and B was higher than critical limit whereas concentration of Cd,Cr,Pb and Co was higher. The bulk density was reduced, while hydraulic conductivity and aggregate stability was increased as compared to sewage free soil. The sewage treated soil was alkaline in reaction with increasing trend of EC than sewage free soil. This soil contains more organic carbon, available N,P and K than sewage free soil. The concentration of Fe,Mn,Zn,Cu,B andMo was considerably higher in sewage irrigated soil than normal soil which may reach the maximum permissible limit in future. The concentration of Cd, Cr, Pb and Co was more in this soil which indicates future toxicity of these elements. The soil microbial count of bacteria,fungi and actinomycetes was higher than the sewage free soil.

The long-term use of sewage water for irrigation was found beneficial in improving soil physical properties like bulk density, aggregate stability, hydraulic conductivity, organic carbon, macro and micro nutrients status of soil but the higher concentration of heavy metal become phytotoxic and enter the food chain suggesting the use of sewage water in agriculture with caution.

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