Effect of sewage effluent disposal on soil characteristics at Haridwar (Uttarakhand), India

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Abstract: The present investigation was conducted to study the effects of sewage effluent disposal on soil characteristics in the district Haridwar (Uttarakhand). The result showed that the sewage effluent loaded with higher value of TDS (696.67 mg L^{-1}), EC (0.78 dS/m^{-1}), pH (7.53), BOD (66.7 mg L^{-1}), COD (125.33 mg L^{-1}), TKN (6.38 mg L^{-1}), Na^+ (56.53 mg L^{-1}), K^+ (6.63 mg L^{-1}), Ca^{2+} (105.64 mg L^{-1}), Mg^{2+} (54.67 mg L^{-1}), PO_4^{3-} (2.30 mg L^{-1}), Fe (1.72 mg L^{-1}), and Zn (0.38 mg L^{-1}) in comparison to control (bore well water). The sewage effluents disposal on soil increased the soil characteristics viz., EC (+59.92%), pH (+0.51%), organic carbon (+50%) and fertility status in terms of TKN (+70.74%), PO_4^{-3}(+19.04%) Na^+ (+39.01%), K (+39.06%), Ca^{++} (+32.97%) and Mg^{++} (+25.08%) which are essential for the soil fertility and growth of agricultural crops. It was also observed that the sewage irrigation also increased the contents of heavy metals such as Zn (+39.27%), and Fe (+40.00%) in the soil. Thus, sewage effluent disposal significantly affected the soil characteristics in the vicinity of sewage treatment plant.
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Introduction

The impact of sewage disposed on the environment has become a threat to the existence of plant, animals and ultimately human life. Pollution is causing wide spread concern and has become an important area of interest in the field of modern research (Longe and Ogundipe, 2010; Mishra, 2012). Sewage effluents are often the main factors responsible for deterioration of water quality as they have a major impact on the chemical loads received by surface water bodies (Drolc *et al.,* 2007; Picot *et al.,* 2009). High levels of nitrogen and phosphorus are generally found in sewage effluents, and contribute to high eutrophication levels and reduce river functionalities (David *et al*., 2012). Rapid urbanization and industrialization is placing an unprecedented pressure on water quality and demand. There are numerous other constraints such as inefficient infrastructure, weak, urban and municipal regulation, inadequate financial services together set to bring deterioration in environment quality (Shah et al., 2010; Padmapriya and Murugesan, 2012; Ali et al., 2013; Kumar and Chopra, 2014). The volume of (Qadir *et al*., 2008) wastewater generated by domestic, industrial and commercial sources has increased with population, urbanization, improved living conditions, and economic development. In urban areas of many (developing) countries, urban and peri-urban agriculture depends, at least to some extent, on wastewater as a source of irrigation water. The quality of the water and the conditions under which this water is used vary greatly. In poor countries this water may, in extreme cases, take the form of diluted raw sewage, even if this is considered illegal (Huibers *et al*., 2004). However, the quality of the wastewater used and the nature of its use vary enormously, both between and within countries. In many low-income countries in Africa, Asia, and Latin America, the wastewater tends to be used untreated, while in middle-income countries such as Tunisia and Jordan, treated wastewater is used (Faruqui *et al*., 2004). Water pollution in some ways is more complex than air pollution because almost anything can be spilled or dumped into water in luding kitchen sink (Anderson, 2004). Sewage is the best example in India sewerage water contains a large variety of wastes ranging from domestic to industrial therefore; quality of such water is not suitable to irrigate any crop because of presence of many toxic chemicals (Murtaza *et al*., 2003; Ghafoor *et al.,* 2004). Leafy vegetables like cauliflower cabbage, spinach, etc. grow quite well in the presence of sewage water (Murtaza *et al*., 2003) whereas vegetables such as radish are sensitive to sewage water (Bakhsh and Hassan, 2005). Vegetables grown by the use of sewage water contain many heavy metals causing serious health hazards to the community and animals as well (Qadir *et al.,* 1999; Murtaza *et al.,* 2003). This concern is of special importance, where un-treated sewage is applied for longer periods to grow vegetables in urban lands. India supports more than 16% of the world's population with only 4% of the world's fresh water resources (Singh, 2003). Although agriculture sector in this country has been major user of water, share of water allocated to irrigation is likely to be decreased by10–15% in next two decades (CWC, 2000). Agricultural wastewater is chemical fertilizers and organic used in agriculture such as pesticide spraying and fertilizer application, which arrive to rivers through drainage. Also, detergents consist of different chemical components such as surfactants, soaps, bleaches and enzymes that reach rivers through sewage (Geetu and Surinderjit, 2012; Zelenakova *et al.,* 2013). In general, the municipal wastewater is a combination of the water and carried wastes removed from residential, in situational and commercial establishments together with infiltration of water, surface water and runoff water (Gautam *et al.,* 2012). The domestic sewage contains a large variety of inorganic and organic impurities and pathogens bacteria and viruses resulting in waterborne diseases. Water is organically polluted by high molecular weight compounds such as sugars, fats, oils, proteins released from domestic and industrial wastes and causing unpleasant odor, color, taste and algal growth (Chavan and Dhulap, 2012; Puerari *et al.,* 2012). Therefore, keeping the above in view the present study was undertaken to assess the effect of treated sewage wastewater on physico-chemicals properties of soil and agricultural crops.

Materials and Methods

Study area

Sarai, Haridwar (29°54'12.8"N, 78°06'31.0"E) was selected for the collection of sewage effluent and a bore well was selected for the collection of bore well water samples. The Sarai is located about 8 Km away from Gurukula Kangri Vishwavidyalaya Haridwar.

Collection of sewage effluent samples and analysis

For analysis of various physico-chemical parameters the sewage effluent and samples were collected from the effluent disposal channel. The bore well water was considered as control and the samples of bore well water were collected from bore well located adjacent to the agricultural fields. The samples were collected in thoroughly cleaned plastic container of 5 liters capacity provides with the double cap device. Some of the parameters like pH were carried out on the spot because time consumed during transportation could alter the results. Remaining parameters could be carried out on composite sample. The collected samples were brought to the laboratory and analyzed for various physico-chemical parameters and heavy metals following parameters namely: total dissolved solids (TDS), electrical conductivity (EC), pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), total Kjheldal nitrogen (TKN), phosphate (PO_4^{3-}), iron (Fe), and zinc (Zn) using standard methods (Chaturvedi and Sankar, 2006; APHA, 2012).

Collection of soil samples and analysis

The composite soil samples from the surface (0-20 cm) were collected in the vicinity of effluent disposal channel emerging from Uttaranchal Pulp and Paper Mill. The bore well water irrigated soil was taken as control. The samples were brought to the laboratory and dried in clean plastic trays for 7 days at room temperature and then sieved through a 2-mm or 5-mm sieve. The samples were analyzed for various Physico-chemical parameters namely: pH, EC, Na^+, K^+, Ca^{2+}, Mg^{2+}, TKN, $PO_4^{-3}$and OC and heavy metals like Fe, and Zn following standard methods (Trivedy and Goyal, 1986; Chaturvedi and Sankar, 2006).

Heavy metal analysis

For heavy metal analysis, 10 ml sample of sewage effluent, 100 ml sample of bore well water and 0.5 g sample of soil (total heavy metal concentration in soil before and after effluent disposal) was digested with a mixture of concentrated HNO_3 and $HClO_4$ (10 ml + 2 ml) separately. The digested samples were filtered through Whatman filter No. 42 and finally the volume was made with 50 ml of 0.1 N HNO_3 and analyzed for heavy metals using AAS (Model ECIL-4129).

Data interpretation and statistical analysis

Mean and standard deviation were also calculated with the help of MS Excel 2013. Graphs were plotted with the help of Sigma plot, 2000.

Results and Discussion

Characteristics of sewage effluent

The mean ± SD values of physico-chemical and heavy metals parameters TDS, EC, pH, BOD, COD, TKN, Na^+, K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-}, Fe, and Zn of sewage effluent discharged by sewage treatment plant (STP), Sarai, Haridwar and bore well water (BWW) are given in table 1.

During the present study, the values of TDS (696.67 mg L^{-1}) of sewage effluent recorded below the prescribed limit of Indian Standards for irrigation water (BIS, 2010). The higher values of TDS in the sewage effluent were recorded as compared to the control (Bore well water). The pH of sewage effluent was alkaline (7.53) in nature and it might be due to the organic matter present in the sewage. The value of EC in the sewage effluent was also noted to be higher and it is likely due to the presence of more ionic species in the sewage effluent (Table 1). The results showed that the values of BOD (66.70 mgL^{-1}), COD (125.33 mgL^{-1}) in the sewage effluent were found lower then BIS standard for inland disposal (Table 1). During the present investigation, the values of TKN, Na^+, K^+, Ca^{2+}, Mg^{2+} and PO_4^{3-} in the sewage effluent were also found higher compared to the control (Table 1). The results revealed that the values of Fe and Zn in the sewage effluent were found below the prescribed limit of BIS standard for inland disposal (Table 1).

Table: 1 Physico-chemical characteristics of control (bore well water) and sewage effluent.

Parameter	Bore well water	Sewage Effluent	BIS for drinking water	BIS for irrigation water
TDS (mg/L)	205±5.65	696.67±15.28	500	1900
EC (dS/m^{-1})	0.67±0.02	0.78±0.10	-	-
pH	7.84±0.10	7.53±0.21	6.5-8.5	5.5-9.0
BOD (mg/L)	2.7±0.54	66.7±1.12	4.0	100
COD (mg/L)	8.67±1.53	125.33±4.04	150-200	250
TKN (mg/L)	0.86±0.01	6.38±0.94	-	100
Na^+(mg/L)	23.43±0.15	56.53±1.01	-	-
K^+ (mg/L)	0.08±0.01	6.63±0.85	-	-
Ca^{2+}(mg/L)	69.33±1.53	105.64±5.88	75	200
Mg^{2+}(mg/L)	14.12±1.43	54.67±1.53	-	-
PO_4^{3-}(mg/L)	0.08±0.01	2.30±0.26	-	-
Fe (mg/L)	0.05±0.01	1.72±0.02	5.00	15
Zn (mg/L)	0.031±0.01	0.38±0.02	0.05	1.0

Values are mean ±SD of four replicates.

Effect of sewage effluent disposal on soil characteristics

The mean ± SD values of physico-chemical and heavy metals parameters EC, pH, TKN, Na^+, K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-}, organic carbon Fe, and Zn of soil after disposal of sewage effluent by sewage treatment plant (STP), Sarai, Haridwar along with bore well water (BWW) are given in Table 2

The sewage effluent disposal increased the values of EC (2.62±0.50 µs/cm), pH (7.71±0.30), PO_4^{3-} (0.63±0.02 mg/Kg), Na^+ (11.61±0.97 mg/Kg), K^+ (0.64±0.04 mg/Kg), Ca^{++} (11.07±0.85 mg/Kg), Mg^{++} (8.61±0.49 mg/Kg), TKN (1.47±0.02 mg/Kg), organic carbon (0.86±0.04 mg/Kg), Fe (2.05±0.04 mg/kg) and Zn (2.75±0.03 mg/Kg) of the soil in comparison to the values of EC (1.05±0.51 µs/cm), pH (7.67±0.54), PO_4^{3-} (0.51±0.03 mg/Kg), Na^+ (0.08±0.20mg/Kg), K^+(0.39±0.07mg/Kg), Ca^{++} (7.42±1.04 mg/Kg), Mg^{++} (6.45±1.01 mg/Kg), TKN (0.43±0.02 mg/Kg), organic carbon (0.43±0.02 mg/Kg), Fe (1.23±0.06 mg/kg) and Zn (1.67±0.03 mg/Kg) of bore well water irrigated soil.

EC and pH

The value of EC (2.62 µs/cm) in the sewage effluent contaminated soil was increased compared to the EC (1.05 µs/cm) of bore well water irrigated soil. The EC (59.92 %) of the sewage effluent contaminated soil was increased significantly compared to the control soil (Figure 1). The increase in the EC of the effluent irrigated soil is likely due to the presence of more salts or ionic species in the sewage effluent. Mohan et al. (2007) reported that the higher EC (4.52 dS m-1) of wastewater is due to the presence of total dissolved solids. Thus, EC is an important criterion to determine the suitability of water and waste water for irrigation. Soils have alkaline pH levels that are greater than 7. If these soils have excessive amount of salts (that is, EC >4 dS m-1) they are classified as saline soils. However, if they also contain appreciable exchangeable sodium (sodium absorption ratio SAR >13) or exchangeable sodium percentage (ESP) >15, they are classified as saline-sodic. Finally, if salt concentration are low (EC<4 dS m-1 and SAR >13 or ESP >15) or high enough to control a soil's chemical attributes, they are known as sodic soils.

The pH of the sewage effluent contaminated soil was recorded to be slightly alkaline (7.71) compared to the pH of control soil (7.67). The pH (0.51%) of the sewage effluent contaminated soil was increased insignificantly in comparison to control soil (Table 2). Charman and Murphy (1991) also reported that the basic pH (8.68-9.86) of the soil reduces the solubility of all micronutrients (except chlorine, boron and molybdenum), especially those of iron, zinc, copper and manganese. The soil pH can also influence plant growth as it affects the activity of beneficial microorganisms. Most nitrogen fixing legume bacteria are not very active in strongly acidic soils. In the acidic soil environment, the availability of the basic cations (Ca^{2+}, Mg^{2+}, K^+, Na^+) becomes lower due to leaching. Mohan et al. (2007) found that soil having pH value of 8.5 and above is expected to have more Na in the exchange complex and when unaccompanied by the presence of soluble salts, it is classified as an alkaline soil.

Total Kjehdahl nitrogen (TKN)

The present study the values of TKN (0.43 mg/Kg) bore well water (Control site) was recorded while the values of TKN (1.47 mg/Kg) soil irrigated with sewage water (Study site) as shown in table 2. The overall increase in the nitrogen in the soil due to the use of sewage water for irrigation purposes, which contains higher amount of nitrogen. Rai *et al.* (2011) also reported higher values of TKN (2.22±0.57 mg/Kg) of sewage effluent in comparison to the TKN (1.61±0.12 mg/Kg) of bore well water.

Sodium and potassium (Na^+ and K^+)

Sodium and potassium is element of nutrient fertilizers elements. The values of Na^+ (11.61 mg/Kg) sewage effluent (Study site) were recorded while the values of Na^+ (0.08 mg/Kg) in bore well water (Control site). The values of K^+ (0.39 mg/Kg) (Control site) was recorded while the values of K^+ (0.64 mg/Kg) (Study site). Singh and Agrawal (2009) also observed that higher values of Na^+ (17.56 mg/Kg) of sewage effluent in comparison to the Na^+ (10.55 mg/Kg) of bore well water. Kumar and Chopra (2011) also observed that higher values of K^+ (32.06 mg/Kg) of bore well water in comparison to the K^+ (41.00 mg/Kg) of sewage effluent.

Calcium and magnesium (Ca^{++} and Mg^{++})

The Ca^{++} and Mg^{++} content of soil sample at the study values the Ca^{++} (11.07 mg/Kg) sewage effluent (Study site) was recorded while the values of Ca^{++} (7.42 mg/Kg) was noted in bore well water (Control site). Gupta *et al*. (2012) also reported lower values of Ca^{++} (2.18 mg/Kg) of sewage effluent in comparison to the Ca^{++} (2.75 mg/Kg) of bore well water. Sharma *et al.* (2006) also observed that lower values of Mg^{++} (0.17 mg/Kg) of bore well water in comparison to the Mg^{++} (0.09 mg/Kg) of sewage effluent. The low concentration of Ca and Mg was also observed in sewage water irrigated soil.

Organic carbon

The values of organic carbon (0.86 mg/Kg) sewage effluent (Study site) were recorded while the values of organic carbon (0.43 mg/Kg) in bore well water (Control site). Thus, organic carbon Pathak *et al.* (2011) also reported higher values of organic carbon (1.95 mg/Kg) of sewage effluent in comparison to the organic carbon (1.27 mg/Kg) of bore well water. Sewage sludge contains 20-40% organic matter of its total dry weight. Thus its uses in agricultural land increase the organic carbon in soil.

Iron (Fe) and Zinc (Zn)

While studying the micronutrient and heavy metal contents in soil sample, the mean concentration of Fe in the present study the soil irrigated with sewage effluent (Study site) and soil irrigated with bore well water (Control water) was found (2.05 mg/kg) and (1.23 mg/kg) was observed in the villages of Sarai (Haridwar). Kumar and Chopra (2015) also reported higher values of Fe (2.66 mg/Kg) of sewage effluent in comparison to the Fe (1.28 mg/Kg) of bore well water. The content of Fe was increased significantly due to disposal of paper mill effluent.

Concentration of Zn in the present study the soil irrigated with sewage effluent (Study site) and soil irrigated with bore well water (Control water) was found (2.75 mg/kg) and (1.67 mg/kg) was observed in the villages of Sarai (Haridwar). Singh and Kumar (2006) also reported higher values of Zn (3.05 mg/Kg) of sewage water in comparison to the Zn (1.25 mg/Kg) of bore well water.

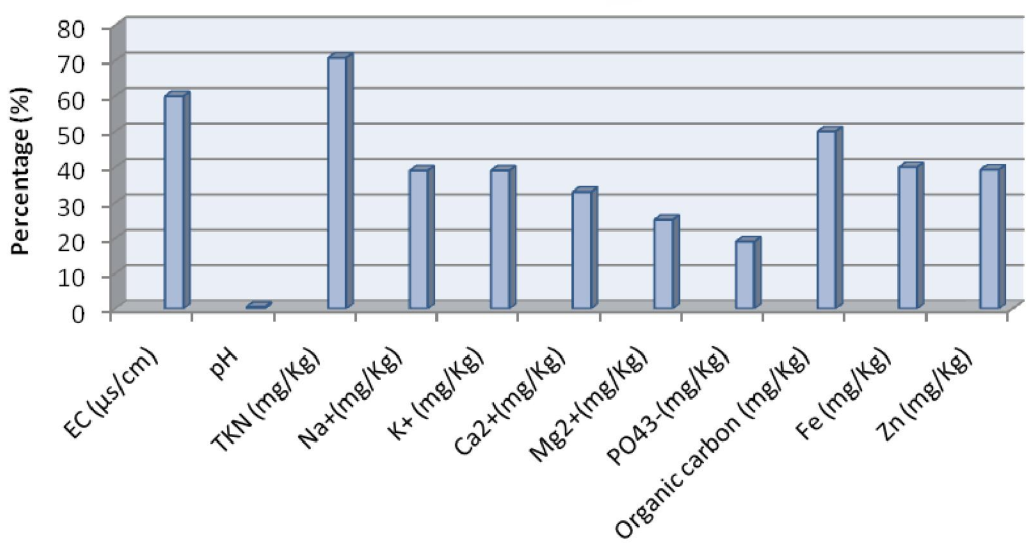

Figure: 1 Percent increase in soil characteristics after disposal of sewage effluent.

Table: 2 Physico-chemical characteristics of soil after disposal of sewage effluent at Sarai, Haridwar.

Parameters	Control site	Study site
EC (µs/cm)	1.05±0.51	2.62±0.50
pH	7.67±0.54	7.71±0.30
TKN(mg/Kg)	0.43±0.02	1.47±0.02
Na^+(mg/Kg)	7.08±0.20	11.61±0.97
K^+ (mg/Kg)	0.39±0.07	0.64±0.04
Ca^{2+}(mg/Kg)	7.42±1.04	11.07±0.85
Mg^{2+}(mg/Kg)	6.45±1.01	8.61±0.49
PO_4^{3-}(mg/Kg)	0.51±0.03	0.63±0.02
Organic carbon (mg/Kg)	0.43±0.02	0.86±0.03
Fe (mg/Kg)	1.23±0.06	2.05±0.04
Zn (mg/Kg)	1.67±0.03	2.75±0.03

Conclusion

The present investigation was conducted that the disposal of sewage effluent increased the EC (+59.92%), pH (+0.51%), organic carbon (+50%) and fertility status in terms of TKN (+70.74%), PO_4^{-3}(+19.04%) Na^+ (+39.01%), K (+39.06%), Ca^{++} (+32.97%) and Mg^{++} (+25.08%) of the soil which are essential for the soil fertility and growth of agricultural crops. It was also observed that the sewage irrigation also increased the amount of heavy metals such as Zn (+39.27%), and Fe (+40.00%) in the soil. Although, the concentration of these metals in the soil was below the permissible limits of Indian standards. However, if the sewage effluent irrigation is used for a prolonged time, the metal enrichment may exceed the permissible limits in soil which can be hazardous for the fertility of the soil. Hence, regular monitoring is needed from time to time where the soil is being irrigated with sewage effluent.

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