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Soil Characteristics Affected by long term Application of Sewage Wastewater

Rana, L . , Dhankhar, R .* and Chhikara , S .

Ecology Laboratory, Department of Environmental Sciences, Maharishi Dayanand University, Rohtak, Haryana, India

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ABSRACT: The long term effects of sewage water irrigation on soil properties and heavy metal concentrations at Rohtak city, Haryana (India) was investigated. At each location, soil samples were collected from the upper layer (0-10cm) for determination of various physico-chemical parameters. Heavy metals (Pb, Cu, Mn, Zn, Cd, Ni, and Fe) were also determined. The chemical analysis of sewage effluent showed that total salt concentration and heavy metal content was high compared to ground water but within the safe limits. Thus, sewage effluent remained within permissible limits for use as irrigation water. Soil analysis revealed that organic carbon, phosphorus, calcium and magnesium content were high in sewage irrigated soils compared to tube well irrigated soils. The soil pH decreased by 0.38 units as a result of sewage water irrigation. The continuous application of untreated sewage effluent for last 35 years resulted into significant accumulation of nutrients and heavy metals in soils. Organic carbon content showed positive correlation with all heavy metals except Zn while pH had negative correlation with all metals except Mn. Electrical conductivity had a positive correlation with all metals.

Key words: Sewage waste water, Irrigation, Soil properties, Correlation, Heavy metals

INTRODUCTION

The clean and safe environment is the basic requirement of human existence. Today, due to constraint in availability of fresh water for irrigation, waste water especially sewage water is being used for irrigation of agricultural fields. Various studies confirm that treated sewage waste water can be useful as an additional water resource for irrigation (Palese *et al.*, 2009; Mehrdadi *et al.*, 2007). Application of sewage water improved the physico-chemical properties and nutrient status of the soil and increases crop production as it supplies N, P and K and also valuable micronutrients than what crop requires (Panicker, 1995). On the other hand, the use of sewage water in agriculture is associated with health risks because of presence of pathogenic micro-organisms (Toze,2006), metallic contaminants like Cu, Ni, Cd, Cr, Zn (Misra & Mani,1991) and polychlorinated substances (Bansal,1998). McGrath and Lane (1989) reported that more than 80% of toxic metals originally added were still present in top soil layers 25 years after sewage sludge application. Toxic effects of heavy metals upon soil micro-organisms and microbial mediated processes have been reviewed by Duxbury (1985) and Doelman (1986).

*Corresponding author E-mail: dhankhar.rd@gmail.com

In India, sewage water generation is 29000 million liters per day against the existing treatment capacity of 6000million liters per day (Central Pollution Control Board, 2004). The use of treated sewage in irrigation was emphasized in the Water (Prevention and Control of Pollution) Act, 1974.Due to lack of facilities; untreated sewage water is being used by farmers to satisfy crop water needs. This indiscriminate continuous use of such effluent for crop production could result in the concentrations that may become phytotoxic (Ghafoor *et al.*, 1999). Most of the crops and vegetable species growing in metal polluted soils are unable to avoid the absorption of these metals (Baker, 1981). Studies have shown that on applying sewage water to soil, Cu is among those metals that would quickly double its concentration in the top soils (Jorge *et al.*, 2005). Bansal et al. (1992) compared the accumulation of Zn, Cu, Mn and Fe in soils irrigated with waste water and tube well water. Accumulation of heavy metals in agricultural soils is a subject of increasing concern due to food safety issues and potential health risks as well as detrimental effects on soil ecosystem (McLaughlin *et al.*, 1999). There is a well recognized need to detect the level of pollution of soil given the increased use of sewage water in agricultural soils. It provides an indication of soil health.

The Sewage effluent of the Rohtak city is discharged into two lined channels both of which join a larger channel. For the past 35 years, farmers owning land along these channels are making use of this untreated sewage effluent for irrigation purposes.The chosen agro-ecosystem, is intensively cultivated for growing vegetables, pulses etc. In this paper, we have studied the long term influence of sewage water on soil properties and heavy metal concentrations. The comparison is also made between the various parameters of the soils irrigated with sewage waste water and tube well water.

MATERIALS & METHODS

The study was conducted in Rohtak city which is located between 76° 25' and 76° 94' East longitudes and 28° 35' and 28° 80' North latitude, lying at 219.84 meters above sea level. The climate in this area is classified as continental with extremes of heat in summer and markedly cold in winters. The annual rainfall of Rohtak is 455mm, most of which is received during the last week of June to September contributed by South-west monsoon. The soil samples at the depth of 0-10cm were collected from seven random spots of sewage irrigated agricultural fields of Rohtak city and of nearby fields irrigated by tube well water. Before chemical analysis, they were air dried, powdered and sieved through a 2mm sieve. Stones and plant materials were removed manually.The water samples were also collected in polythene bottles from the sewage disposal site and from four tube wells, located in tube well irrigated fields. The hydrogen ion concentration and electrical conductivity of sewage water samples were determined immediately after collection by pH meter and electrical conductivity meter respectively. Dissolved oxygen, B.O.D., Ca^{2+}, Mg^{2+}, Chloride, Nitrate, sulphate and phosphorus were measured as per the method given by APHA (1992). Heavy metals like Ni, Cd, Zn, Cu, and Pb were estimated after wet digestion with 1:4 mixtures of $HClO_4$ and HNO_3, followed by measurement of respective concentrations with the help of atomic absorption spectrophotometer. The pH of the soil samples was determined using glass electrode pH meter. Soil salinity was determined in soil extracts using conductivity meter and expressed as electrical conductivity (E.C.ds/m). Soluble captions (K^+, Na^+) were determined by Flame photometer (Rhoades, 1982). Total alkalinity (CO_3 and HCO_3) and Cations (calcium and magnesium) were determined as per the method given in USDA Handbook No.60 (US Salinity Lab Staff, 1954). Organic carbon was determined by Walkley and Black rapid titration method. The method is based on organic matter oxidation by K-dichromate. Available Phosphorous was determined by the method prescribed by Bray and Kurtz, 1945. Chloride was determined by standard silver nitrate titration method (Jackson, 1967). All heavy metal concentrations in solution phase were determined by using atomic absorption spectrophotometer (AAS). Extractable metals were determined by AAS using DTPA as single extract ant (Lindsay & Norvell, 1978). The data obtained were subjected to mean and standard deviation. Correlation coefficient between physico-chemical parameters, metal concentrations and interaction of both was carried out in sewage irrigated soil samples and tested for significance following Rao and Richard (2001). The data were analyzed on Microsoft Excel and SPSS 7.5 software programs.

RESULTS & DISSCUSSION

The sewage effluent samples and tube well water samples were characterized as shown in Table1. Tube well water samples were analyzed to evaluate the suitability of sewage water as a source of irrigation. The tube well water exhibited almost neutral hydrogen ion concentration value (7.3) while the pH of sewage water is slightly alkaline in reaction (7.6). The enhancement of pH is due to addition of various soluble salts in sewage water. Despite the increase of 3.94%, the pH value of sewage waste water was within the permissible limits in respect of its use on agricultural lands(Desai *et al.*,1990).The salt content/E.C. of sewage water (2.30ds/m) was 51.3% higher than that of tube well waters (1.12ds/m) indicating that industrial effluent discharged are brackish. The total dissolved solids in the sewage water were found to be 26.27% more than that of tube well waters. With respect to tube well water samples studied, the dissolved oxygen of sewage waste water sample (1.42g/l) was low. Low dissolved oxygen is indicative of higher value of biological oxygen demand. Thereby, B.O.D. of sewage water was quite high compared to the tube well water samples; it also exceeded the prescribed limit of 100mg/L. This condition of high biological oxygen demand value may pose problem to the use of sewage water for irrigation purpose.

The nutrient elements were present in high concentration in sewage waste water, with phosphorus (6.4 mg/L) content being 80.15% higher the content in well waters (1.27 mg/L) and nitrate content(25 mg/L) 94.4% more than that of tube well water(1.4 mg/L). Both were exceeding the prescribed limits of 5mg/L and 10mg/L for phosphorus and nitrate content respectively. High nitrate concentration may be due to the presence of urea[$CO(NH_2)_2$] which is the major source of nitrogen in sewage (Ganguly and Maiti, 2004). The sulphate content in sewage water was 125.68mg/L which is 48.13% higher than of tube well water samples (65.18 mg/L).The variation in the amount of nutrients present in the sewage water may be due to the variation in the mineralogical composition of their sources from

Table 1.Characteristics of sewage and tubewell water

Parameters	Tube-well water (Mean values)	Sewage waste water	Percent increase
1.pH	7.3	7.6	3.94
2. E.C.(ds/m)	1.12	2.30	51.3
3.Carbonates	nil	nil	-
4. Bicarbonates(me/L)	9.35	14	33.21
5.Chlorides(me/L)	3.8	5	24
6. Ca+Mg(me/L)	5.2	8	35
7.S.A.R.	1.2	1.8	33.33
8.D.O.(mg/L)	4.5	1.42	-68.44
9.B.O.D.(mg/L)	3	120	97.5
10.Phosphorus(mg/L)	1.27	6.4	80.15
11. T.D.S.(mg/L)	870	1180	26.27
12.Sulphate(mg/L)	65.18	125.68	48.13
13.Nitrate(mg/L)	1.4	25	94.4
14. Ni(ppm)	0.015	0.17	91.17
15.Cd(ppm)	N.D.	0.03	100
16.Zn(ppm)	0.04	1.47	97.27
17.Cu(ppm)	N.D.	0.32	100
18.Pb(ppm)	N.D.	0.35	100
19.Fe(ppm)	0.05	1.26	96

where they are disposed off. The chloride content of sewage effluent (3.8 meq/L) was 24% higher than that of tubewell (5 meq/L) water samples. This parameter may not pose a problem for use as irrigation water. An alkalinity of the effluent seems to be due to bicarbonates (14 meq/L) only because carbonates were not observed in the effluent. The calcium and magnesium content of sewage effluent has increased by 35% compared to tube well water samples. This increase may be due to the addition of certain compounds (which imparts hardness) after domestic use of the water (Ganguly and Maiti, 2004). The concentration of heavy metals in sewage effluent depends on the nature of industries and domestic uses (Misra *et al.*, 1992). High content of Cd and Ni have earlier been reported in sewage water contaminated with effluent discharge from electroplating industries (Narwal *et al.*, 1990). In the present study, though the concentration of heavy metals viz. Ni, Cd, Zn, Cu, Pb and Fe were higher in sewage effluent with respect to ground water samples but still it is within the limits prescribed for land disposal. Physico-chemical properties of the soils are given in Table 2. Repeated application of sewage effluent to agricultural lands can have significant effects on soil properties. The analysis of soil samples (Table 3) reveals high chloride, bicarbonate, calcium and magnesium content of sewage irrigated soil compared to tube well irrigated soils.The carbonates in sewage irrigated soils form sparingly insoluble solid phases with many metals and have been observed to account for the major portion of several metals (Karpanagiotis *et al.*, 1991). A strong positive correlation has been found between Fe and Cl content and between Cd and Cl content (Table 4). The importance of chloride in increasing the mobilization and availability of Cd through the formation of Cd-chloro complexes has been reported to increase tissue Cd content of wheat and Swiss chard in soils amended with evaporative dried sludge (Weggler-Beaton *et al.*, 2000). It has been suggested that high chloride levels in sewage water should be lowered before use on agricultural land.The soils irrigated with sewage water were weakly alkaline with a pH value of 7.84, 0.38 units less than that of tube well irrigated soils. The presence of significant quantities of mineralizable nitrogen and readily degradable organic matter in sewage sludge influences sludge pH. The soil pH influences the solubility and nutrient availability and also acts as prime factor affecting potential metal availability. In general, heavy metal cations are most mobile under acidic conditions (Christensen, 1984). As expected, all heavy metal ions show negative correlation with pH except Mn (Table-4). A significant positive correlation has been found between pH and Ca+Mg concentration and between pH and chloride (Table 3). The long term addition of sewage water to agricultural lands enhanced electrical conductivity value from 0.99ds/m for tube well irrigated to 1.65ds/m for sewage irrigated soil due to the high salt content present in the sewage effluents. Sewage application to soil may constitute a source of plant nutrients but simultaneously it may also increase heavy metal content. The electrical conductivity is positively correlated with all the heavy metals in soils and show significant positive correlation with Fe and Mn. A significant correlation was also observed between E.C. and chloride. High concentration of organic matter in sewage water reflected by high B.O.D. value has resulted in enhancement of available and

Table 2. Physico-chemical properties of soils irrigated with sewage and tubewell water

Parameters	Tubewell irrigated soil Mean values ±S.D.	Sewage water irrigated soil Mean values ±S.D.	Percent increase
1. pH	8.15±0.1718	7.84±0.0989	-3.80
2. E.C.(ds/m)	0.975+0.0181	1.65+0.0302	40.90
3. Carbonates	Nil	Nil	-
4. Bicarbonates (mg/L)	197.57+6.32	246.14+12.54	19.73
5. Chlorides(mg/L)			
6. Ca+Mg(mg/L)	275.2±4.15	388.5±12.99	29.16
7. Org.Carbon(%)	215.14±14.14	253±6.42	14.96
8. Pottassium(ppm)	0.707±0.0335	0.882±0.0372	19.84
9. Sodium (ppm)	8.13+0.283	20.14+3.225	59.63
10. Phosphorous	11.27+1.217	13.69+1.512	17.67
(Kg/hec.)	14.15+0.704	20.98+2.50	32.55
11. Fe(ppm)			
12. Mn (ppm)	2.482±0.828	11.24±1.487	77.91
13. Ni (ppm)	0.462±0.0610	2.04±1.05	77.35
14. Cd (ppm)	0.311±0.0644	4.28±1.418	92.73
15. Zn (ppm)	N.D.	0.61±0.050	100
16. Cu (ppm)	2.538+0.877	10.62+1.33	76.10
17. Pb (ppm)	0.652+0.2498	3.82+0.587	82.93
	1.06+0.304	3.59+0.370	70.47

Table 3.Correlation coefficient of physico-chemical parameters of soil as influenced by sewage water irrigation

	E.C.	pH	HCO_3	Cl	Ca+Mg	O.C	K	Na	P
E.C.	1								
Ph	-0.447	1							
HCO_3	0.293	-0.134	1						
Cl	0.820**	-0.683**	0.210	1					
Ca+Mg	-0.077	0.702**	0.157	-0.426	1				
O.C	0.320	0.196	0.333	-0.148	0.403	1			
K	-0.501	0.470	-0.819**	-0.425	0.317	-0.383	1		
Na	-0.116	-0.149	0.264	-0.421	0.180	0.582*	-0.293	1	
P	-0.193	0.376	0.160	-0.381	0.834**	0.386	0.289	0.404	1

*** Significant at 5% level r>0.532, **Significant at 1% level r>0.661(n=7)**

Table 4. Correlation coefficient of heavy metals in soil with physico-chemical properties of soil as influenced by sewage water

	Fe	Mn	Ni	Cd	Zn	Cu	Pb
E.C.	0.832**	0.540*	0.323	0.250	0.498	0.316	0.174
pH	-0.601*	0.336	-0.215	-0.465	-0.046	-0.236	-0.013
O.Carbon	0.376	0.191	0.397	0.070	-0.216	0.223	0.410
HCO3	-0.064	0.116	0.587*	0.262	-0.144	-0.339	-0.391
Ca+Mg	-0.240	0.128	0.471	-0.557*	0.370	-0.273	0.349
Na	0.091	-0.620*	0.656*	-0.238	-0.252	-0.266	0.215
K	-0.288	-0.159	0.368	-0.483	0.191	0.080	0.405
P	-0.130	-0.300	0.580*	-0.291	0.168	-0.0619	0.592*
Cl	0.700**	0.386	0.0493	0.556*	0.369	0.438	0.0349

*** Significant at 5% level r>0.532, **Significant at 1% level r>0.661(n=7)**

total nutrients in soil over the years as compared to tube well irrigated soil. There is significant increase of 32.55%, 59.63% in available phosphorus and potassium content respectively in sewage irrigated soil. Sludge containing significant quantities of calcium and phosphorus has an increased quantity to retain heavy metals (Brown *et al.*, 1997).Sodium was also accumulating in sewage irrigated soil. Sewage irrigated soil has 0.882% organic carbon compared to 0.707% of tube well irrigated soil. Most of the differences in organic matter content and electrical conductivity maybe attributed to long term application of waste water in soil (Ross et al., 1982).Organic carbon content have positive correlation with almost all nutrients and heavy metals but none of them was found to be significant as evident from the table 3 and 4. Thus, the availability of micronutrients and heavy metals can be increased with improving organic carbon status of soil (Trehan, 1996). The degradation of sludge organic matter may be a significant factor in release of heavy metals in sewage sludge amended soils (McBride, 1995). This is supported by the fact that Cd and Zn in sludge are largely associated with organic fractions (Karpanagiotis *et al.,* 1991). The analysis of sewage irrigated soil samples showed that the contents of DTPA extractable micronutrients i.e. Zn, Cu, Fe and heavy metals Ni, Cd, Pb increased appreciably as compared to the tubewell irrigated soils since the sewage effluent contained higher concentration of these elements. In the present study, the Cu (82.93%) and Ni (92.73%) concentrations showed highest percent of increase while Pb (70.47%) showed the lowest percent of increase in sewage irrigated soils than that of tube well irrigated soils. However, Cd was found in soil samples from sewage irrigated fields only. The continuous use of sewage waste water for crop production result in accumulation of trace elements in concentration that may become phytotoxic (Kirkham, 1983). The increase in DTPA extractable metallic cations was also reported by Gupta *et al.,* 1998. The extent of build up of metals in sewage water irrigated soils often depends on sewage water composition and the period of its application(Bansal *et al.,*1992), in this case being 35 years. In the present study, in spite of higher percentage increase in contents of heavy metals in sewage irrigated soils, they were all within the safe limits prescribed by WHO. The inter-metallic correlation as shown in Table 5 reveals significant positive correlation between Fe and Cu, Fe and Pb, Cu and Cd, Cu and Pb. The importance of Fe oxides and hydroxides in reducing the availability of sludge borne metals has been widely acknowledged (Smith 1996, Chaney *et al.,* 2000).

Table 5.Correlation coefficient of heavy metals in soil as influenced by sewage water irrigation

	Fe	Mn	Ni	Cd	Zn	Cu	Pb
Fe	1						
Mn	0.199	1					
Ni	0.209	-0.312	1				
Cd	0.338	0.163	-0.301	1			
Zn	0.313	0.225	0.369	-0.517	1		
Cu	0.625*	0.235	-0.399	0.682**	-0.171	1	
Pb	0.541*	-0.151	0.185	0.026	0.221	0.634*	1

*** Significant at 5% level r>0.532, **Significant at 1% level r>0.661(n=7)**

Bioavailability of metals depends on the type and genetic features of soil forming rocks, soil composition, and amount of organic matter and other chemical and physical properties of soil (Lokeshwari and Chandrappa, 2006). It also depends on the concentrations of anions and chelating ligands present in water, pH, redox status and the presence of adsorbent sediments (Mido and Satake, 2003). Indeed, the concentration of free metal ions in soil solution has been shown to be closely linked to toxicity (Ma *et al.,* 1999; McBride, 2001). This is because the free ion species of cationic metals is the dominant form absorbed by organisms (Kochian, 1991). Lokeshwari and Chandrappa 2006 reported highest bioavailability of Fe for plants and animals in sewage-fed lake water.

CONCLUSION

The present study reveals that the sewage waste water can be used as an alternative to fresh water irrigation and as a source of fertilizers, since it has high contents of both organic matter and nutrients (N, P and K) and even after 35 years of its continuous use, heavy metals were found within the permissible limits in sewage irrigated soils. Nevertheless, the agricultural use of these effluents should be well controlled, because of the persistence of metals in the soil in an extractable and plant available form for many years. For this reason, it is necessary to control the quality of both soils and waste water in order to adjust the dose applied. The present trend of indiscriminate use of untreated sewage water must be controlled. It should be treated before its use on land or it should be used after proper dilution.

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