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Effect of sewage and industrial effluents application on soil physical properties and nutrient uptake by plants in Karnal (Haryana), India

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Abstract
The present investigation, a field survey experiment was conducted during summer season of 2015 in Karnal district of Haryana. The treatments consisted of six irrigation sites; in which five irrigations sites with sewage and industrial effluents and one irrigated site with tube well water. The treatments were replicated three times under randomized block design, with soils and crops plant. Effect of continuous irrigation of sewage and industrial effluent on soil physical properties, nutrients uptake by plants in the adjoining areas of Karnal district of Haryana was ascertained. The organic matter content of sewage and industrial effluents is high and its addition to agricultural soils often improves soil physical properties. The uptake of primary nutrients (N, P and K), micronutrients (Fe, Zn, Mn and Cu) and heavy metals (Pb, Cd, Cr and Ni) in leafy plants grown under sewage and industrial effluents irrigation was higher as compared to cereal crops and then tube well water irrigation plants.

Keywords: effect, sewage, industrial effluents, soil, physical properties, plant and nutrients

Introduction

According to Indian society of soil science (ISSS-2015), the soils of India have been grouped under major soil orders, namely Vertisols (26.62 mha), Aridisols (13.35 mha), Ultisols (8.41 mha), Mollisols (1.64 mha), Alfisols (42.20 m ha), Inceptisols (129.34 mha), Entisols (78.75 m ha) and others (27.97 mha). Each soil group as well as sub-group hasa distinct physical and chemical properties influencing soil-water–plant continuum and thus contributing to distinct advantages and constraints in various operations of crop management resulting in differential productivity. Haryana is one of the most agriculturally important states of India contributes about 7% to the national food grain production with only about 1.33% of geographical area. Soils of Haryana are one the important arable soil types in North India, improving their productivity is considered to be an effective means of ensuring national food security. Most of the soil of Haryana state falls under the aridisols as per the USDA soil taxonomical classification system.

The availability of plant nutrients is becoming scarce due to rise in cost and that of water has always remained uncertain due to its dependence on climate. The situation is getting worse due to competition from other sectors and changing climatic pattern and also due to deteriorating soil quality because of increased anthropogenic activity. It is a matter of great concern that degraded lands form more than 57% of the total reporting area against 17% in the whole world. Hence, pressing need has arisen for managing our precious soil resources for improving and sustaining its various functions so that demand for quality food is met and quality of environment is improved. Previously, agricultural research focused primarily on a specific soil function i.e. medium of crop growth and hence, emphasized on management of soil and inputs for enhancing plant nutrient supply.

The scope of increasing land area for producing food is very limited. Bringing of marginal lands under plough is very risky and may pose threat to fragile ecosystem. Hence, meeting food demand mostly depends upon supply of plant nutrients and water as well as capacity of soil to perform various functions related to nutrient and water cycling environment.

Due to rapid industrialization and urbanization has produced a tremendous increase in the generation of sewage and industrial effluents. It has been used in agriculture for many years as a fertilizer containing beneficial amounts of organic matter and macro and micronutrients.

However, it may containundesirably high concentrations of heavy metals which may have adverse effects oncrops, and ultimately, consumers. They arealso relatively immobile insoil and accumulate in the surface layer of the soil and remainthere almost indefinitely. The available fraction, however, is readily mobilized in the soilenvironment and taken up by the plant roots.The build-up of heavy metals in the soil profile may constitute a hazard not only to plants but also to consumers of crops (Chang *et al.* 1984). *Itai-Itai* disease is caused by dietary intake of Cd and *Minamata* disease is caused by intake of mercury in human. Lead intake in humans causes *encephalopathy*, *schizophrenia* and chromium intake causes cardiovascular diseases, *ulceration* and *carcinoma.* Cadmium also causes *proteinuria, glucosuria* and *aminoaciduria*.

Agricultural uses of sewage and industrial effluents have shown promise for a variety of field crops (e.g. wheat, maize, sorghum, forage grasses) and production of vegetables (e.g. lettuce, cabbage, beans, potatoes, cucumbers (Shiralipour *et al*. 1992) [17]. The organic matter content of sewage and industrial effluents is high and its addition to agricultural soils often improves soil physical properties (Antonious *et al*. 2009) [1]. On the other hand, accumulation of heavy metals by plants grown in sewage and industrial effluents irrigated soilscan be a serious problem that requires continuous monitoring. Risks of soil contamination when sewage and industrial effluents are used as fertilizer or irrigation have been a matter of frequent concern.

Materials and Methods

To evaluate the effect of sewage and industrial effluents on soil physical properties and nutrients uptake by plants, an industrial town of Haryana, namely Karnal was selected. Collection of sewage and industrial effluents from areas falling under city of Karnal. A pumping station is located in the area near the villages Unchasiwana and Ganjogarhig. The Sewage and Industrial effluents are discharged into a linked channel that carries the sewage and industrial effluents. Farmers owning land along this channel are making use of this sewage and industrial effluents for irrigation purposes and the process is going on unknown period of time (informally reported 50 years). Soils of the areas are loamy sand, silty loam and sandy loam nature expressed. There the wheat, berseem, vegetables and seasonal flowers production sites along the channel are irrigated with sewage and industrial effluents. Soil samples from field irrigated with sewage and industrial effluents were collected from five sites at a depth of 0-15 cm and onesoil samples from field irrigated with tube well water was collected from site at a depth of 0- 15 cm. After collection, the sewage and industrial effluents and tube well waters were stored in neutral plastic bottles. Several parameters were measured separately in sewage and industrial effluents like pH and Electrical conductivity (Jackson, 1973) [7], Organic Carbon (Walkley and Black's, 1934) [19], Phosphorus (Olsen *et al.* 1954) [12], Potassium, Calcium, Magnesium and Sodium (Jackson, 1973) [7], Carbonate, Bicarbonate and Chloride (Richards, 1954) [15], Sulphate (Chensin and Yien, 1950) [4], Nitrate (NO_3^-), micronutrients viz. Iron (Fe), Magnesium (Mn), Copper (Cu), Zinc (Zn), and heavy metals viz. Lead (Pb), Nickel (Ni), Cadmium (Cd), Chromium (Cr) were determined by using atomic absorption spectrophotometer (Lindsay and Norvell, 1978) [10] by their standard methods and soil physical properties were analysed separately viz. bulk density (Blake, 1965) [2], porosity, texture (Robinson, 1922) [16], water retention percentage (Bruce and Luxmoore, 1986) [3], hydraulic conductivity (Klute and Dirksen, 1986) [8]. Plants samples were analysed for total nitrogen by calorimetric method (Lindsay and Norvell, 1978) [10], total phosphorus by ammonium vanadomolybdo-phosphoric acid yellow colour method (Koenig and Johnson, 1942) [9], total potassium by flame photometry method (Isaac and Kerber, 1971) [6], micronutrients (Fe, Zn, Mn, Cu) and heavy metals (Pb, Cd, Cr, Ni) by atomic absorption spectro-photometry method (Isaac and Kerber, 1971) [6].

Results and Discussion

The chemical composition of sewage and industrial effluents and tube well waters were assessed for pH, EC, OC, P, K^+, Ca^{2+}, Mg^{2+}, Na^+, CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-,Fe, Mn, Cu, Zn, Pb, Ni, Cd, and Cr contents. (Table.1). the pH, EC, OC of sewage and industrial effluents (8.47-8.52), (1.56-1.71), (0.16-0.14) was higher than the tube well waters (8.27), (1.26), (0.03). All the sewage and industrial effluents and tube well waters were alkaline in reaction. The higher electrical conductivity value of the sewage and industrial effluents indicates that the discharge of chemicals as cations and anions were higher in the sewage and industrial effluents than tube well water. The organic carbon content of sewage and industrial effluents is quite variable depending upon the contributing source, mode of collection and treatment provided. Sewage and industrial effluents are containing dissolved organic and inorganic substances. The concentration of almost all nutrients elements tended to be higher in sewage and industrial effluents respect to tube well water.

Table 1: Chemical composition of sewage and industrial effluents and tube well waters

Parameters	Sewage and Industrial Effluents		Tube well waters
	I st	II nd	
pH	8.47	8.52	8.27
EC (dSm^{-1})	1.56	1.71	1.26
OC (me L^{-1})	0.16	0.14	0.03
P (me L^{-1})	0.29	0.46	0.11
K^+ (me L^{-1})	1.14	2.23	0.10
Ca^{2+} (me L^{-1})	1.99	2.11	1.06
Mg^{2+} (me L^{-1})	5.98	6.39	3.18
Na^+ (me L^{-1})	6.40	8.18	6.31
CO_3^{2-} (me L^{-1})	0.00	0.00	0.00
HCO_3^- (me L^{-1})	5.48	6.58	2.60
Cl^- (me L^{-1})	6.35	7.30	5.88
SO_4^{2-} (me L^{-1})	2.86	3.80	2.27
NO_3^- (me L^{-1})	0.45	0.81	0.42
Fe (me L^{-1})	10.14	6.25	2.56
Mn (me L^{-1})	0.24	0.19	0.15
Cu (me L^{-1})	0.21	0.20	0.19
Zn (me L^{-1})	0.16	0.15	0.12
Pb (me L^{-1})	0.13	0.12	0.10
Ni (me L^{-1})	0.12	0.09	0.02
Cd (me L^{-1})	0.31	0.32	0.30

Effect of sewage and industrial effluents irrigation on soil physical properties

The application of sewage and industrial effluents on the soil affects the physical properties like texture, bulk density, porosity, hydraulic conductivity and water retention percentage of the soil.

Soil texture refers to the weight proportion of the separates for particles less than 2 mm in diameter as determined from a laboratory particle-size distribution. The need for fine distinctions in the texture of the soil layers results in a large number of classes and subclasses of soil texture. The soil texture separates content was found to slightily changes on irrigation with sewage and industrial effluents. The soil particle size depicted that the experimental soils was of loamy sand and sandy loam type. The soils material has a total of 30 percent or more very coarse, coarse, and medium sand but a total of less than 25 percent very coarse and coarse sand, less than 30 percent fine sand, and less than 30 percent very fine sand is known as sandy loam. The soils material has 50 percent or more silt and 12to less than 27 percent clay; or material has 50 to less than 80 percent silt and less than 12 percent clayis known as silt loam. Material has a total of 25 percent or more very coarse, coarse, and medium sand, a total of less than 25 percent very coarse and coarse sand, and less than 50 percent fine sand and less than 50 percent very fine sand; ormaterial has a total of 25 percent or more very coarse and coarse sand and 50 percent or more medium sand is called loamy sand.

Significantly lower bulk density in sewage and industrial effluents irrigated soils was observed than tube well water irrigated soils. This can be attributed to improvement in bulk density in the sewage and industrial effluents irrigated soils due to addition of organic matter, which plays an important role for decreasing soil bulk density. We observed a negative correlation between soil organic matter and bulk density on a soil amended with sewage and industrial effluents irrigation. According to Mathan (1994) [11] and Subramani *et al*. (2014) [18], continuous use of sewage and industrial effluents irrigation recorded lowerbulk density of soils than tube well water irrigated soils.

The porosity of soils irrigated with sewage and industrial effluents was higher as compared to those for the tube well water irrigated soils. This can be attributed to improvement in total porosity in the sewage and industrial effluents irrigated soils due to addition of organic matter, which plays an important role in improving soil porosity. Similar finding was also reported by Mathan (1994) [11], Subramani *et al*. (2014) [18].

The hydraulic conductivity of the sediment will resist the water flow. Small grains area available for flow, low hydraulic conductivity and large grains size showed large area available for flow, high hydraulic conductivity. We recorded significantly increased hydraulic conductivity in sewage and industrial effluents irrigated soils than tube well water irrigated soils. Continuous use of sewage and industrial effluents irrigation recorded improvement in hydraulic conductivity of soils than tube well water irrigated soils. Otis (1984) [13], however, reported that the application of sewage reduced the hydraulic conductivity of soils due to pore clogging by suspended solids. This can be justified as the organic suspended solids may impeded water transmission initially by temporarily plugging soil surface and by clogging of pores; however, the effect of organic matter addition through sewageand industrial effluents on aggregation improves soil structure and enhances hydraulic conductivity. Similar finding was also reported by Mathan (1994) [11], Subramani *et al*. (2014) [18].

The water retention percentage of soils irrigated with sewage and industrial effluents was higher as compared to those for the tube well water irrigated soils. This can be attributed to improvement in total porosity and aggregate stability in the sewage and industrial effluents irrigated soils due to addition of organic matter, organic matter holds 10 times more water its weight, its particles have a charged surface that attracts water so that it adheres to the surface. Organic matter plays an important role in improving soil physical conditions. Rattan *et al*. (2001) [14] observed enhanced available water content in the soils due to continuous application of sewage waters. Similar finding was also reported by Mathan (1994) [11], Subramani *et al*. (2014) [18].

Nutrient uptake by plants

A comparative study of four crops (Be rseem, wheat, marigold and cauliflower) irrigated with sewage and industrial effluents found that when sewage and industrial effluents was applied, there was increase in nutrient uptake compared to grown with tube well water. Similar increases in dry matter were found for those crops irrigated with sewage and industrial effluents. In city, farmers reported increase in overall yields of berseem, wheat, marigold and cauliflower from the use of sewage and industrial effluents. The high nutrient content in sewage and industrial effluents favours the growth of high-value crops such as vegetables. The uptake of nutrients largely depends on crop, variety, soil type and fertility, cropping systems and yield potentials.

In the case of nitrogen, phosphorus and potassium, these wage and industrial effluents irrigated be rseem plants grown on loamy sand soils of Karnal were observed to N, P, K uptake 223 kg ha^{-1}, 35 kg ha^{-1}, 176kg ha^{-1}, which is produce 16.58 t ha^{-1} of total dry matter. Wheat crops N, P, K uptake 79 kg ha^{-1}, 24 kg ha^{-1}, 108 kg ha^{-1} in a loamy sand soils and 74 kg ha^{-1}, 25 kg ha^{-1}, 166 kg ha^{-1} in a sandy loam soil to produce 8.79 t ha^{-1} and 8.97 t ha^{-1} of total dry matter respectively irrigated after sewage and industrial effluents but wheat plants N, P, K uptake 32kg ha^{-1}, 13 kg ha^{-1}, 86kg ha^{-1} in sandy loam soils to produce 7.91 tha^{-1} of total dry matter after irrigation of tube well water. The cauli flowercrop N, P, Kuptake 124kg ha^{-1}, 26 kg ha^{-1}, 75kg ha^{-1} in silty loam soils to produce 5.29 t ha^{-1} of total dry matter after irrigation of sewage and industrial effluents.Marigold plants are uptake N, P, K 321 kg ha^{-1}, 35 kg ha^{-1}, 110 kg ha^{-1}in a sandy loam soils to produce 6.53 t ha^{-1} of total dry matter after sewage and industrial effluents irrigation. The sewage and industrial effluents irrigated plant samples were recorded significantly greater uptake of N, P, K ($Kgha^{-1}$) in plant samples than tube well water irrigated plant samples.

In the case of micronutrients viz. Fe, Zn, Mn and Cu, thesewage and industrial effluents irrigated berseem plants grown on loamy sand soils of Karnal were observed to micronutrients viz., Fe, Zn, Mn and Cu uptake 4401gha^{-1}, 513gha^{-1}, 948 gha^{-1},63gha^{-1}. Wheat crops to micronutrients viz., Fe, Zn, Mn and Cu uptake 1370 gha^{-1}, 250 gha^{-1}, 85 gha^{-1}, 44 gha^{-1} in a loamy sand soils and 1360 gha^{-1}, 230 gha^{-1}, 120 gha^{-1}, 52 gha^{-1}in a sandy loam soilsthrough respectively irrigation after sewage and industrial effluents but wheat plants micronutrients viz., Fe, Zn, Mn and Cu uptake 1170 gha^{-1}, 108 gha^{-1}, 5 gha^{-1}, 21 gha^{-1}in sandy loam soils after irrigation of tube well water. The cauli flower crops micronutrients viz., Fe, Zn, Mn and Cu uptake 1103 gha^{-1}, 335 gha^{-1}, 28 gha^{-1}, 21 gha^{-1} in silty loam soils after irrigation of sewage and industrial effluents. Marigold plants are uptake to micronutrients viz., Fe, Zn, Mn and 3320 gha^{-1}, 407 gha^{-1}, 300 gha^{-1}, 94 gha^{-1} in a sandy loam soils after sewage and industrial effluents irrigation.The sewage and industrial effluents irrigated plant samples were recorded significantly greater uptake of micro nutrients viz., Fe, Zn, Mn, and Cu (gha^{-1}) in plant samples than tube well water irrigated plant samples.

In the case of heavy metals viz. Pb, Cd, Ni, the sewage and industrial effluents irrigated berseem plants grown on loamy sand soils of Karnal were observed to heavy metals viz., Pb, Cd, Ni uptake 31 gha^{-1}, 20 gha^{-1}, 26 gha^{-1}. Wheat crops to heavy metals viz. Pb, Cd, Ni uptake 15 gha^{-1}, 10 gha^{-1}, 75 gha^{-1} in a loamy sand soils and 17 gha^{-1}, 9 gha^{-1}, 44 gha^{-1} in a sandy loam soils through respectively irrigation after sewage and industrial effluents but wheat plants heavy metals viz., Pb, Cd, Ni uptake9 gha^{-1}, 2 gha^{-1}, 17 gha^{-1} in sandy loam soils after irrigation of tube well water. The cauli flower crops heavy metals viz. Pb, Cd, Ni uptake 7 gha^{-1}, 4 gha^{-1}, 26 gha^{-1} in silty loam soils after irrigation of sewage and industrial effluents.Marigold plants are uptake to heavy metals viz. Pb, Cd, Ni uptake 86 gha^{-1}, 22 gha^{-1}, 53 gha^{-1} in a sandy loam soils after sewage and industrial effluents irrigation.The sewage and industrial effluents irrigated plant samples were recorded significantly greater uptake of heavy metals viz. Pb, Cd, Ni (g ha^{-1}) in plant samples than tube well water irrigated plant samples.

Table 2: Physical properties of soils irrigated with sewage and industrial effluents and tube well water

Sites No.	Mechanical Analysis			Texture	Bulk density (Mg m^{-3})	Porosity	Hydraulic Conductivity	Water Retantion
	Sand (%)	Silt (%)	Clay (%)		(Mg m^{-3})	(%)	(cm hr^{-1})	(%)
Site-1	78.20	12.50	9.30	Loamy Sand	1.37	48	0.318	21.75
Site-2	80.90	6.70	12.40	Loamy Sand	1.41	47	0.24	19.75
Site-3	14.00	62.00	24.00	Silty Loam	1.35	45	0.636	17.65
Site-4	68.10	14.50	17.40	Sandy Loam	142	46	0.594	13.45
Site-5	75.10	9.50	15.40	Sandy Loam	1.40	45	0.848	12.65
Site-6	70.10	15.50	14.40	Sandy Loam	1.43	40	0.063	12.45
SE(m)	-	-	-	-	0.003	0.046	0.001	0.065
CD at 5%	-	-	-	-	0.010	0.147	0.003	0.082

Site-1 to 5 (irrigated with sewage and industrial effluents), Site-6 (tube well water),

Sites No.	Crops	Dry Matter	N	P	K	FE	ZN	MN	CU	PB	CD	NI	CR
		(t ha^{-1})	(kg ha^{-1})			(g ha^{-1})							
Site-1	Berseem	16.58	223	35	176	4401	513	948	63	31	24	26	-
Site-2	Wheat	8.79	79	24	108	1370	250	85	44	15	10	75	-
Site-3	Cauliflower	5.29	124	26	75	1103	335	28	21	7	4	26	-
Site-4	Wheat	8.97	74	25	166	1360	230	120	52	17	9	44	-
Site-5	Marigold	6.53	321	35	110	3320	407	300	94	86	22	53	-
Site-6	Wheat	7.91	32	13	56	117	180	5	21	9	2	17	-
Site- (m)		-	0.054	0.066	0.036	0.069	0.16	0.23	0.07	0.32	0.27	0.25	-
CD at 5%		-	0.173	0.211	0.116	0.219	0.52	0.73	0.22	1.03	0.65	0.79	

Table 3: Nutrients and heavy metals uptake in plants after irrigated with sewage and industrial effluents and tube well water.

Sites No.	Crops	Dry Matter	N	P	K	fe	Zn	Mn	Cu	Pb	Cd	Ni	Cr
		(t ha^{-1})	(kg ha^{-1})			(g ha^{-1})							
Site-1	Berseem	16.58	223	35	176	4401	513	948	63	31	24	26	-
Site-2	Wheat	8.79	79	24	108	1370	250	85	44	15	10	75	-
Site-3	Cauliflower	5.29	124	26	75	1103	335	28	21	7	4	26	-
Site-4	Wheat	8.97	74	25	166	1360	230	120	52	17	9	44	-
Site-5	Marigold	6.53	321	35	110	3320	407	300	94	86	22	53	-
Site-6	Wheat	7.91	32	13	56	117	180	5	21	9	2	17	-
Site- (m)		-	0.054	0.066	0.036	0.069	0.16	0.23	0.07	0.32	0.27	0.25	-
CD at 5%		-	0.173	0.211	0.116	0.219	0.52	0.73	0.22	1.03	0.65	0.79	

Conclusion
The results from the sites under study where sewage and industrial effluents is being used for about some decades showed the improvement of soil physical properties and nutrients uptake in plants. Thus, the efficient application of sewage and industrial effluents can effectively increase water resource for irrigation and may prove to be a boon for agriculture production.

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