Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(1): 835-839
Received: 18-11-2018
Accepted: 20-12-2018

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Effect of sewage and industrial effluents application on soil physical properties and nutrients uptake by plants under Faridabad district of Haryana, India

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Abstract
The present investigation, a field survey experiment was conducted during summer season in Faridabad 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 Faridabad district of Haryana was ascertained. The organic suspended solids (organic matter) content of sewage and industrial effluents are 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 fodder plants (berseem) and vegetable plants (tomato) 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 nutrients

Introduction

Faridabad is a leading industrial centre and situated in the National Capital region bordering the Indian Capital and union territory of delhi to its north, gurugram district to west and uttar Pradesh to its east and south. It is the most populous city of Haryana. Geographically district is covering an area of 742.9 sq km. The soils of Faridabad are falls under ustic moisture and hyperthermic soil temperature regimes. Liquid waste substances released by municipal and industries are known as sewage and industrial effluents. Due to ever increasing population, great volume of domestic sewage and industrial effluents is being produced in cities. Indiscriminate disposal of such effluents are the cause for pollution of soil and ground water supplies. 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. 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. 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.

Due to rapid industrialization and urbanization has produced a tremendous increase in the generation of sewage and industrial effluents. However, it may contain undesirably high concentrations of heavy metals which may have adverse effects on crops, and ultimately, consumers. They are also relatively immobile in soil and accumulate in the surface layer of the soil and remain there almost indefinitely. The available fraction, however, is readily mobilized in the soil environment and taken up by the plant roots. 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 cause sencephalopathy, 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 soils can 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.

Method and materials

To evaluate the effect of sewage and industrial effluents on soil physical properties and nutrients uptake by plants, an industrial town of Haryana, namely Faridabad was selected. Collection of sewage and industrial effluents from areas falling under city of Faridabad. A pumping station is located in the area near the villages Barauli, Sururpur, Fatehpur and Quaraisipur. 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. Soils of the areas are sand and sandy loam nature expressed. There the wheat, berseem and tomato 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 one soil sample 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) [13], Potassium, Calcium, Magnesium and Sodium (Jackson, 1973) [7], Carbonate, Bicarbonate and Chloride (Richards, 1954) [15], Sulphate (Chensin and Yien, 1950) [5], Nitrate (NO3−), 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) [3], porosity, texture (Robinson, 1922), water retention percentage (Bruce and Luxmoore, 1986) [4], hydraulic conductivity (Klute and Dirksen, 1986) [8]. Plants samples were analysed for total nitrogen by calorimetric method Lindner (1944), 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 (Lindsay and Norvell, 1978) [10].

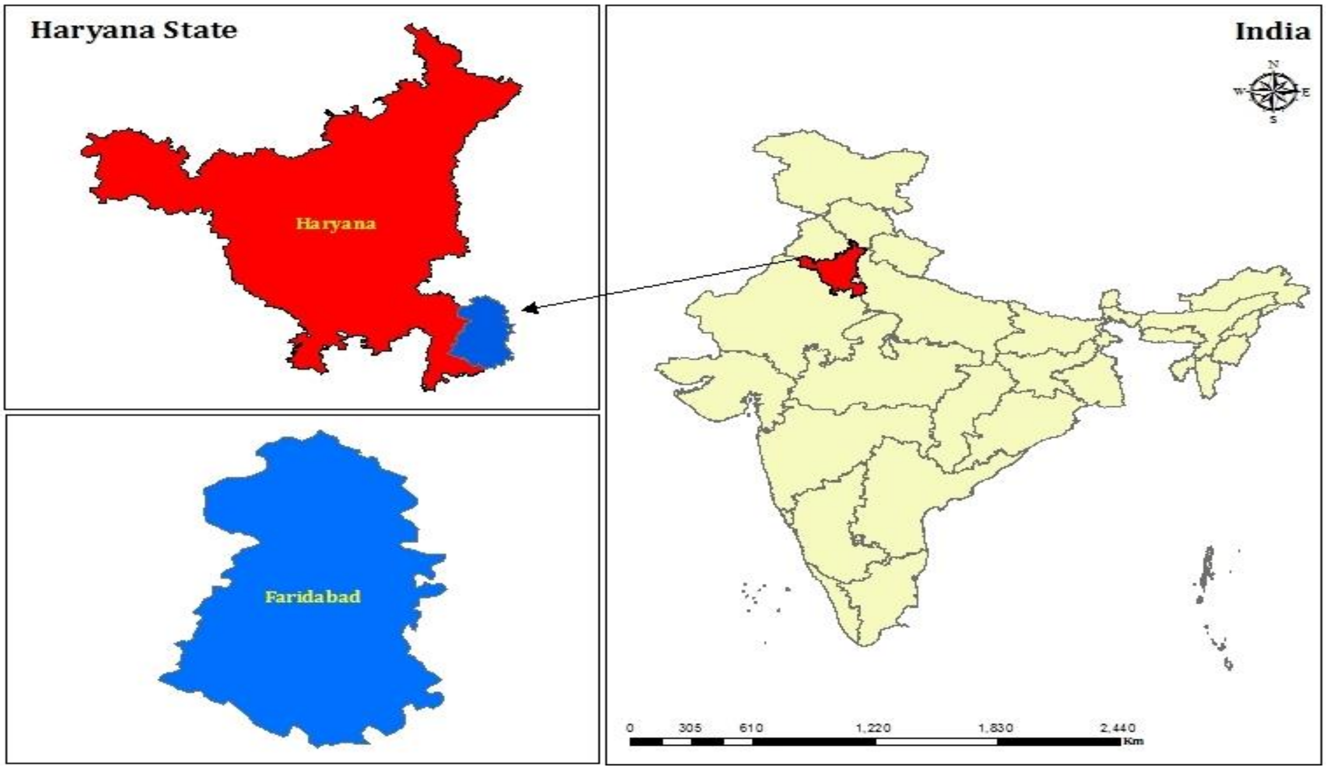

Fig 1: Location Map

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 high electrical conductivity (2.14, 2.56, 2.35dS m^{-1}) 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, a high amount of phosphorus (0.498, 0.478, 0.386 meL^{-1}), potassium (0.41, 0.71, 0.61 meL^-

[1]), calcium (1.68, 2.01, 1.67 meL^{-1}), magnesium(5.00, 6.66, 5.05 meL^{-1}), sodium (14.27, 1.71, 16.07 meL^{-1}), bicarbonate(6.72, 6.13, 5.35 meL^{-1}), chlorine (9.47, 12.05 11.22 meL^{-1}), sulphate (4.65, 6.63, 6.13 meL^{-1}), nitrate (0.19, 0.71, 0.64 meL^{-1}), iron (4.139, 9.889, 10.240 meL^{-1}), manganese (0.181, 1.04, 0.472 meL^{-1}), copper (0.207, 0.191, 0.208 meL^{-1}), zinc (0.154, 0.152, 0.153 meL^{-1}), lead (0.103, 0.106, 0.100 meL^{-1}), cadmium (0.17, 0.14, 0.09 meL^{-1}), nickel (0.29, 0.25, 0.31 meL^{-1}). The organic carbon content (0.14, 0.16, 0.08 meL^{-1}) of sewage and industrial effluents is quite variable depending upon the contributing source of organic suspended solids, 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. So sewage and industrial effluents provide nutrient enriched water supply to the farmer's field. Since some of these effluents are a rich source of plant nutrients, therefore, soil provides the logical sink for their disposal. But many untreated and contaminated sewage and industrial effluents may have high concentration of several heavy metals such as Cd, Ni, Pb and Cr (Arora *et al*., 1985 and Narwal., 1993) [2, 12].

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

Parameters	Sewage and Industrial effluents			Tube well Waters	SE (m)	CD at 5%
	Ist	IInd	IIIrd			
pH	8.41	8.39	8.34	8.20	0.002	0.007
EC (dsm^{-1})	2.14	2.56	2.35	0.38	0.004	0.014
OC (me L^{-1})	0.14	0.16	0.08	0.02	0.001	0.03
P (me L^{-1})	0.498	0.478	0.386	0.086	0.002	0.008
K^+ (me L^{-1})	0.41	0.71	0.61	0.05	0.19	0.068
Ca^{2+} (me L^{-1})	1.68	2.01	1.67	0.13	0.018	0.064
Mg^{2+} (me L^{-1})	5.00	6.66	5.05	0.42	0.17	0.061
Na^+ (me L^{-1})	14.27	16.71	16.07	3.13	0.044	0.154
CO_3^{2-} (me L^{-1})	-	-	-	-	-	-
HCO_3^- (me L^{-1})	6.72	6.13	5.35	0.61	0.009	0.032
Cl^- (me L^{-1})	9.47	12.05	11.22	1.91	0.011	0.033
SO_4^{2-} (me L^{-1})	4.65	6.63	6.13	1.12	0.012	0.040
NO_3^- (me L^{-1})	0.19	0.71	0.64	0.05	0.009	0.031
Fe (me L^{-1})	4.139	9.889	10.24	4.07	0.001	0.005
Mn (me L^{-1})	0.181	1.04	0.472	0.152	0.001	0.002
Cu (me L^{-1})	0.207	0.191	0.208	0.137	0.001	0.003
Zn (me L^{-1})	0.154	0.152	0.153	0.124	0.001	0.003
Pb (me L^{-1})	0.103	0.106	0.100	0.094	0.001	0.002
Ni (me L^{-1})	0.29	0.25	0.31	0.18	0.001	0.003
Cd (me L^{-1})	0.17	0.14	0.09	0.04	0.001	0.004
Cr (me L^{-1})	2.14	2.56	2.35	0.38	0.004	0.014

Site Ist = Barauli, Site IInd = Sururpur, Site IIIrd= Fatehpur and Site tube wel water = Quaraisipur

Effect of sewage and industrial effluents irrigation on soil physical properties

When 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. Textural analysis of the soil in the experimental area revealed a sand and sandy loam soil with sand, silt and clay almost have the different percentages of soil separates. Sandy loam soil was the dominant under the selective experimental soil (Table 2). The soil texture separates content was found to slightly changes on irrigation with sewage and industrial effluents. The soil particle size depicted that the experimental soils was of sandy loam and sand type.

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

Sites No.	Mechanical Analysis			Texture (Mg m^{-3})	Bulk density (%)	Porosity (cm hr^{-1})	Hydraulic Conductivity	Water Retantion
	Sand (%)	Silt (%)	Clay (%)					
Site-1	68.00	15.00	17.00	Sandy Loam	1.41	45	0.679	16.97
Site-2	71.00	14.00	13.00	Sandy Loam	1.42	46	0.707	15.97
Site-3	73.00	12.00	15.00	Sandy Loam	1.38	47	0.636	15.21
Site-4	69.00	14.00	17.00	Sandy Loam	1.44	45	1.591	17.97
Site-5	90.10	6.00	3.90	Sand	1.48	44	2.334	11.58
Site-6	72.10	14.50	13.40	Sandy Loam	1.51	42	0.212	10.28
SE(m)	-	-	-	0.085	-	0.003	0.79	0.002
CD at 5%	-	-	-	-	0.010	NS	0.007	0.271

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

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 (t ha-')	N	P	K	Fe	Zn	Mu	Cu	Pb	Cd	Ni	Cr
			(kg ha-')			(cf. ha-')							
Site-1	Berseem	1526	16434	5035	25217	4251	520	835	66	47	19	222	
Site-2	Wheat	723	8638	29A4	107.	3540	182	65	41	13	7	78	
Site-3	Wheat	833	88.	2633	116.	3620	154	122	45	14	8	71	
Site-4	Tomato	16.	200.	7165	26836	2532	932	166	377	33	20	20	
Site-5	Wheat	9.	7178	2534	110.	2100	192	82	53	16	8	78	
Site-6	Wheat	8.	42.	1436	92.	1140	112	15	4	7	3	5	
Mira)		-	0.050	0.073	0.036	434	238	0.327	0.092	0.336	0.29	0.314	
CD at 5%		-	0.160	0.233	0.111	1535	0.760	1.	0.293	1.064	0.93	1.	

We recorded significantly lower bulk density in sewage and industrial effluents irrigated soils 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 Subramani *et al*., (2014) [18], continuous use of sewage and industrial effluents irrigation recorded lower bulk 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].

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), 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 suspended solids (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) 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].

Nutrients Uptake by Plants

A comparative study of three crops (berseem, wheat and tomato) 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 and tomato 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, the sewage and industrial effluents irrigated tomato plants grown on sandy loam soils of Faridabad were observed to N, P, K uptake 200.13 kg ha^{-1}, 73.65 kg ha^{-1}, 268.96 kg ha^{-1}, which is produce 16.01 t ha^{-1} of total dry matter. In the all selected crops, tomato gave a higher total dry matter content and higher content of primary nutrients with sewage and industrial effluents irrigation. Wheat crops N, P, K uptake 86.38, 88.05 and 73.78 kg ha^{-1}, 29.44,26.93 and 25.94 kg ha^{-1}, 106.61, 116.09 and 109.63 kg ha^{-1} in a sandy loamy to sandy soils to produce 7.83, 8.93 and 8.68 t ha^{-1} of total dry matter respectively irrigated after sewage and industrial effluents but wheat plants N, P, K uptake 42.17 kg ha^{-1}, 14.56 kg ha^{-1}, 92.17 kg ha^{-1} in sandy loam soils to sandy soils to produce 7.53 tha^{-1} of total dry matter after irrigation of tube well water. The berseem crop N, P, Kuptake 164.94 kg ha^{-1}, 50.75 kg ha^{-1}, 252.17 kg ha^{-1} in sandy loam soils to produce 15.86 t ha^{-1} of total dry matter after irrigation of sewage and industrial effluents. The sewage and industrial effluents irrigated plant samples were recorded significantly greater uptake of N,P,K (kg ha^{-1}) in plant samples than tube well water irrigated plant samples. In the case of micronutrients (viz., Fe, Zn, Mn and Cu) analysis observed that higher uptake of Fe (4251 gha^{-1})and Mn (835 gha^{-1}) by berseem plant and higher uptake of Zn (932 gha^{-1}) and Cu (377 gha^{-1}) by tomato plants. The micronutrients (viz., Fe, Zn, Mn and Cu) of sewage and industrial effluents irrigated plants grown on sandy loam to sandy soils of Faridabad 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 sandy loam soils of Faridabad were observed to heavy metals viz., Pb, Cd, Ni uptake 47 gha^{-1}, 19 gha^{-1}, 222 gha^{-1}. Wheat crops to heavy metals viz., Pb, Cd, Ni uptake 13, 14 and 16 gha^{-1}, 7, 8 and 8 gha^{-1}, 78,71 and 78 gha^{-1} in a sandy loamy to sand soils through respectively irrigation after sewage and industrial effluents but wheat plants heavy metals viz., Pb, Cd, Ni uptake 7 gha^{-1}, 3 gha^{-1}, 5 gha^{-1} in sandy loam soils after irrigation of tube well water. The tomato plants heavy metals viz., Pb, Cd, Ni uptake 33 gha^{-1}, 20 gha^{-1}, 20 gha^{-1} in sandy loam soils after irrigation of sewage and industrial effluents.During the analysis of research observed that higher uptake of Pb and Ni by berseem plant and higher uptake of Cd by tomato plants followed by berseem plants. 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.

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.

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