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Composition of Sewage and Non-Sewage Water of Different District of Haryana, India

Sushil*, R. S. Garhwal and Dinesh

Department of Soil Science, CCS Haryana Agricultural University Hisar-125004, India

**Corresponding author*

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ABSTRACT

Raw sewer and tube well water samples were collected from various sewer disposal sites and nearby fields in Kurukshetra, Kaithal, Narwana, Jind and Charkhi Dadri (Haryana) where these waters are directly used for irrigating the crops. The mean values of pH (8.49), electrical conductivity (1.91 dSm^{-1}), chemical oxygen demand (762.0 mg L^{-1}) and biological oxygen demand (227.5 mg L^{-1}) were highest in sewage water of Kaithal. The highest mean value of Ca^{2+} (4.84 mgL^{-1}) was observed in the sewage water of Charkhi Dadri while Mg^{2+} (7.41 mg L^{-1}) and Na^{+} (10.50 mg L^{-1}) were recorded highest in the sewage water of Narwana. The mean value of K^{+} content was highest (2.07 mg L^{-1}) in the sewage water of Jind district. The mean values of anions like carbonates (CO_3^{2-} 0.90 mg L^{-1}) and bicarbonates (HCO_3^{-} 4.52 mg L^{-1}) were highest in district Jind, sulphate (SO_4^{2-}0.74 mg L^{-1}) in district Kaithal and Cl^{-} (12.06 mg L^{-1}) in the sewage water of Narwana. Highest mean value of zinc (0.19 mg L^{-1}) content was observed in the sewage water of Kaithal. The highest mean value of copper (0.20 mg L^{-1}) was observed in sewage water of Kurukshetra and Kaithal district. The highest mean value of Fe (6.45 mg L^{-1}) was observed in the sewage water of Kurukshetra district. The highest mean value of Mn (0.48 mg L^{-1}) was observed in the sewage water of Kaithal district. The mean value of cadmium (Cd) was highest in the sewage water of Jind (0.31 mg L^{-1}). Chromium (Cr) content was absent in the sewage and non-sewage water collected from all the sites in Haryana. The mean value of lead (Pb) (0.13 mg L^{-1}) was highest in the sewage water of Kaithal. The mean value of cobalt (Co) (0.06 mg L^{-1}) was highest in the sewage water of Kurukshetra district.

Introduction

Population growth, especially in the developing countries, has increased the demand for a huge quantity of water for domestic, municipal, and industrial sectors. With the increasing scarcity of fresh water resources that are available to agriculture, the use of urban waste water for irrigation is increasing. The growth of towns, cities, and development of industries by 19^{th} century leads to problem of disposal of sewage, which encouraged the use of sewage wastewater in irrigation. Waste water is composed of 99.9 per cent water and 0.1 per cent of other materials (suspended colloidal and dissolved solids). The practice of use of domestic sewage in farming is becoming prevalent as the demand of water is increasing. Due to fast industrial development and the growth of population, the availability of water decreases day-to- day. This increase in the population has led to increased demand of water and the increased generation of waste water. The high quality water is preserved and the lower quality is used for agricultural purposes.

Irrigation with sewage became a prevalent practice in arid and semiarid regions, where it was readily available and economic to freshwater. The final aim of sewage management is the protection of the environment which the ultimate goal of wastewater management in a manner corresponding with public health and socio-economic concerns. The increase in world population has not only put pressure on limited water resources but also increased the volume of waste generation (Darvishi *et al.*, 2010). The growing competition for scarce water resources, coupled with law of limiting ground water pumping, has led to utilization of low quality water in irrigated agriculture.

An estimated 38,354 million litres per day of sewage water is generated in major cities of India. The sewage water is a potential water resource with stability of water quantity and reliable supply. Nutrients and water being the most critical inputs in agriculture, harvesting the nutrients and irrigation potential of sewage water are of prime importance for maximizing the food, fodder and fuel production. Sewage water is a rich source of both beneficial and harmful elements. Many small to medium scale industries operating in peri-urban residential areas of cities dispose their contaminated effluents directly in sewage system.

The composition of sewer waters is dependent on the composition and quantity of the industrial effluents discharged into the sewer systems (Kirkham, 1974; Larsen *et al.*, 1975; Arora *et al.*, 1985) thus, the resultant sewer water contains variable amounts of plant nutrients, toxic metals, oils, grease, fat and soluble salts. The raw sewer water gets entry into the agricultural fields and may affect the soil, plants, human and animal health, depending upon its composition (Anderson and Nilsson, '1973; Gupta *et al.*, 1986, 1994; Narwal *et al.*, 1990).

Opportunities exist as sewage effluents from municipal origin are rich in organic matter and also contain appreciable amounts of major and micronutrients (Feign *et al.*, 1991; Pescod, 1992; Gupta *et al.*, 1998; Brar *et al.*, 2000). Accordingly nutrient levels of soils are expected to improve considerably with continuous irrigation with sewage (Baddesha *et al.*, 1986; Narwal *et al.*, 1993; Brar *et al.*, 2000). The increased competition for freshwater among urban and semi-urban centres, industries and agriculture, particularly irrigated agriculture under severe pressure as irrigation has been the largest user of water (Van der Hoek *et al.*, 2002). Therefore, the use of treated, partially-treated or untreated wastewater has received more attention (Yao *et al.*, 2013). Bouwer (1994) stressed about the need of water management on local, regional, national and international level. Keeping the above facts in view, the study was undertaken to evaluate the chemical composition of sewage and non-sewage water of peri-urban area of Haryana state so as to use this water for agricultural purposes.

Materials and Methods

Study area

The present study has been conducted in Haryana state which is one the northern state of India. The geographical location of the state is between 27°39' to 30°35' N latitude and 74°28' and 77°36' E longitude. In present study, five districts were selected for the present study namely (i) Kurukshetra, (ii) Kaithal, (iii) Narwana, (iv) Jind and (v) Charkhi Dadri. In each district, four sites were selected for the sampling of sewage and non-sewage sources of water. From each site two sample of sewage and two sample of non-sewage water were collected from discharge out-lets. The sewage water sample were collected in duplicate, i.e. one already treated with a mixture of 1:1 HNO_3 and distilled water to avoid adsorption of heavy metals on the walls of bottle and in another un-acidified bottle rinsed with only distilled water. Un-acidified sewage water samples were used for the determination of pH, EC, COD, BOD, soluble cations and anions, micro-nutrients and heavy metals.

Sample analysis

The pH was determined by systronic digital pH meter (Jackson, 1973). Electrical conductivity was estimated in the filtered sample with the help of Elico conductivity meter bridge (Jackson, 1973). Biological oxygen demand was calculated by multiplying organic matter content of sewage water by 0.711 (Schulz, 1938). The chemical oxygen demand (COD) of sewage water was determined by open reflux method (Tandon, 1998). Ca^{2+} was estimated by compleximeteric titration with standard 0.01 N EDTA and pH-12 obtained with the help of NaOH by using ammonium purpurate as indicator, when pink colour of the solution changed to purple (Jackson, 1973). Mg^{2+} was estimated by titrating with 0.01N EDTA by buffering the solution to pH 10 with NH_4Cl-NH_4OH buffer by using Erichrome black T indicator (Jackson, 1973). Na^+ was determined by flame photometer with the help of a standard curve outlined by (Jackson, 1973). K^+ was determined by flame photometer with the help of a standard curve outlined by (Jackson, 1967). CO_3^{2-} and $HCO_3^{2-}$was estimated by titrating a known volume of the sewage water with standard H_2SO_4 first in the presence of phenolphthalein and then with methyl red indicator (Richards, 1954). Cl^- was determined by titrating with standard (0.02 N) $AgNO_3$ solution using potassium chromate as indicator. The end point was obtained when white precipitate of AgCl change to brick red colour suggesting complete precipitation of chloride with Ag (Richards, 1954). SO_4^{2-} was determined by EDTA-titration method as described by (Chesnin and Yien, 1951). Total Zn, Cu, Mn, Fe, Cd, Pb, Co, and Cr were estimated in acidified digested samples using atomic absorption spectrophotometer (AAS). The statistical analysis was accomplished by Statistical Software Package for Agricultural Research Workers (Sheoran *et al.,* 1998).

Results and Discussion

Chemical and biological composition of sewage and non-sewage water in some cities of Haryana is presented in table 1. The pH value of sewage water was found higher (8.49 to 8.58) in the sewage water of Kaithal followed by Kurukshetra (8.31 to 8.36), Narwana (8.10 to 8.40), Jind (8.00 to 8.42) and Charkhi Dadri (8.00 to 8.12). The mean pH value of the sewage water collected from all the sites was higher (8.54) as compared to the pH of non-sewage water (8.22). The pH of sewage water ranged from 8.00 to 8.58 whereas it was ranged from 7.80-8.28 in non-sewage water. The EC value of sewage water was found higher (1.63 to 2.18 dSm^{-1}) in the sewage water of Kaithal followed by Kurukshetra (1.51 to 1.27 dSm^{-1}), Narwana (1.08 to 1.57 dSm^{-1}), Jind (1.05 to 1.63 dSm^{-1}) and Charkhi Dadri (1.04 to 1.13 dSm^{-1}). The mean EC value of the sewage water collected from all the sites was higher (1.91 dSm^{-1}) as compared to the EC of non-sewage water (0.34 dSm^{-1}). Electrical conductivity of sewage water ranged from 1.04 to 2.18 dSm^{-1} where as it was ranged from 0.19 to 0.35 dSm^{-1} in non-sewage water. Similar results were reported by Singh *et al.,* (2017) during their survey of five sites in Haryana and revealed that pH and electrical conductivity of sewage and industrial effluents irrigated soils was much higher than tube well water irrigated soils. Also in the present study the sewage water had the pH in the range from 8.00 to 8.58 and when it was applied in the soils, it resulted into slight decrease in the pH (7.70 to 8.40) at 0-15 cm depth while at higher depth

15-30 cm it was ranged from 7.75 to 8.70. The decrease in the soil pH due to sewage water might be ascribed to the reason that sewage water is slightly alkaline in nature. The EC of sewage water ranged from 1.1 to 3.8 dSm^{-1} which may cause salinity in soil and ultimately restricting the plant growth (Antil, 2012). Similar results were corroborated by Yadav *et al.,* (2003), Abril (2005), Hussain (2005) and Sial *et al.,* (2006).

The COD value of sewage water was found higher (652.00 to 872.00 mg L^{-1}) in the sewage water of Kaithal followed by Kurukshetra (470.00 to 510.00 mg L^{-1}), Narwana (470.00 to 628.00 mg L^{-1}), Jind (460.00 to 485.00 mg L^{-1}) and Charkhi Dadri (450.00 to 467.50 mg L^{-1}). The mean COD value of the sewage water collected from all the sites was higher (762.00 dSm^{-1}) as compared to the COD of non-sewage water (172.50 dSm^{-1}). The COD of sewage water ranged from 450-872 mg L^{-1} whereas it was ranged from 92-180 mg L^{-1}in non-sewage water.

The BOD value of sewage water was found higher (190.00 to 250.00 mg L^{-1}) in the sewage water of Kaithal followed by Kurukshetra (220.00 to 235.00 mg L^{-1}), Narwana (150.00 to 160.00 mg L^{-1}), Jind (120.00 to 180.00 mg L^{-1}) and Charkhi Dadri (120.00 to 140.00 mg L^{-1}). The mean value of BOD in sewage water was found higher (227.5 mg L^{-1}) in Kaithal followed by Kurukshetra (220.0 mg L^{-1}), Narwana (155.0 mgL^{-1}), Jind (150.0 mg L^{-1}) and Charkhi Dadri (130.0 mg L^{-1}). The mean BOD of the sewage water collected from all the sites was higher (227.50 mg L^{-1}) as compared to the BOD (77.50 mg L^{-1}) of non-sewage water. The BOD of sewage water ranged from 120-250 mg L^{-1} whereas it was ranged from 40 to 80 mg L^{-1} in non-sewage water. The BOD of sewage water ranged from 120-250 mg L^{-1} and it was found higher as compared to the permission limit (100 mg L^{-1}) prescribed for the effluent to be discharged on land for irrigation (100 mg L^{-1}, ISI Standard, 1982). These results corroborated with the findings of Arora *et al.,* (1985) for municipal waste water of Ludhiana and according to Yadav *et al.,* (2003) and Karthikeyan and Singh (2004) for sewage waters from different districts of Haryana State. Similar results were also reported by Dubey *et al.,* (2007).

Water soluble cations and anions in sewage and non-sewage water

Sewage water contains all the cations and anions in higher amounts as compared to non-sewage water. The cations like Ca^{2+}, Mg^{2+}, Na^+ and K^+ in sewage water ranged from 2.16 to 5.12, 5.12 to 7.84, 5.69 to 11.43 and 0.64 to 2.29 mg L^{-1}, respectively, while these were ranged from 1.15 to 2.10, 2.55 to 4.65, 2.63 to 5.60 and0.25 to 0.52 mg L^{-1} in non-sewage water, respectively. Similar results were reported by Yadav *et al.,* (2003), Azevedo *et al.,* (2005), Nayan *et al.,* (2012), Blum *et al.,* (2013).

The highest mean value of Ca^{2+} (4.84 mgL^{-1}) was observed in the sewage water of Charkhi Dadri while Mg^{2+} (7.41 mg L^{-1}) and Na^+ (10.50 mg L^{-1}) were recorded highest in the sewage water of Narwana. The mean value of K^+ content was higher (2.07 mg L^{-1}) in the sewage water of Jind district. Sodium content were found highest (10.50 mg kg^{-1}) in the soils irrigated with sewage water in Narwana and lowest (6.56 mg kg^{-1}) in Kurukshetra.

The mean values of anions like (CO_3^{2-} 0.90 mg L^{-1}) and (HCO_3^- 4.52 mg L^{-1}) were highest in district Jind, sulphate (SO_4^{2-} 0.74 mg L^{-1}) in district Kaithal and Cl^- (12.06 mg L^{-1}) in the sewage water of Narwana. All the anions like CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-} in sewage water ranged from 0.20 to 0.98, 2.45 to 4.56, 5.64 to 12.47 and 1.68 to 3.46 mg L^{-1} respectively, while the non-sewage water contains 0.11 to 0.33, 0.42 to 2.85, 1.54 to 5.87 and 0.21 to 0.97 mg L^{-1} respectively. Both the ions i.e. sodium and chloride are meant for specific ion toxicity. These ions from soil or water can be accumulated in the root zone of the sensitive plants and can cause enough toxicity which ultimately reduces the yield (Ayers and Wescott, 1985). However, in present study the sodium (2.63 to 5.60 mg L^{-1}) and chloride ions (5.64 to 12.47 mg L^{-1}) were found safe as per the permissible limit given by Azul (2002) (Table 1). The sulphates ranged from 1.68 to 3.46 mg L^{-1} in the sewage water of different cities in Haryana but within the permissible limit (Table 5).

Table.1 Chemical and biological composition of sewage and non-sewage water in some cities of Haryana

Location	Ph		EC (dSm^{-1})		COD (mg L^{-1})		BOD (mg L^{-1})	
	Sewage	Non-Sewage	Sewage	Non-sewage	Sewage	Non-sewage	Sewage	Non-sewage
Kurukshetra-1	8.36	8.28	1.51	0.32	510.00	180.00	250.00	70.00
Kurukshetra-2	8.31	8.10	1.27	0.30	470.00	165.00	190.00	50.00
Mean	**8.34**	**8.19**	**1.39**	**0.31**	**490.00**	**172.50**	**220.00**	**60.00**
Kaithal-1	8.49	8.00	1.63	0.29	652.00	110.00	220.00	75.00
Kaithal-2	8.58	8.24	2.18	0.32	872.00	130.00	235.00	80.00
Mean	**8.54**	**8.12**	**1.91**	**0.31**	**762.00**	**120.00**	**227.50**	**77.50**
Narwana-1	8.40	8.19	1.57	0.32	628.00	128.00	160.00	80.00
Narwana-2	8.10	8.24	1.08	0.35	470.00	145.00	150.00	40.00
Mean	**8.25**	**8.22**	**1.33**	**0.34**	**549.00**	**136.50**	**155.00**	**60.00**
Jind-1	8.00	7.96	1.05	0.27	510.00	108.00	120.00	60.00
Jind-2	8.42	7.81	1.63	0.23	460.00	92.00	180.00	80.00
Mean	**8.21**	**7.89**	**1.34**	**0.25**	**485.00**	**100.00**	**150.00**	**70.00**
Charkhi Dadri-1	8.12	7.80	1.21	0.19	485.00	150.00	120.00	40.00
Charkhi Dadri-2	8.00	7.93	1.04	0.24	450.00	160.00	140.00	60.00
Mean	**8.06**	**7.87**	**1.13**	**0.22**	**467.50**	**155.00**	**130.00**	**50.00**
Range	8.00 - 8.58	7.80-8.28	1.04-2.18	0.19-0.35	450-872	92-180	120-250	40-80

Table.2 Cation and anion composition of sewage and non-sewage water in different cities of Haryana

Location	Cations (mg L^{-1})								Anions (mg L^{-1})							
	Ca^{2+}		Mg^{2+}		Na^{+}		K^{+}		CO_3^{2-}		HCO_3^{-}		Cl^{-}		SO_4^{2-}	
	SW	NSW	SW	NSW	SW	NSW	SW	NSW	SW	NSW	SW	NSW	SW	NSW	SW	NSW
Kurukshetra-1	4.72	1.54	7.68	3.24	7.42	2.70	2.15	0.25	0.34	0.15	3.10	0.52	7.35	1.57	3.45	0.84
Kurukshetra-2	4.24	1.23	5.12	3.58	5.69	3.10	1.96	0.52	0.21	0.11	2.45	0.42	5.64	1.72	2.83	0.64
Mean	4.48	1.39	6.40	3.41	6.56	2.90	2.06	0.39	0.28	0.13	2.78	0.47	6.50	1.65	3.14	0.74
Kaithal-1	2.38	1.50	6.56	3.05	9.36	2.63	1.56	0.50	0.61	0.33	4.21	2.85	8.24	2.05	3.46	0.97
Kaithal-2	2.16	1.21	6.25	2.98	5.97	2.87	1.31	0.35	0.42	0.28	3.35	1.22	6.68	1.54	3.12	0.84
Mean	2.27	1.36	6.41	3.02	7.67	2.75	1.44	0.43	0.52	0.31	3.78	2.04	7.46	1.80	3.29	0.91
Narwana-1	3.55	1.32	7.84	3.98	11.43	5.60	0.85	0.40	0.84	0.12	4.12	2.65	12.47	5.87	2.61	0.25
Narwana-2	2.64	1.15	6.97	3.69	9.57	4.87	0.64	0.35	0.55	0.21	3.85	2.55	11.64	4.13	2.39	0.36
Mean	3.10	1.24	7.41	3.84	10.50	5.24	0.75	0.38	0.70	0.17	3.99	2.60	12.06	5.00	2.50	0.31
Jind-1	4.27	1.95	6.54	3.20	10.12	3.10	1.84	0.34	0.81	0.21	4.56	2.45	9.74	3.95	2.71	0.52
Jind-2	3.86	2.10	5.18	4.65	8.64	2.68	2.29	0.41	0.98	0.19	4.48	2.34	7.46	3.67	3.01	0.33
Mean	4.07	2.03	5.86	3.93	9.38	2.89	2.07	0.38	0.90	0.20	4.52	2.40	8.60	3.81	2.86	0.43
Charkhi Dadri-1	5.12	1.22	7.45	2.55	8.91	4.20	1.34	0.25	0.34	0.11	4.51	1.68	6.95	2.74	1.68	0.27
Charkhi Dadri-2	4.56	1.65	6.78	3.41	8.72	3.54	1.12	0.52	0.20	0.17	3.20	1.53	5.81	1.56	2.05	0.21
Mean	4.84	1.44	7.12	2.98	8.82	3.87	1.23	0.39	0.27	0.14	3.86	1.61	6.38	2.15	1.87	0.24
Range	2.16-5.12	1.15-2.10	5.12-7.84	2.55-4.65	5.69-11.43	2.63-5.60	0.64-2.29	0.25-0.52	0.20-0.98	0.11-0.33	2.45-4.56	0.42-2.85	5.64-12.47	1.54-5.87	1.68-3.46	0.21-0.97

SW-sewage water, NSW-non-sewage water

Table.8 Micro-nutrients and heavy metals in sewage and non-sewage water of different cities in Haryana

Location	Micro-nutrients (mg L^{-1})								Heavy metals (mg L^{-1})							
	Zn		Cu		Fe		Mn		Cd		Cr		Pb		Co	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
Kurukshetra-1	0.13	0.03	0.20	0.03	6.17	0.02	0.14	0.00	0.31	0.00	0.00	0.00	0.13	0.01	0.05	0.00
Kurukshetra-2	0.10	0.02	0.20	0.01	6.73	0.01	0.23	0.00	0.29	0.00	0.00	0.00	0.11	0.01	0.06	0.00
Mean	0.12	0.03	0.20	0.02	6.45	0.02	0.19	0.00	0.30	0.00	0.00	0.00	0.12	0.01	0.06	0.00
Kaithal-1	0.20	0.01	0.19	0.01	4.28	0.01	0.43	0.01	0.25	0.00	0.00	0.00	0.13	0.01	0.03	0.00
Kaithal-2	0.18	0.01	0.20	0.01	3.12	0.00	0.52	0.01	0.28	0.00	0.00	0.00	0.12	0.01	0.03	0.00
Mean	0.19	0.01	0.20	0.01	3.70	0.01	0.48	0.01	0.27	0.00	0.00	0.00	0.13	0.01	0.03	0.00
Narwana-1	0.08	0.01	0.23	0.03	4.30	0.01	0.13	0.00	0.22	0.00	0.00	0.00	0.09	0.00	0.01	0.00
Narwana-2	0.10	0.01	0.14	0.01	5.12	0.00	0.22	0.00	0.19	0.00	0.00	0.00	0.10	0.00	0.01	0.00
Mean	0.09	0.01	0.19	0.02	4.71	0.01	0.18	0.00	0.21	0.00	0.00	0.00	0.10	0.00	0.01	0.00
Jind-1	0.11	0.02	0.12	0.01	3.56	0.01	0.16	0.00	0.30	0.00	0.00	0.00	0.14	0.02	0.01	0.00
Jind-2	0.12	0.02	0.14	0.02	2.11	0.02	0.22	0.00	0.31	0.00	0.00	0.00	0.11	0.00	0.02	0.00
Mean	0.12	0.02	0.13	0.02	2.84	0.02	0.19	0.00	0.31	0.00	0.00	0.00	0.12	0.01	0.02	0.00
Charkhi Dadri-1	0.14	0.02	0.11	0.01	3.18	0.01	0.31	0.00	0.18	0.05	0.00	0.00	0.08	0.01	0.04	0.00
Charkhi Dadri-2	0.13	0.01	0.13	0.01	4.08	0.01	0.28	0.00	0.20	0.00	0.00	0.00	0.07	0.03	0.03	0.00
Mean	0.14	0.02	0.12	0.01	3.63	0.01	0.30	0.00	0.19	0.03	0.00	0.00	0.08	0.02	0.04	0.00
Range	0.08-0.20	0.01-0.03	0.11-0.23	0.01-0.03	2.11-6.73	0.00-0.02	0.13-0.52	0.00-0.01	0.18-0.31	0.00-0.05	0.00-0.00	0.00-0.00	0.07-0.14	0.00-0.03	0.01-0.06	0.00-0.00

Table.3 Correlation of EC with pH, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, CO_3^{2-} and HCO_3^{2}

Variables	Pearson Correlation Coefficient	P value
pH	0.739*	0.0002
Cl^-	0.942**	<.0001
SO_4^{2-}	0.976**	<.0001
Ca^{2+}	0.964**	<.0001
Mg^{2+}	0.966**	<.0001
Na^+	0.965**	<.0001
K^+	0.966**	<.0001
CO_3^{2-}	0.890**	<.0001
HCO_3^{2-}	0.881**	<.0001

*Significant at P = 0.05 level; ** Significant at P = 0.0001 level

Table.4 Correlation of pH with EC, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, CO_3^{2-}, and HCO_3^{2}

EC	**0.739***	**0.0002**
Cl^-	0.860**	<.0001
SO_4^{2-}	0.768**	<.0001
Ca^{2+}	0.842**	<.0001
Mg^{2+}	0.796**	<.0001
Na^+	0.823**	<.0001
K^+	0.827**	<.0001
CO_3^{2-}	0.888**	<.0001
HCO_3^{2-}	0.912**	<.0001

*Significant at P = 0.05 level; ** Significant at P = 0.0001 level

Table.5 Tolerance limits for inland surface water, Class – E (irrigation, industrial cooling or controlled waste disposal)

S No.	Characteristic	Values in present study (mg L^{-1})	Tolerance limit	Inference
1.	Sulphates (SO_4^{2-}) (max.)	1.68-3.46	1000	In limit
2.	Chlorides (Cl^-) (max.)	5.67-12.47	600	In limit

Source: Indian Standards (1982)

Table.6 Micronutrient status of sewage water in Kaithal district

Micro-nutrient	Sewage water (mg L^{-1})	Permissible limit (mg L^{-1})	Inference
Zinc	0.19	<2.0	In limit
Copper	0.20	0.20	In limit
Manganese	0.43	0.20	Higher

Table.7 Correlation among organic matter at 0-15 cm of soil with the heavy metals present in sewage water

Variables	CEC [cmol (+) kg^{-1}]	Organic carbon (%)	Cd	Pb	Co
			(mg L^{-1})		
CEC [cmol (+) kg^{-1}]	1				
Organic carbon (%)	0.832^{NS}	1			
Cd	0.569^{NS}	0.879^{*}	1		
Pb	0.405^{NS}	0.831^{NS}	0.862^{NS}	1	
Co	0.814^{NS}	0.571^{NS}	0.252^{NS}	0.065^{NS}	1

*Significant at P = 0.05 level

Correlation of EC with pH, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, CO_3^{2-} and HCO_3^{2-}

The EC values of sewage water collected from all the sites under study have strongly positive correlation with pH, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, CO_3^{2-}, and HCO_3^{2-}.

The pH of sewage water is significantly and positively correlated with EC ($P \leq 0.05$) while EC was positively correlated with all the cations and anions ($P \leq 0.0001$) level depicting that an increase in the soluble anions and cations resulted an increase in the EC of the sewage water while the EC of the non-sewage water was quite low as compared to EC of the sewage water from all the sites under study (Table 3).

Correlation of pH with EC, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, CO_3^{2-}, and HCO_3^{2-}

The pH values of sewage water collected from all the sites under study have strongly positive correlation with EC, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, CO_3^{2-}, and HCO_3^{2-}. EC of the sewage water is significantly and positively correlated with pH at ($P \leq 0.05$) level while pH have highly and positive correlation with all the cations and anions at ($P \leq 0.0001$) level indicated that increase in the soluble anions and cations resulted into increase in the pH of the sewage water while the pH of non-sewage water was quite low as compared to pH value of the sewage water collected from all the sites under study (Table 4).

Micronutrients and heavy metals in sewage and non-sewage water

Zinc (Zn), Cu, Fe and Mn were higher in sewage water as compared to non-sewage water of all the cities under study. The zinc content in the sewage water varied from 0.08 to 0.20 mg L^{-1} while it was 0.01 to 0.03 mg L^{-1} in non-sewage water. The highest mean value of zinc content was observed in the sewage water collected from Kaithal (0.19 mg L^{-1}). The Cu content in sewage water ranged from 0.11 to 0.23 mg L^{-1} while it ranged from 0.01 to 0.03 mg L^{-1} in non-sewage water. The highest mean value of copper was observed (0.20 mg L^{-1}) in sewage water of Kurukshetra and Kaithal district. The Fe content in sewage water ranged from 2.11 to 6.73 mg L^{-1}while it ranged from 0.00 to 0.02 mg L^{-1} in non-sewage water. The highest mean value of Fe content in sewage water (6.45 mg L^{-1}) was observed in Kurukshetra district while it was only 0.02mg L^{-1} in non-sewage water of Jind and Kurukshetra. Manganese content in the sewage water ranged from 0.13 to 0.52 mg L^{-1}while it was ranged from 0.00 to 0.01 mg L^{-1} in non-sewage water. The highest mean value of Mn content (0.48 mg L^{-1}) in sewage water was observed in Kaithal district while it was only 0.01 mg L^{-1} in non-sewage water of Kaithal.

Micronutrients like Zn, Cu, Fe, Mn are essential for plant growth (Wintz *et al.*, 2002). Zinc (0.19 mg L^{-1}), copper (0.2 mg L^{-1}) and Manganese (0.43 mg L^{-1}) were found higher in sewage water of Kaithal as compared to other districts. The permissible limit of zinc, copper and manganese in sewage water is <2.0, 0.2 and 0.20, respectively (Table 7) while iron was higher in the sewage water of Kurukshetra (Table 5 2 & Fig 6). Heavy metals like cadmium (Cd) was found highest in the sewage water of Jind (0.31 mg L^{-1}) followed by Kurukshetra (0.30 mg L^{-1}) while Pb was found highest in sewage water of Kaithal district (Table 7). Antil (2012) reported Cd range in Haryana soils under the influence of sewage water was 0.15 to 5.80 mg L^{-1}. In present study, the concentration of Fe, Mn, Zn, and Cu was higher in sewage water as compared to non-sewage water and indicates that sewage water is a good source of micronutrient and help to correct their deficiency and reduces the application of costly chemical fertilizers (Kharache *et al.*, 2011).

Sewage contains higher amounts of heavy metals like the Cd ranged from 0.18 to 0.31, Pb 0.07 to 0.14, Co 0.01 to 0.06 mg L^{-1}. The mean value of Cadmium was higher in the sewage water of Jind (0.31 mg L^{-1}) and Kurukshetra district (0.30 mg L^{-1}). Chromium content was absent in the sewage and non-sewage water collected from all the sites in Haryana. The mean value of Pb (0.13 mg L^{-1}) was found higher in the sewage water of Kaithal. The mean value of Co (0.06 mg L^{-1}) was found higher in the sewage water of Kurukshetra district.

From the above study it can be concluded that in the sewage water, the pH, electrical conductivity, calcium carbonate, chemical oxygen demand, biological oxygen demand, water soluble anions and cations, micronutrients and heavy metals were found higher amount as compared to non-sewage water. These chemical properties of the sewage water make it safe to use it for irrigating the fields at the time of water scarcity, drought spells or under limited supply and waste water management conditions. This can be strengthened in the peri-urban areas to reduce the cost of cultivation by providing micro nutrients from waste water.

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