IMPACT OF INDUSTRIAL EFFLUENTS AND SEWAGE ON GROUND WATER QUALITY

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Industrialization plays a vital role in the growth and development of any country. The idea of industrialization originated in the UK, where the first industrial estate was established in Manchester in 1886. This rapid industrialization also has a direct and indirect adverse effect on our environment. Industrial development manifested due to setting up new industries or expansion of existing industrial establishments resulted in the generation of industrial effluents, particularly small scale cottage industries which discharge untreated effluents, and these untreated effluents cause air, water, soil, and soil solid waste pollution. The present method of transportation of these effluents and their ultimate disposal and treatment for making effluents innocuous and safe are inadequate and unplanned, and their development at the hands of municipal bodies and corporations suffers from negligence and a shortage of funds. The apathy of industrialists towards treating the effluents from their respective units prior to discharge to sewers or open surface drains, storm water canals, rivers, etc. Untreated water near the disposal point creates a foul smell and bad odor. This bad odor is due to the decomposition of floating solids present in untreated sewage.

Heavy metals are essential for properly functioning biological systems, but their deficiency or excess could lead to several disorders [12]. Industrial effluents discharged from the textile and tannery contain more metals, especially chromium, copper, and cadmium. These effluents are released on the land as well as dumped into the surface water, which ultimately leaches to groundwater and leads to contamination due to the accumulation of toxic metallic components, resulting in a series of well-documented problems in living beings because they cannot be degraded entirely [13] Hence, industrial effluents offer a broad scope of environmental problems. Health hazards are becoming more complex and critical in developing countries like India and developed countries.

The net result is immense scale pollution of the water bodies, which may act as a source of water supply for domestic use in habitats of localities. This loss of water quality is causing health hazards and death of humans, livestock, aquatic life, crop failure, and loss of aesthetics. It is alarming that most of the cities and industries in India do not have wastewater treatment facilities. Large quantities of untreated municipal sewage and industrial effluents are being discharged directly to surface water or side-by-river bodies, resulting in a severe water pollution problem. Due to high organic loads and toxic materials, industrial effluents have become a significant source of water pollution. High levels of pollutants, mainly organic matter in river water, cause an increase in Biological Oxygen Demand

(BOD)1, Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and fecal coliform. They make water unsuitable or unfit for drinking, irrigation, or any other use or purpose.

Worldwide, water bodies are the primary means of waste disposal, especially the effluents from nearby industries. This effluent from industries has a great deal of influence on the pollution of the water body3, which can alter the physical, chemical, and biological nature of the receiving water body. The initial effect of waste is to degrade the physical quality of the water. Later, biological degradation becomes evident in the number, variety, and organization of the living organisms in the water. Often, the water bodies readily assimilate waste materials they receive without significant deterioration of some quality criteria; the extent of this is referred to as its assimilative capacity5.

Therefore, the input of waste into water bodies does not always negatively impact the aquatic environment because of the self-purification property of the water bodies. Industries turn out wastes peculiar in terms of type, volume, and frequency depending on the type of industry and population that uses the product6. Present studies were carried out in the Jajmau industrial estate of Kanpur city, where a large number of tanning industries are functioning, and the study also identifies the number of industries majorly contributing to water pollution in the industrial estate area, their impact on groundwater resources which can be identified by analyzing physicochemical characteristics of groundwater quality of the study area.

MATERIAL AND METHOD

Study Area

Kanpur city is situated between the parallels of 250 26' and 260 58' north latitude and 790 31' and 800 34' east longitude. It is situated on the most essential holy river, Ganga, about 126 meters above sea level. It is also situated on the main Delhi-Howrah railway trunk line, National Highways No.2 and 25, and state highway.

Climate and Geology

Kanpur's climate is characterized by hot summer and dryness, except in the southwest monsoon season. The climate in Kanpur can be divided broadly into four seasons. The period from March to the middle of June is the summer season, followed by the southwest monsoon, which lasts till the end of September, October, and the first half of November from the post-monsoon or transition period. The cold season spreads from about the middle of November to February. The climate is tropical, and the shade temperature varies from 2°C to 48 °C. The rainy season extends from June to September, with maximum rainfall typically occurring during July and August. About 89 percent of the annual rainfall is received during the monsoon months (June to September). The total rainfall in the district varies from 450 mm to 750 mm. The annual rainfall in Kanpur Nagar was 441 mm in 2004 and 783 mm in general (Statistics Diary 2005). The relative humidity varies from 15% to 85%. The relative humidity in Kanpur ranges from less than 30 percent in the summer season to 70 percent in the monsoon season. The district lies in the Ganga basin, formed by alluvium from the early quaternary period. In the district, no complicated or consolidated rock exposures are encountered. Alluvium's main constituents (sand, silt and clay) occur in variable proportions in different sections. The mineral products of the district of saline earth from which saltpeter and salt are derived and limestone conglomerates (U.P. District Gazette, Kanpur).

Determination of physicochemical environmental parameters

The concentration of dissolved oxygen (DO) in the water samples was estimated using the Winkler method to measure dissolved oxygen by titrating a sample with a series of reagents. The samples were analyzed for several physicochemical parameters employing standard methods [23]. The parameters included pH total dissolved solids (TDS) and the alkalinity described by Trivedi and Goel [24] by titrating against sodium thiosulphate as an indicator. The biochemical oxygen demand (BOD), TDS, and TS determination of the water sample in mg/L was carried out using the standard methods [23]. The dissolved oxygen content was determined before and after incubation. Sample incubation was for 5 days at 20°C in a BOD bottle, and BOD was calculated after the incubation period. Determination of chemical oxygen demand (COD) was carried out according to the method described by Ademoroti [16]. COD was determined after oxidation of organic matter in strong tetraoxosulphate VI acid medium by $K_2Cr_2O_7$ at 148°C, with back titration.

Determination of heavy metal environmental parameters

For the analysis of total heavy metals (dissolved and suspended), water (200 mL) samples were digested with 5 mL of di-acid mixture (HNO_3:$HClO_4$: 9:4 ratio) on a hot plate and filtered by Whatman No. 42 filter paper and made up the volume to 50 mL by double distilled water for analysis of eight heavy metals *viz.* Fe, Mn, Zn, Cu, Ni, Cr, and Pb. using atomic absorption spectrophotometer (GBC-902, Australia) [15] The obtained data were subject to statistical analysis to test the analysis of variance (ANOVA) and correlation among all the parameters using SPSS statistical package.

RESULT AND DISCUSSION

In order to evaluate the groundwater quality appraisal, 50 groundwater samples from 10 sites (5 from each site) were collected near the industrial area (5 sites) and sewage system (5 sites). The groundwater samples were analyzed for physicochemical properties like EC, pH, DO, BOD and COD, cations (Ca, Mg, Na, and K), anions (CO_3, HCO_3, Cl, and SO_4), and heavy metal *viz.* (Fe, Mn, Zn, Cu, Ni, Cr and Pb).

Physico-Chemical Properties

pH

The overall pH values ranged from 6.79-7.59, with a mean value of 7.18. The highest mean value of pH 7.52 was recorded at groundwater site III, whereas the lowest mean pH 6.88 was recorded at Groundwater site X, nearby sewage sites (Table 1). The variation in pH between the two sites, nearby industrial effluent (I-V) and sewage system sites (VI-X) was found to be non-significant.

Electrical conductivity (EC)

The overall mean value of EC was 0.60 dS m^{-1}, which varied from 0.22 to 0.93 dS m^{-1}. The highest mean value (0.93 dS m^{-1}) was obtained in groundwater site II, followed by site V (0.89 dS m^{-1}). The lowest mean value (0.23 dS m^{-1}) was obtained in groundwater site X. A significant variation in EC of the groundwater samples was found between two sites (industrial effluent and sewage site)

(Table 1). The variation in EC is due to the difference in soluble salts in the two groundwater sites. The EC of the groundwater samples at all five places was higher than that of the sewage site samples.

According to the USDA classification of EC, groundwater samples were distributed in 12, 28, and 50 percent of low (C1), medium (C2), and high (C_3) categories respectively (Table 3).

Table 1: Effect of industrial effluents & sewage on quality of water (*n=50*)

Site of GW	#@	pH	EC (dS m^{-1}	TDS (µg L^{-1})	DO (µg L^{-1})	BOD (µg L^{-1})	COD (µg L-1)
Nearby industrial effluent sites							
GW-I	**Range**	7.19-7.28	0.80-0.82	246.1-351.6	6.65-6.72	1.06-1.10	8.30-8.34
	Mean*	7.23	0.81	268.76	6.68	1.08	8.32
	SD	± 0.03	± 0.01	± 44.18	± 0.02	± 0.02	± 0.02
GW-II	**Range**	6.97-7.01	0.92-0.93	282-304.7	7.85-7.92	1.17-1.21	8.49-8.53
	Mean	6.99	0.93	289.9	7.89	1.19	8.51
	SD	± 0.02	± 0.01	± 8.9	± 0.02	± 0.02	± 0.02
GW-III	**Range**	7.48-7.58	0.83-0.84	463.9-493.2	6.79-6.83	1.16-1.19	8.43-8.48
	Mean	7.52	0.83	483.5	6.81	1.17	8.45
	SD	± 0.04	± 0.00	± 11.4	± 0.02	± 0.01	± 0.02
GW-VI	**Range**	7.28-7.38	0.84-0.85	293.6-418.0	7.01-7.06	0.99-1.05	8.66-8.79
	Mean	7.32	0.85	406.9	7.04	1.02	8.74
	SD	± 0.04	± 0.00	± 10.1	± 0.02	± 0.02	± 0.05
GW-V	**Range**	6.93-7.01	0.88-0.89	224.6-243.2	7.58-7.72	1.15-1.17	8.53-8.67
	Mean	6.96	0.89	234.6	7.62	1.16	8.60
	SD	± 0.03	± 0.00	± 7.6	± 0.06	± 0.01	± 0.05
Nearby sewage system sites							
GW-VI	**Range**	7.29-7.46	0.47-0.55	376.6-401.8	6.96-7.01	1.25-1.38	7.73-8.56
	Mean	7.36	0.50	386.8	6.99	1.31	8.24
	SD	± 0.07	± 0.03	± 10.1	± 0.02	± 0.06	± 0.33
GW-VII	**Range**	7.37-7.59	0.38-0.40	302.3-316.1	6.99-7.05	1.44-1.50	7.43-7.57
	Mean	± 7.50	± 0.39	± 308.5	± 7.01	± 1.47	± 7.52
	SD	0.08	0.01	5.1	0.02	0.02	0.06

GW-VIII	Range	6.98-7.11	0.27-0.29	173.1-183.5	7.93-8.01	0.40-1.19	5.88-6.17
	Mean	7.02	0.28	176.5	7.98	1.13	5.97
	SD	± 0.05	± 0.01	± 4.1	± 0.04	± 0.05	± 0.12
GW-IX	Range	6.97-7.04	0.22-0.24	1.27-139.6	7.73-7.96	0.82-1.04	4.71-4.87
	Mean	7.00	0.23	133.0	7.78	0.91	4.78
	SD	± 0.03	± 0.01	± 5.6	± 0.10	± 0.08	± 0.06
GW-X	Range	6.79-7.02	0.31-0.32	249.6-263.8	7.19-7.25	1.12-1.23	6.92-7.14
	Mean	6.88	0.32	256.7	7.22	1.17	7.05
	SD	± 0.10	± 0.01	± 6.1	± 0.02	± 0.06	± 0.09
Overall	Range	6.79-7.59	0.22-0.93	127.7-493.2	6.65-8.01	0.40-1.50	4.71-8.79
	Mean	7.18	0.60	295.0	7.30	1.16	7.62
	SD	± 0.23	± 0.27	± 103.3	± 0.46	± 0.15	± 1.27
E/S	t-*test*	0.76	24.2	3.18	-1.51	-1.75	7.21
		NS	Sig.	Sig.	NS	NS	Sig.

Total dissolved solid (TDS)

The overall TDS values of groundwater ranged from 127.7 to 493.2 µg L^{-1} with a mean value of 295.0 µg L^{-1}. The highest TDS mean value was 483.5 µg L^{-1} obtained in site III groundwater, followed by site IV (406.9 µg L^{-1}), whereas the lowest mean TDS value of 133.0 µg L^{-1} was recorded in groundwater site IX. A significant variation in the amount of TDS was found between two sites (GW, I-V) and (GW, VI-X) of groundwater samples. Depending on the source and industrial load, these variations may be due to adding organic matter through sewage effluents.

Dissolved oxygen (DO)

In groundwater samples, dissolved oxygen ranged from 6.65 to 8.01 µg L-1 with a mean value of 7.30 µg L^{-1}. The highest mean value, 7.98, followed by 7.89 µg $L^{-1,}$ was recorded in the sample collected from sites VIII and II, respectively, from the Jajmau area of Kanpur district. The lowest mean value, 6.68 µg $L^{-1,}$ was observed in groundwater site I, representing a nearby industrial effluent site. The DO values of groundwater samples significantly differ between the two sites (industrial effluent and sewage site) as per *Fisher's* t-test. This difference may be due to the difference in the amount of organic matter added by these two sources into groundwater.

Biological oxygen demand (BOD)

The overall mean value of BOD in groundwater samples was recorded at 1.16 µg L-1, which varied from 0.40 to 1.50 µg L^{-1}. The highest mean value of BOD (1.31 µg L^{-1}) was recorded in groundwater site VI, whereas the lowest mean value of BOD, 0.91 µg $L^{-1,}$ was observed in the sample collected from the groundwater site IX nearby sewage sites (Table 1). The BOD values obtained between the nearby industrial effluent and sewage sites were non-significant.

Chemical oxygen demand (COD)

The COD value of groundwater ranged from 4.71 to 8.79 µg L^{-1} with a mean value of 7.62 µg L^{-1}. The lowest mean value, 4.78 µg $L^{-1,}$ was observed in the groundwater samples of site IX near the sewage site. The highest mean value, 8.74, followed by 8.60 µg $L^{-1,}$ was recorded in the samples collected from sites III and IV, respectively. There are non-significant differences in the samples of groundwater collected from two sites in the Jajmau area of Kanpur district.

ION CONCENTRATION IN GROUNDWATER

Cations (Ca, Mg, Na, and K)

Site-wise range and mean values of different cations present in groundwater samples are given in Table 2. Among the cations, the overall highest proportion of Ca (2.48 me L^{-1}) was observed, which was followed by Na (2.14 me L^{-1}), Mg (0.97 me L^{-1}) and K^+ (0.25 me L^{-1}). The overall Ca, Mg, Na, and K concentrations varied from 0.73 to 4.08, 0.23 to 1.93, 0.99 to 3.81, and 0.05 to 0.59 me L^{-1}, respectively. The highest mean values for Ca (3.98 me L^{-1}), Mg (1.89 me L^{-1}), K (0.56 me L^{-1}), and Na (2.34 me L^{-1}) were recorded at sites III, II, IV, and VI, respectively. The lowest mean values for Ca, Mg, Na, and K were 1.16, 0.37, 1.68, and 0.10 me L^{-1} reported in the groundwater sites VIII, IX, VIII, and VIII near the sewage site. A significant variation was observed in groundwater's Ca, Mg, and K content collected from two sites [19]. The value of Na in the groundwater samples of the above two sites was found to be non-significant.

Table 2. Effect of industrial effluent and sewage on cations and anions of groundwater near industrial area and sewage system (*n=50*)

Site of GW	#@	Cations (me L^{-1})				Anions (me L^{-1})			
		Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4
Nearby industrial effluent sites									
GW-I	Range	2.81-3.39	0.76-1.28	2.16-2.55	0.24-0.31	0.11-0.68	1.57-1.95	2.67-3.63	1.06-1.42
	Mean	(3.08)	(0.91)	(2.24)	(0.26)	0.31	1.67	3.15	1.21
	SD	± 0.25	± 0.23	± 0.17	± 0.03	± 0.22	± 0.16	± 0.36	± 0.14
GW-II	Range	2.73-3.14	1.86-1.93	1.86-2.78	0.31-0.38	0.11-0.19	1.51-1.69	4.19-4.37	1.46-1.72
	Mean	2.98	1.89	2.31	0.34	0.16	1.58	4.26	1.58
	SD	± 0.19	± 0.03	± 0.39	± 0.03	± 0.03	± 0.06	± 0.08	± 0.11
GW-III	Range	3.89-4.08	0.96-1.05	1.83-2.09	0.21-0.33	0.21-0.29	2.29-2.51	2.38-2.69	1.18-1.67
	Mean	3.98	1.01	1.95	0.28	0.24	2.39	2.51	1.38
	SD	± 0.07	± 0.03	± 0.10	± 0.04	± 0.03	± 0.09	± 0.12	± 0.19
GW-VI	Range	3.09-3.19	1.59-1.68	1.72-1.94	0.49-0.59	0.29-0.72	2.55-2.80	2.11-3.54	1.28-1.67

	Mean	3.13	1.63	1.84	0.56	0.48	2.65	2.54	1.41
	SD	± 0.04	± 0.03	± 0.09	± 0.04	± 0.15	± 0.09	± 0.58	± 0.15
GW-V	Range	3.46-3.70	1.09-1.29	2.26-2.43	0.26-0.45	0.23-0.35	2.33-2.75	2.76-3.18	1.03-1.80
	Mean	3.60	1.18	2.34	0.39	0.28	2.47	2.99	1.31
	SD	± 0.10	± 0.08	± 0.06	± 0.08	± 0.04	± 0.17	± 0.16	± 0.30
Nearby sewage system sites									
GW-VI	Range	1.99-2.57	0.52-1.06	2.57-3.81	0.11-0.22	0.08-0.14	2.05-3.00	2.15-3.03	1.10-1.33
	Mean	2.25	0.72	3.24	0.16	0.10	2.38	2.55	1.21
	SD	± 0.25	± 0.20	± 0.47	± 0.04	± 0.02	± 0.35	± 0.41	± 0.10
GW-VII	Range	1.67-2.13	0.51-1.00	1.22-3.48	0.10-0.33	0.14-0.62	1.57-2.66	1.62-2.04	0.84-1.05
	Mean	1.91	0.77	2.37	0.17	0.37	1.95	1.79	0.92
	SD	± 0.19	± 0.19	± 0.86	± 0.10	± 0.22	± 0.41	± 0.19	± 0.10
GW-VIII	Range	0.97-1.34	0.38-0.65	1.56-1.82	0.06-0.16	0.07-0.38	1.58-2.13	1.20-1.84	0.53-0.76
	Mean	1.16	0.51	1.68	0.10	0.14	1.81	1.35	0.58
	SD	± 0.17	± 0.13	± 0.09	± 0.04	± 0.13	± 0.21	± 0.26	± 0.10
GW-IX	Range	0.73-1.08	0.23-0.61	1.42-2.01	0.05-0.23	0.10-0.34	1.15-2.98	0.75-1.05	0.25-0.45
	Mean	0.91	0.37	1.69	0.13	0.15	1.68	0.88	0.35
	SD	± 0.15	± 0.15	± 0.23	± 0.07	± 0.10	± 0.74	± 0.14	± 0.08
GW-X	Range	1.34-2.42	0.41-1.19	0.99-3.48	0.11-0.24	0.08-0.25	1.99-3.06	1.46-1.59	0.48-0.83
	Mean	1.72	0.63	1.71	0.15	0.13	2.36	1.51	0.58
	SD	± 0.47	± 0.33	± 1.08	± 0.05	± 0.06	± 0.42	± 0.05	± 0.14
Overall	Range	0.73-4.08	0.23-1.93	0.99-3.81	0.05-0.59	0.07-0.72	1.15-3.06	0.75-4.37	0.25-1.80
	Mean	2.48	0.97	2.14	0.25	0.26	2.14	2.40	1.08
	SD	± 1.02	± 0.49	± 0.64	± 0.15	± 0.17	± 0.48	± 1.00	± 0.43
E/S	t-test	12.9 (Sig)	7.96 (Sig)	0.00(NS)	8.60 (Sig)	2.54 (Sig)	0.46(NS)	7.96 (Sig)	8.60 (Sig)

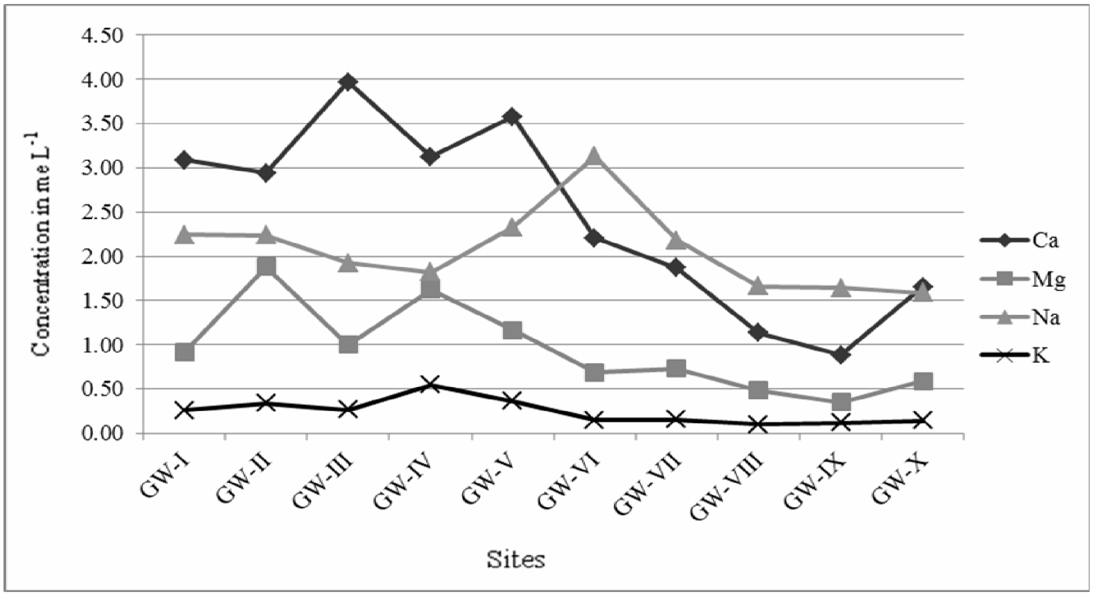

Figure 1. Concentration of Ca, Mg, Na and K in groundwater

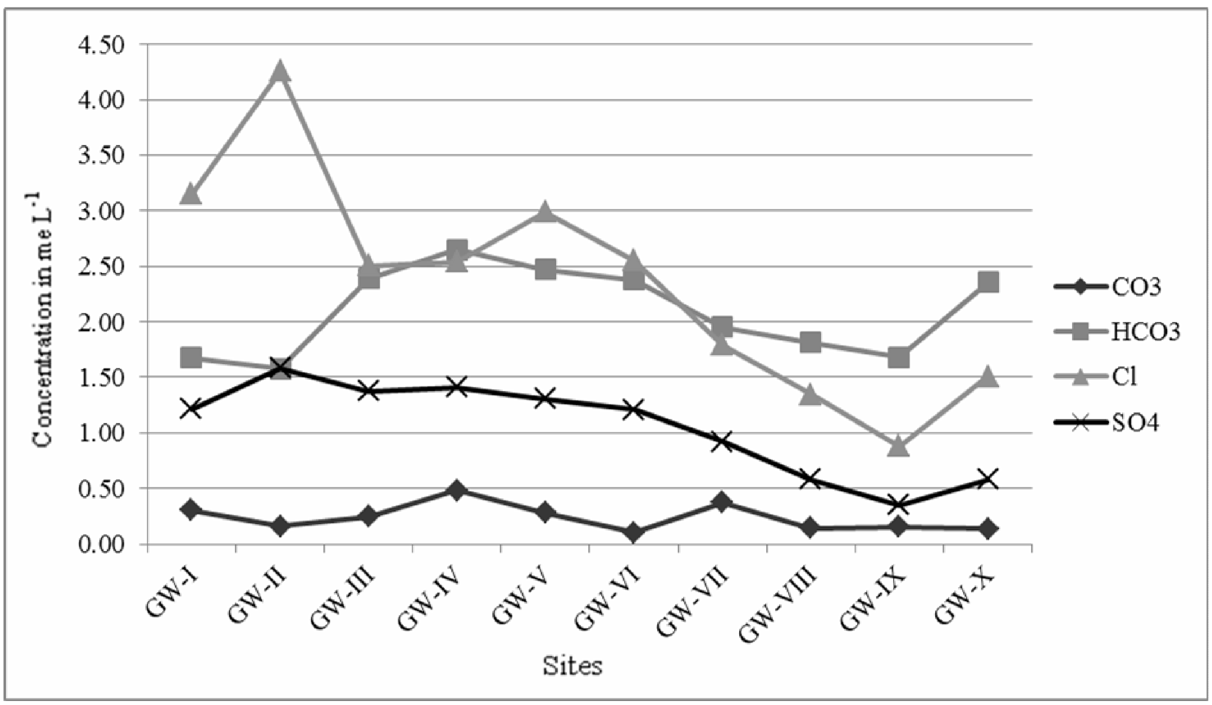

Figure 2. Concentration of CO_3, HCO_3 Cl and SO_4 in groundwater

Anions (CO_3, HCO_3, Cl and SO_4)

The highest overall mean value of 3.40 me L^{-1} was recorded for Cl, which was followed by HCO_3 (2.14 me L^{-1}), SO_4 (1.08 me L^{-1}), and CO_3 (0.26 me L^{-1}), respectively. The overall range values for CO_3, HCO_3, Cl, and SO_4 were 0.07 to 0.72, 1.15 to 3.06, 0.75 to 4.37 and 0.25 to 1.80 me L^{-1}, respectively The highest mean value of CO_3 (0.48 me L^{-1}) and HCO_3 (2.65 me L^{-1}) was observed in groundwater site IV, whereas Cl (4.26 me L^{-1}) and SO_4 (1.58 me L^{-1}) in site II nearby the industrial effluents site (Table 2). The lowest mean values of CO_3, HCO_3, Cl, and SO_4 were 0.10, 1.68, 0.88, and

0.58 me L^{-1} in the groundwater sites VI, IX, IX, and VIII, respectively. Based on the *t-test* value, the CO3, Cl, and SO4 concentrations varied significantly from affluent to sewage sites, but HCO3 was found to be non-significant between the two sites, which may be due to industrial effluents containing more anions than sewage; the result visualized in figure 1, 2 [18]

Table 3. Effect of industrial effluents & sewage on water quality indices of groundwater (*n=50*)

Site of GW	#@	Water Quality Indices (WQI)			
		TH	RSC	SAR	SSP
Nearby industrial effluent sites					
GW-I	Range	165.3-224.0	-2.86- -0.94	1.41-1.91	30.6-40.0
	Mean	190.8	-2.18	1.56	33.6
	SD	± 18.76	± 0.69	± 0.19	± 3.45
GW-II	Range	221-243.4	-3.31- -2.84	1.18-1.84	26.0-35.9
	Mean	230.2	-3.14	1.43	29.8
	SD	± 9.78	± 0.23	± 0.28	± 4.28
GW-III	Range	233-246.3	-245- -2.08	1.16-1.34	25.828.9
	Mean	238.4	-2.35	1.22	26.8
	SD	± 4.88	± 0.15	± 0.07	± 1.25
GW-VI	Range	225.4-230.9	-1.85- -1.18	1.12-1.26	24.5-26.8
	Mean	228.0	-1.62	1.18	25.5
	SD	± 1.99	± 0.26	± 0.06	± 0.94
GW-V	Range	237.5-241.5	-2.16- -1.77	1.45-1.57	30.0-31.9
	Mean	239.0	-2.02	1.50	31.0
	SD	± 1.70	± 0.16	± 0.05	± 0.74
Nearby sewage sites					
GW-VI	Range	128.6-175.4	-1.11-0.36	1.95-3.09	41.1-56.0
	Mean	145.7	-0.53	2.56	49.2
	SD	± 18.57	± 0.54	± 0.45	± 5.75
GW-VII	Range	125.9-155.8	-0.72-0.60	1.09-3.01	31.8-53.7

	Mean	138.5	-0.31	1.90	42.2
	SD	± 12.65	± 0.59	± 0.77	± 9.49
GW-VIII	**Range**	84.9-105.2	0.00-0.84	1.68-2.19	46.0-54.8
	Mean	93.4	0.29	1.82	48.3
	SD	± 8.34	± 0.32	± 0.20	± 3.59
GW-IX	**Range**	59.8-107.2	-0.07-1.79	1.76-2.38	50.2-60.6
	Mean	76.4	0.55	2.05	53.6
	SD	± 20.11	± 0.71	± 0.26	± 3.20
GW-X	**Range**	98.2-167.2	-1.41-1.07	0.73-3.18	20.9-56.9
	Mean	128.3	-0.04	1.47	36.0
	SD	± 26.16	± 0.97	± 0.99	± 14.09
Overall	**Range**	59.8-246.3	-3.31-1.79	0.73-3.18	20.9-60.6
	Mean	173.6	-1.04	1.73	38.6
	SD	± 60.34	± 1.35	± 0.59	± 11.39

WATER QUALITY INDICES OF GROUNDWATER

Total hardness (TH)

The overall mean value of TH was 173.6, which varied from 59.8 to 246.3. The lowest (59.8) and the highest (246.3) TH values were reported in water samples collected from groundwater site IXs and III, respectively, from the Jajmau area of Kanpur district. The highest (239.0) and the lowest (76.4) mean TH values were registered in water samples collected from groundwater site V and site IX, respectively. The concentration of total hardness was maximum and lower towards the sewage site.

Residual sodium carbonate (RSC)

The overall RSC values ranged from 3.31 to 1.79 me L^{-1} with a mean value of -1.04 me L^{-1}. The highest mean value (RSC 0.55 me L^{-1}) was recorded in groundwater site IX, whereas the lowest mean value (-3.14 me L^{-1}) was obtained in site II [17].

The RSC values of 96 percent of groundwater samples were found safe, and the remaining 4 percent were in the marginal category; USDA suggested a 2.5 me L^{-1} critical value for the RSC of groundwater.

Soluble sodium percentage (SSP)

The overall mean value of SSP was 38.6 and ranged from 20.9 to 60.1. The highest mean value (53.6) was recorded in groundwater site IX, whereas the lowest mean value (25.5) was observed in groundwater site IV near the effluent site. Overall, the groundwater samples concerning SSP were calculated as 98.2 percent safe and 2.0 percent unsafe (Table 3).

Sodium absorption ratio (SAR)

The overall mean value of SAR was 1.73, which varied from 0.73-3.18. The lowest (1.18) and the highest (2.56) SAR mean values were reported in water samples collected from groundwater site VI and site IV, respectively, from the Jajmau. The 100 percent water samples are safe as per their SAR value. The result can be visualized in Table 3.

Table 4. Effect of industrial effluents & sewage discharge on heavy metal concentration in groundwater (*n=50*)

Site of GW	#@	Heavy metals (µg L^{-1})						
		Fe	**Mn**	**Zn**	**Cu**	**Ni**	**Cr**	**Pb**
Industrial effluent sites								
GW-I	**Range**	410.3-463.5	49.0-102.9	14.4-16.6	14.0-15.3	31.5-52.5	16.1-16.5	18.1-26.5
	Mean	440.7	84.2	15.6	14.4	41.3	16.2	23.4
	SD	± 20.81	± 22.28	± 0.86	± 0.56	± 9.07	± 0.16	± 3.25
GW-II	**Range**	487.0-497.7	98.0-122.4	19.5-22.8	17.0-18.7	43.6-76.3	16.7-17.0	22.7-28.7
	Mean	492.9	109.7	21.3	17.9	55.2	16.8	25.8
	SD	± 3.89	± 10.16	± 1.37	± 0.67	± 13.45	± 0.10	± 2.48
GW-III	**Range**	418.6-426.2	58.8-83.3	9.2-11.7	6.6-7.9	58.0-76.3	8.4-8.9	22.5-41.4
	Mean	422.3	72.5	10.3	7.2	67.1	8.6	32.9
	SD	± 3.01	± 9.42	± 0.98	± 0.53	± 8.88	± 0.20	± 7.92
GW-VI	**Range**	363.9-380.6	83.5-117.5	113.8-6.8	11.5-14.6	31.7-58.2	10.7-10.9	13.2-20.6
	Mean	371.8	98.0	15.3	12.8	41.2	10.9	16.6
	SD	± 7.00	± 13.41	± 1.14	± 1.29	± 10.84	± 0.09	± 2.92
GW-V	**Range**	291.8-342.7	53.9-53.9	25.0-29.0	9.0-9.9	30.6-38.0	13.0-13.4	8.5-22.3
	Mean	308.5	44.1	26.5	9.5	34.1	13.2	12.6
	SD	± 19.78	± 7.74	± 1.65	± 0.37	± 2.81	± 0.17	± 5.57
Sewage sites								
GW-VI	**Range**	228.6-233.7	39.5-40.3	4.0-5.1	3.7-7.8	31.2-45.1	5.7-6.0	24.3-28.0
	Mean	230.6	40.0	4.7	5.6	37.1	5.9	25.9
	SD	± 2.01	± 0.30	± 0.43	± 1.74	± 6.07	± 0.13	± 1.81

GW-VII	**Range**	203.3-207.3	42.7-43.8	7.8-10.1	6.3-10.5	35.8-47.5	5.1-5.4	33.1-39.8
	Mean	205.0	43.3	9.0	8.7	44.6	5.2	37.2
	SD	± 1.43	± 0.52	± 0.86	± 1.69	± 4.96	± 0.13	± 2.69
GW-VIII	**Range**	126.9-132.0	32.0-33.2	11.0-13.7	6.5-13.6	47.3-58.4	4.5-4.9	29.7-35.2
	Mean	129.1	32.8	12.3	9.3	50.4	4.7	32.3
	SD	± 1.84	± 0.53	± 0.97	± 2.65	± 4.56	± 0.13	± 2.33
GW-IX	**Range**	104.5-109.5	27.5-28.5	16.8-19.0	9.5-12.6	51.8-58.2	2.8-3.2	12.3-33.6
	Mean	107.4	27.9	17.7	11.4	54.0	3.0	25.8
	SD	± 2.00	± 0.38	± 0.80	± 1.32	± 2.80	± 0.11	± 8.58
GW-X	**Range**	157.3-166.8	9.8-11.2	19.9-22.5	16.1-19.1	52.2-55.5	4.0-4.2	20.7-40.7
	Mean	160.6	10.4	21.2	17.4	54.0	4.1	28.5
	SD	± 3.97	± 0.52	± 0.94	± 1.23	± 1.31	± 0.09	± 8.11
Overall	**Range**	104.5-497.7	9.8-122.4	4.0-29.0	3.7-19.1	30.6-76.3	2.8-17.0	8.5-41.4
	Mean	286.9	56.3	15.4	11.4	47.9	8.9	26.1
	SD	± 133.94	± 32.62	± 6.36	± 4.18	± 11.76	± 4.93	± 8.53
E/S	**t-*test***	12.0	8.41	2.78	1.57	-0.05	11.4	-2.72
		Sig.	Sig.	Sig.	NS	NS	Sig.	Sig.

HEAVY METAL CONTENT IN GROUNDWATER

The overall Fe, Mn, Zn, and Cu contents of the groundwater samples were ranged from 104.5 to 497.7, 9.8 to 122.4, 4.0 to 29.0 and 3.7 to 19.0 µg L^{-1} with corresponding mean values 286.9, 56.3, 15.4 and 11.4 µg L^{-1}, respectively. The highest mean value of Fe, Mn, and Cu were 492.9, 109.7, and 17.9 µg $L^{-1,}$ respectively, for the groundwater site II, and Zn 26.5 g L^{-1} highest value at site V, whereas the lowest corresponding value was 107.4, 10.4, 4.7 and 5.6 µg L^{-1} at site IX, X, and VI, respectively (Table 4). Significant variations were observed in Fe, Mn, and Zn content between two sites of groundwater samples.

The overall content of Ni, Cr, and Pb in groundwater samples ranged from 30.6 to 76.3, 2.8 to 17.0, and 8.5 to 41.4 µg L^{-1} with corresponding mean values, 47.9, 8.9, and 26.1 µg L^{-1}, respectively. The highest mean values of Ni, Cr, and Pb were 67.1, 16.8, and 37.2 µg L^{-1} at the groundwater sites III, II, and VII, respectively. The corresponding lowest values of the groundwater samples were 34.1, 3.0 and 12.6 µg L-1 at sites V, IX, and V, respectively (Table 4). A significant variation was observed in the Cr, Pb, and Cu values between the two groundwater sample sites. This difference may be due to adding more organic and inorganic substances by industrial effluents than sewage [19, 18].

CONCLUSION

The above research findings concluded that the groundwater samples were more contaminated with industrial effluent than sewage release. Further, it is clear that the ground, more than water samples from industrial effluent sites, contains toxic substances within the prescribed limits and requires treatment before disposal on land and water for safe use and environmental safety.

REFERENCES

Kulkarni G. J., Water supply and sanitary engineering, Farooq Kitab Ghar, Karachi, 10th Ed. 497, (1997)

Hari O., Nepal S., Aryo M.S., and Singh N., Combined effect of waste of distillery and sugar mill on seed germination, seeding growth and biomass of Okra (Abelmoschus esculentus (Moench.), *J. Environ. Bio.* **3** (15), 171-175, **(1994)**

Sangodoyin. A.Y., groundwater and surface water pollution by open refuse dump in Ibadan Nigeria. Discovery and Innovations, **3**(1), 24-31,**(1991)**

Gray N.F., Biology of wastewater treatment, Oxford University Press, Oxford and New York. 829,**(1989)**

Argun M.E., Dursun S., Gur K., Ozdemir C., Karatas M. and Dogan S., Nickel adsorption on the modified pine tree materials, Environ. Technology, **3** (26), 479-488, **(2005)**

Odumosu A. O. T., Management of liquid industrial wastes, Inter match, Lagos 6 (1992)

American Public Health Association Standard Methods for the Examination of water and waste water **(1995)**

US EPA sample preservation in methods for chemical analysis of water and wastes, EPA-600/4-79-020,15-20, **(1983)**

Anonymous Guidelines for drinking water quality, World Health Organization (WHO), (2), 231, (1996)

Gupta V. K. and Sharma S., Removal of zinc from aqueous solutions using bagasse fly ash - A low-cost adsorbent, *Indust. Engi. Chem. Res.,* **42** (25) 6619-6624, **(2003)**

Kumar U. and Bandyopadhyay M Sorption of cadmium from aqueous solution using pretreated rice husk, *Biores. Technol.,* **97** (1), 104-109, **(2006)**

Ward, N. I. Environmental analytical chemistry. In: Fifield, F. W. and Haines, P. J., eds Trace Elements. Blackie Academic and Professional, U.K.1995:320–28.

Malarkodi, M., Krishnasamy, R., Kumaraperumal, R. and Chitdeshwari, T. Characterization of heavy metal contaminated soils of Coimbatore district in Tamil Nadu. *Journal of Agronomy* **6**(1): 147-51 **(2007)**

ISI. Methods of sampling and test (Physical and chemical) for water and wastewater: 3025: IS 10500: 1991.

APHA, AWWA, and WPCF (2005) In Standard methods for the examination of water and waste water. American Public Health Association, Washington; D.C 20th edition, New York.

Ademoroti CMA (1996) Standard method for water and effluents analysis. Foludex press Ltd, Ibadan 22-23, 44-54, 111-112.

S.G. Rajput, K.B. Polara, Brijesh Yadav and Som Raj, Characterization and categorization of soil and water of cultivated coastal Bhavnagar district of Gujarat, *Journal of Soil and Water Conservation* **12**(3): 219-226 **(2013).**

Tewari Anurag, Dubey Ashutosh,and Pratibha Singh, Impact of tanning industries on groundwater resource, *Journal of Environment Research and Development,* **6** (3) 609-615, **(2012)**

Deepali and Gangawar K.K. Metal concentration in textile tannery effluents, associated soils 0and groundwater, *New York Science Journal,* **3**(4) 82-89 **(2010)**

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