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Assessment of Physico-chemical Drinking Water Quality for Surface, Groundwater and Effluents of Industrial Cluster near Kashipur and Water of Kosi River

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Authors' contributions

This work was carried out in collaboration among all authors. Author PM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AS, AKR and PS managed the analyses of the study. Author YK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In developing countries, one of the main concerns is contaminated drinking water. The rise in demands and development pressure is also changing the characteristics of water resources. The freshwater sources are increasingly being depleted as surface water resources have become too polluted for human consumption. To address this issue, water samples were collected from industrial clusters in Kashipur town and from the Kosi River. Industrial effluents were obtained from six locations and samples from twelve sites were drawn from the groundwater. Water supplies have been sampled from boreholes, open wells, rivers and some piped waters throughout the town of this area. The specimens are examined for their concentration of physico-chemical and heavy metals to

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detect pollution issues and recommend acceptable solutions. Results of the assessment confirmed that in the studied area there was the presence of various health and aesthetic parameters of concern. Apart from Kosi bank and Cheema drain, most of the effluents are acceptable for discharge into the water body. Most of the groundwater surrounding these three industries was not suitable as groundwater samples for drinking purposes at Dhouri pratha 1, Glycol gate no.1, Artesian well sugarcane center, petrol pump, and Parmanandpur-2. In addition, factors of environmental significance, such as turbidity, iron, and manganese, have a negative impact on many groundwater sources. Using alternative sources, improving water supply structures and treating water can be solutions to improve drinking water quality in this area.

Keywords: India; water samples; effluents; heavy metals; groundwater; surface water; water pollution.

1. INTRODUCTION

India is the world's second most populated country with 1.21 billion people growing at 1.2 % annually in 2011-15 (Census 2011; Anonymous 2015). So, to feed such a large bulk mass of population, country needs a large number of resources. One of these important resources is water. Water resources are needed for all forms of developmental activities, including agricultural, commercial, household, leisure and environmental activities. The majority of these activities required fresh surface water and groundwater. The per capita availability of freshwater resources is declining in India due to the increase in population in the last six decades. The depletion of available freshwater resources and worsening water quality are all posing severe challenges in handling the country's water resources. The annual per capita availability of renewable freshwater in the country has fallen from around 6042 cubic meters in 1947 to 1545 cubic meters in 2011 (Chakraborty, B. [1]. When surface water supplies become too defiled for human use, groundwater reserves becomes more and more depleted. Water pollution is one of the most critical issues in the world today. Industrial water pollution is a major problem for industrialization and developing countries [2]. Polluted wastewater from industry effluents contains undesirable color, smell, taste, turbidity, organic matter, harmful chemical toxic and heavy metals, pesticides, oily content, industrial waste materials, radioactive materials, high-total solids (TDS) acids, alkalis, viruses, bacteria, protozoa, rotifers, and worms. Pollution of surface waters, groundwaters and seawater are all harmful to human and animal health. Most streams and other outlets of fresh or wastewater are polluted by industrial waste and effluent [3,4]. Some contaminants such as lead (Pb), arsenic (As), mercury (Hg), chromium (Cr), nickel (Ni), barium (Ba), cadmium (Cd), cobalt (Co), selenium (Se), vanadium (V), and pesticides are very dangerous and toxic even in part per billion (ppb) range [5,6]. Minerals such as zinc (Zn), copper (Cu), and iron (Fe) are useful for the health of humans and animals in smaller doses afterward becomes toxic. Some chemicals are toxic to both humans and animals, such as cyanides, thiocyanides, phenolic compounds, fluorides, and radioactive substances [7]. Pulp paper industry is one of the highest polluting industries in India and is highly water intensive (Saadia, A., & Ashfaq, A. [8]. After paper making, it produces toxic effluent [9]. Three industries namely Cheema Paper Ltd., Multiwall Paper & Board Factory and Indian Glycol Limited (IGL) are located in the industrial cluster near Kashipur town of Uttarakhand state. Due to industrial effluent of this industrial cluster, the groundwater and surface water of nearby areas are being contaminated. There is also doubt about the concentration of heavy metals in the groundwater. The extent of pollution of groundwater and surface water and their suitability for drinking and agricultural purposes as well as the level of heavy metals in water resources should, therefore, be studied [10,11]. Keeping above in view, the present study is conducted to investigate the problems of pollution faced by the people of nearby areas of the industrial cluster near Kashipur town and Water of Kosi River.

2. MATERIALS AND METHODS

2.1 Site Description, Geology and Sample Collection

The study area lies between 29°11'8.33"N to 29°9'17.17"N latitude and 78°59'33.78"E to 79'2'15.85"E Longitude in the Kashipur town of Uttarakhand State. Kosi and Bahela rivers are two important rivers in this study area. A number of industries like Indian Glycol Ltd, Cheema Paper Ltd., and Multiwal Paper & Board Factory are located in the industrial cluster. These three industries are discharging their effluents into

Kosi and Bahela rivers through two different effluent channels. The effluent of IGL is discharged into the effluent channel which passes through Dhouri Pratha, University Sugarcane Center and finally falls into Bahela River. The effluents of Cheema Paper Ltd. and Multiwal Paper & Board Factory are discharged into the effluent channel which passes through Parmanandpur, Mukandpur and finally falls into Kosi River (Fig. 1). In this manner, these three industries, located in the study area, are polluting the shallow aquifer and surface water resources of the *Tarai* region. The samples were collected for Industrial effluents from 6 locations and the groundwater samples were taken from 12 locations as shown in Table 1. The effluent sample at Kosi bank and Kosi River are shown in (Fig. 2).

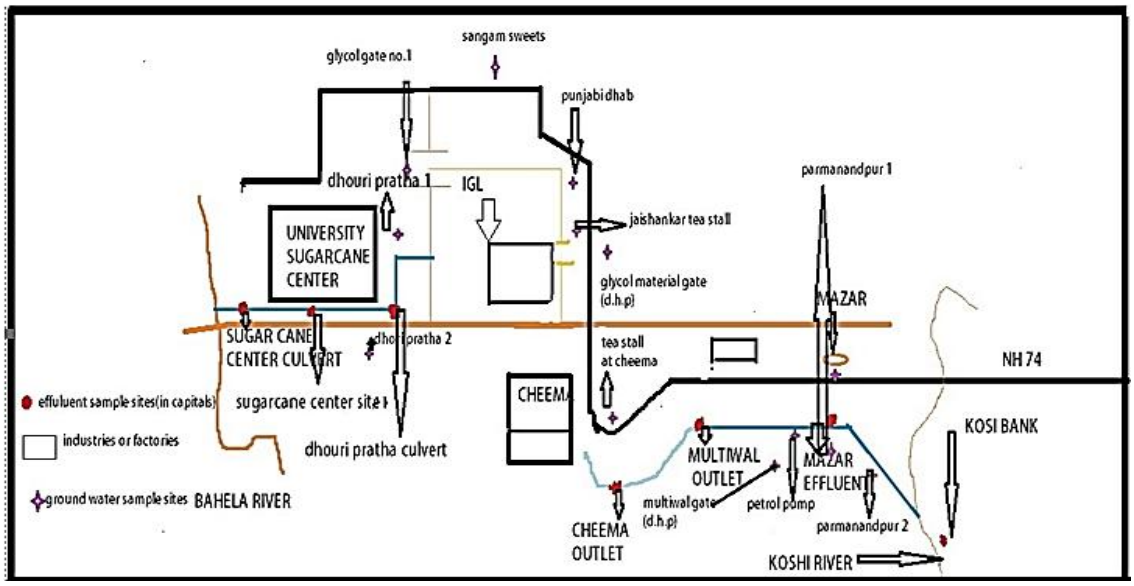

Fig. 1. Location of water sampling sites (Not to the scale)

Table 1. Locations of samples collected from the effluent channel and groundwater

Location of effluent channel		Groundwater samples location			
1	Dhouri pratha culvert	1	Glycol gate no-1	7	Tea stall at cheema
2	Sugarcane center site 1	2	Dhouri pratha-1	8	Multiwall gate (DHP)
3	Cheema outlet	3	Dhouri pratha-2	9	Petrol pump
4	Multiwall outlet	4	Sangam sweets	10	Parmanandpur-1
5	Kosi bank	5	Panjabi dhaba	11	Parmanandpur-2
6	Kosi river	6	Jaishankar tea stall	12	Mazar

A B

Fig. 2. Water sample collection at A- Kosi Bank, B-Kosi River

Table 2. Water quality parameters and analytical methods for water source evaluation

Parameter	Standard analytical method	Instrument
Odor	Inhaling	----
Colour	Visual interpretation	----
pH	----	pH meter
Turbidity	----	Multi-parameter Water Quality Instrument known as troll 9500
Acidity, Alkalinity	Titrimetric method using phenolphthalein as an indicator	----
Free Carbon di-Oxide	Titrimetric method using phenolphthalein as an indicator at pH 8.3	----
Conductance and total dissolved solids (TDS)	----	Pocket EC tester and TDS tester
Calcium, Magnesium content and Hardness	Titration method using EDTA.	----
Chlorine	Titration method using AgNO3	
Nitrate, Ammonia	----	Multi parameter water quality instrument TROLL9500
Potassium, Sodium	----	Flame Photometer
Determination of Heavy Metals		
Arsenic (As), Copper (Cu), Lead (Pb) Zinc (Zn), Nickel (Ni), Cobalt (Co) and Iron (Fe).	Nitric acid –hydrochloric acid method	----
	Atomic absorption spectroscopy (AAS)	----

2.2 Physico-chemical Analysis of Samples

Water samples were collected from the different sources applying the procedures indicated. Samples are gathered using clear plastic bottles and stored in the incubator so that the physical and chemical characteristics of water samples do not change. The Physico-chemical analysis was performed in the water quality laboratory of the Department of Irrigation and Drainage Engineering. Heavy metal concentration was tested in the Department of Environmental Science, College of Basic Sciences & Humanities of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. Physical-chemical variables such as pH and turbidity are directly measured by the pH meter and the multi-parameter water quality device known as troll 9500. While the others were analyzed in the laboratory (see Table 2). All samples are cleaned with distilled water and then washed again before testing with the goal liquid. Samples are processed in 0.5 L polyethylene bottles for metallic component assessments (iron, manganese, zinc, copper, brass, cadmium, and chromium), where concentrated nitric acid was dosed to achieve pH < 2.

The electrical conductivity and TDS were measured by Pocket EC tester and TDS tester instrument respectively. The nitrate and ammonia were measured by using a multi-parameter water quality instrument TROLL9500. The Free Carbon di-oxide measured by standard analytical Titrimetric method using phenolphthalein as an indicator at pH 8.3. Table 2 summarizes the water quality parameters, the analytical methods and the instruments used for the analyses.

2.3 Heavy Metals Analysis of Effluents

Heavy metals concentration determination followed a standard procedure using Atomic absorption spectroscopy (AAS) which involves sample digestion. The physical-chemical parameters and heavy metals concentration was compared with the Bureau of Indian Standards [12] for checking their suitability for drinking purposes. Nitric acid -hydrochloric acid method was used for the digestion of water samples for heavy metal analysis. 50 ml of water was taken in a beaker and mixed with 3 ml of HNO3. The beaker was placed on a hot plate and heated till volume reduced to 50% of the initial volume. It was then cooled for the period up to which it

reaches the room temperature. After cooling, the beaker was placed on a hot plate again and heated until the sample volume reduces to 5ml. Then, 10 ml of HCl and 15 ml of distilled water were added and heated for another 15 min. The contents obtained were filtered and centrifuged [13]. The filtered solution was then directly aspired and the concentration of heavy metals was obtained by atomic absorption spectrophotometer (AAS) in mg/l [14].

3. RESULTS AND DISCUSSION

The Physico-chemical properties and heavy metals: the concentration of effluents and the groundwater in the vicinity of the industrial clusters near Kashipur town are presented and discussed. The effluents discharge from three industries namely Multiwall paper and board factory, Indian Glycol limited, Cheema paper Ltd and groundwater samples around these industries, as well as the water of the Kosi river, were collected on 17 May 2016 from 18 sites. The Physico-chemical parameters, irrigation quality parameters assessment, and heavy metals concentration of water samples were obtained using the standard procedure and the results obtained were compared with BIS [12].

3.1 Physico-chemical Characteristics of Ground and Surface Waters

The values of Physico-chemical properties of groundwater and effluents are shown in Tables 3(a & b) and 4 respectively.

The pH value for groundwater samples was observed from 6.6 at Artesian Well at Sugarcane Center to 8 at Mazar. As per the BIS norm, the pH was found to be within the acceptable range of 6.5-8.5. Fakayode [15] stated that a liquid body's pH is a significant factor that affects chemical reactions such as solubility and toxicity to metals. The value of pH of effluent at Sugarcane Site 1 was 5.3 and at Dhouri Pratha 5.4 which was below permissible range (5.5-9) and hence the effluent of IGL industries was not suitable for discharging into the water body and it can also cause problems for aquatic life too.

The electrical conductivity of groundwater samples varied between 310 µs/cm at Artesian well near Sugarcane center to 1160 µs/cm at Tea Stall at Cheema. The permissible limit of electrical conductivity for discharging effluents into the water body is 3400 µs/cm. All the values of EC in the study area lie within the permissible range. Therefore, it was safe from the electrical conductivity point of view. The permissible range for TDS for drinking purposes is 500-2000 mg/l whereas, the permissible limit of TDS for effluents for discharging into the water body is 2000 mg/l. Groundwater samples and effluent discharge showed values within the permissible range. Therefore, the groundwater and surface water were safe from the TDS point of view.

Total Alkalinity is a measure of the amount of buffering capacity in the water. It acts as a cushion for pH [16]. The value of alkalinity for groundwater varied between 150 mg/l at Dhouri Pratha -1 to 640 mg/l at Parmanandpur-2. The permissible limit of alkalinity for human consumption is 200 mg/l to 600 mg/l. The value at Parmanandpur-2 exceeded the maximum permissible limit. Therefore, unsafe drinking water caused because of Cheema Paper Ltd. and Multiwal Paper & Board.

3.2 All Parameters are in mg/l Except pH, EC and Turbidity, EC in µs/cm and Turbidity in Nephelometric Turbidity Unit (NTU)

The permissible limit of calcium for human consumption is 75-200 mg/l. The value of calcium was found more than the lower permissible limit at Parmanandpur-2, Glycol Gate no.1, Mazar and Dhouri-Pratha 1.

All the values for chloride lie within the permissible limit so this water was safe for human consumption from chloride point of view as the permissible range of chloride in water for human consumption is 250 mg/l whereas the permissible limit of chloride for effluent for discharging into the water body is 1000 mg/l, hence surface water from effluent channels were safe for discharging into the water body and human health.

The permissible limit of effluents for sodium to discharge into the water body is 300 mg/l. Therefore, all the effluents were suitable for discharging into the water body from the sodium point of view. The value of turbidity for groundwater samples varied between 0.8 NTU at Mazar to 19.6 NTU at the petrol pump. The permissible limit of turbidity in the groundwater for human consumption is 5 NTU. The value of turbidity was found more than permissible limit at Dhouri-Pratha 1, Artesian well sugarcane center and at the petrol pump. The value of turbidity for effluent varied between 7.4 NTU at Multiwal outlet to 95.6 NTU at Cheema outlet. The permissible limit of turbidity for effluents for

Table 3(a). Physico-chemical properties of groundwater

Sl no.	Parameter	Acceptable limit-permissible limit in absence of source	Glycol gate no.1	Dhori Pratha 1	Dhori Pratha 2	Sangam Sweets	Artesian well sugarcane center	Jaishankar tea stall near to material gate
1	pH	6.5-8.5	7	7	7.5	7.1	6.6	7.1
2	Temperature (C°)	-	24	34	25	25	24	24.5
3	Acidity	-	262.5	200	92.5	152.5	102.5	125
4	Alkalinity	<(200-600)	370	150	270	175	165	190
5	NH_4	-	0.112	0.130	0	0	0	0.0022
6	Ca	<(75-200)	224.4	224.4	146.9	126.5	183.6	163.2
7	Calcium hardness	<(200-600)	560.3	560.3	366.7	315.82	458.45	407.51
8	Nitrate	<45	0.04	0.98	0.02	0.98	0.01	0.9
9	Cl	<(250-1000)	25.24	57.43	0.12	0.1249	0.29100	0.2426
10	Na		24	22	28	20	14	26
11	K	-	27	29	20	28	17	22
12	Free CO_2	-	287.5	64.4	50.6	82.8	87.4	92
13	Turbidity	<5	1.1	18.5	1.2	1.8	18.5	1.3
14	EC	-	840	810	450	670	310	640
15	TDS	< (500-2000)	560	540	300	450	210	430

Table 3(b). Physico-chemical properties of groundwater

Sl. no.	Parameter	Acceptable limit- Permissible limit in absence of source	Tea stall at cheema	Multiwal gate (D.H.P)	Petrol pump	Mazar	Parmanandpur1	Parmanandpur2
1	pH	6.5-8.5	7.4	7.5	6.9	8	7.3	7.4
2	Temperature(C°)	-	27.5	28	24	26	28.5	25
3	Acidity	-	107.5	172.5	205	110	187.5	180
4	Alkalinity	<(200-600)	185	170	430	180	475	640
5	NH_4	-	0	0	0.3136	0	0.0081	14.55
6	Ca	<(75-200)	183.6	191.76	89.76	244.8	122.4	204
7	Calcium hardness	<(200-600)	458.45	478.82	224.1	611.2	305.63	509.4
8	Nitrate	<45	0.03	0.02	0.90	0.9	0.01	0.09
9	Cl	<(250-1000)	0.0762	0.1153	65.44	0.077	86.86	107.5
10	Na		25	16	18	15	20	18
11	K	-	23	19	24	21	33	26
12	Free CO_2	-	73.6	57.5	142.6	62.1	138	131.1
13	Turbidity	<5	1.2	1.2	19.6	0.8	9.7	2.6
14	EC	-	1160	330	1120	370	1130	1040
15	TDS	< (500-2000)	780	220	750	250	760	700

Table 4. Physico-chemical properties of effluents

Sl. no.	Parameter	Acceptable limit-permissible limit in absence of source	Kosi bank	Kosi river	Sugarcane center site 1	Dhouri pratha culvert	Cheema outlet	Multiwal outlet
1	pH	5.5-9	7.4	**7.7**	**5.3**	**5.4**	7.2	7.1
2	Temperature(C°)	-	34	33	33	29	31	31.5
3	Acidity	-	152.5	207.5	102.5	232.5	175	125
4	Alkalinity	-	230	225	165	265	190	240
5	Free CO_2	-	161	78.28	87.4	96.6	115	89.7
6	Ca	75-200	85.68	118.32	183.6	138.72	204	163.2
7	Ca hardness	-	213.95	295.45	458.45	346.38	509.388	407.5104
8	Cl	1000	71.49	9.02	157.8	25	112.9	121.4
9	Na	300	33	15	15	13	26	25
10	K	-	28	22	23	19	24	30
11	NH_4	-	0.98	0	15.02	0	29.71	19.88
12	Nitrate	-	0.09	1	157.8	25.09	112.9	121.4
13	Turbidity	10-25	28.307	25.4	18.5	68.5	95.6	7.4
14	EC	3400	1910	820	1210	880	1330	1280
15	TDS	2000	1280	550	810	590	890	860

Table 5(a). Heavy metal concentration of groundwater

Sl. no.	Parameter	Permissible limit /range	Glycol gate no.1	Dhouri Pratha 1	Dhouri Pratha 2	Sangam sweets	Jaishankar tea stall	Sugarcane center artesian well
1	Arsenic (µg/ml)	0.05	2.410	12.116	19.360	18.432	14.572	0.000
2	Copper (µg/ml)	0.05-1.5	0.026	0.043	0.054	0.024	0.082	0.039
3	Lead (µg/ml)	0.1	0.679	0.894	0.615	0.609	0.800	0.908
4	Zinc (µg/ml)	5-10	0.586	0.747	0.728	0.665	1.589	0.761
5	Nickel (µg/ml	-	0.217	0.213	0.203	0.205	0.230	0.086
6	Cobalt (µg/ml)	-	0.168	0.206	0.179	0.131	0.100	0.135
7	Iron (µg/ml)	3	0.738	3.945	2.384	0.909	1.521	0.654

Table 5(b). Heavy metal concentration of groundwater

Sl. no.	Parameter	Permissible limit /range	Tea stall at cheema	Multiwall Gate(dhp)	Petrol pump	Parmanandpur 1	Parmanandpur 2	Mazar
1	Arsenic (µg/ml)	0.05	11.465	5.040	13.638	0.163	12.838	0.00
2	Copper (µg/ml)	0.05-1.5	0.038	0.035	0.053	0.040	0.041	0.027
3	Lead (µg/ml	0.1	0.771	0.605	0.893	0.851	0.758	0.733
4	Zinc (µg/ml)	5-10	0.6071	1.022	1.080	1.089	0.468	0.627
5	Nickel (µg/ml)	-	0.223	0.120	0.260	0.219	0.184	0.149
6	Cobalt (µg/ml)	-	0.183	0.192	0.155	0.130	0.150	0.128
7	Iron (µg/ml)	0.3-1	1.423	0.704	8.436	8.359	1.148	0.570

Table 6. Heavy metal concentration of effluents

Sl. no.	Parameter (µg/ml)	Permissible limit for discharging into water body	Dhouri pratha culvert	Cheema outlet	Sugarcane center site 1	Multiwall outlet	Kosi river	Kosi bank
1	Arsenic	0.2	8.181	1.975	9.426	14.262	7.741	0.00
2	Copper	3	0.092	0.047	0.030	0.050	0.086	0.205
3	Lead	0.1	0.682	0.565	0.514	0.740	0.884	0.866
4	Zinc	5	1.75	0.329	0.576	1.136	1.75	0.865
5	Nickel	3	0.308	0.271	0.282	0.273	0.235	0.381
6	Cobalt	-	0.195	0.211	0.134	0.217	0.151	0.268
7	Iron (µg/ml)	3	4.758	1.758	4.335	1.880	5.2	5.6

discharging into the water body is 25 NTU. The value at Dhouri-Pratha culvert, Cheema outlet, and Kosi bank has been observed to be higher than the allowable limit Water turbidity is often associated with higher infection rates triggering microorganisms such as bacteria and other parasites [17].

3.3 Heavy Metals

The samples from six effluents, 11 groundwater, and one Kosi River sites were collected to test the heavy metals present in the surface and the groundwater. The samples were tested for Arsenic, Copper, Lead, Zinc, Nickel, Cobalt and Iron. The heavy metals concentration in groundwater and effluents are given in Tables 5 (a &b) and 6 respectively. The value of arsenic in groundwater varied between 0 mg/l at Sugarcane Center Artesian Well and Mazar to 19.360 mg/l at Dhouri-Pratha 2. The permissible limit of Arsenic in the groundwater for human consumption is 0.05 mg/l. It is found that most of the sites were not suitable for human consumption. The value of arsenic for effluent varied between 0.00 mg/l at Kosi bank to 14.262 mg/l at Multiwall outlet. Excessive arsenic concentration had the potential for increased cancer risk of the skin, lungs, liver, and kidney (National Research Council [18]. The permissible range of copper in water for human consumption is from 0.05 mg/l to 1.5 mg/l. Long term exposure to copper may experience liver or kidney damage [19]. The values for copper lie within the permissible range, hence all the groundwater were safe for drinking purpose from the copper point of view as well as all effluents were also safe for discharging into the water body from the copper point of view as the concentration of copper for all effluents was well within the permissible limit. The concentration of lead in the groundwater varied from 0.605 µg/ml at Multiwal gate to 0.908 mg/l at Sugarcane Center Artesian Well. The permissible limit of lead in water for drinking purposes is 0.1 mg/l. The concentration of lead in all groundwater, as well as the effluent to be released into water body samples, was found to exceed the permissible limit. Therefore, the entire sites were not safe for discharging into the water body. The high level of lead above the recommended range causes a delay in normal physical and mental development in babies and young children [16].

The zinc limit for human consumption in water is 5 µg / ml to 10 µg / ml, hence the groundwater is suitable for human consumption from the zinc point of view. The concentration of zinc in effluents varied between 0.329 µg/ml at Cheema outlet to 1.75µg/ml at Dhouri Pratha and Kosi bank. The permissible limit of zinc in effluents for discharging into the water body is 5 µg/ml, hence all the effluent are safe for discharging into the water body. Long-term nickel exposures can lead to reduced body weight, damage to the liver and inflammation of the skin [19]. The permissible limit of nickel for effluents for discharging into the water body is 3 µg/ml, hence all the effluents are suitable for discharging into the water body. The concentration of iron for groundwater varied between 0.57 µg/ml at Mazar to 8.436 µg/ml at the Petrol pump.

The permissible limit of iron in water for human consumption is 3 µg/ml. The concentration of iron at Dhouri-pratha 1 (3.945 µg/ml), Petrol pump (8.436 µg/ml) and Parmanandpur 1 (8.359 µg/ml) was more than the permissible limit and were not suitable for human consumption. The concentration of iron for effluent varied between 1.758 µg/ml at Cheema outlet to very high values above 8 µg/ml at Dhouri Pratha and Kosi Bank. The permissible limit of iron in the effluent for discharging into the water body is 3 µg/ml, hence effluent at sugarcane center site 1, Dhouri Pratha culvert and Kosi Bank was not suitable for discharging into the water body. High iron concentrations can increase the risk of pathogenic organisms; as most of these organisms require iron to develop [20].

The probable reason for increasing the heavy metals concentration in groundwater is due to the leaching effect. The excess amount of some of the high concentrations of heavy metals in the groundwater can also cause animal, livestock, and plant health issues [6].

4. CONCLUSIONS

The water of Kosi River and the groundwater of the surrounding area of the industrial cluster near Kashipur town of Uttarakhand state were tested for 15 Physico-chemical properties and 7 heavy metals. The suitability of water resources of the study area for drinking purposes was also assessed with the help of criteria given by Bureau of Indian Standards [12]. The concentration of all the Physico-chemical parameters of water was found to be within the permissible limit except for turbidity due to effluents at most of the sites (max 95.6 NTU) and some groundwater sites such as Dholi pratha 1, Artesian well sugarcane center and at the petrol

pump. Turbidity exceeds permissible limit 5 NTU for human consumption. Most of the effluents were suitable for discharging into water body except at Kosi bank, Cheema outlet (in these 2 sites turbidity was more than permissible), Sugarcane Center Site 1 (pH was more than permissible limit) and Dhouri pratha culvert (both pH and Turbidity was more than the permissible limit). From the analysis of the effluent sample, it was concluded that most of the groundwater vicinity to these three industries were not suitable for drinking purpose as groundwater samples at Dhouri-pratha 1 (Turbidity and Ca content was more than the permissible limit), Glycol gate no.1 (Ca content was more than the permissible limit), Artesian well sugarcane center, petrol pump (in these 2 sites Turbidity was more than permissible limit) and Parmanandpur-2 (Alkalinity was more than the permissible limit). The concentration of Arsenic, Lead, and Copper was more than the permissible limit in the effluents at several locations which indicates that these effluents were not suitable for discharging into water body and proper treatment of effluents should be done before discharge. The concentration of Arsenic and Lead in the Kosi river were more than the Permissible limit. Therefore, it was observed that the water of the Kosi river was unsuitable for irrigation as well as for drinking purposes. It was concluded that effluents from the industrial cluster of Kashipur were affecting the groundwater.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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