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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(11): 2183-2189

www.thepharmajournal.com
Received: 21-09-2022
Accepted: 26-10-2022

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Effect of sugar factory effluent on physico-chemical characteristics of groundwater in surrounding area

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Abstract
The present study was conducted in the surrounding area of sugar factory. Wastewater from the industries are directly discharged into water source or in the open field which causes groundwater contamination and soil contamination. Total twelve samples were collected from the study area, three samples from the main industrial drain and remaining nine samples from open wells situated in the surrounding agriculture area of sugar factory. Samples were evaluated for physiochemical water quality parameters such as Temperature, pH, EC, TDS, Total hardness, calcium, magnesium, sodium, potassium, chloride, nitrate, sulphide, carbonate, bicarbonate, COD, BOD, oil and grease, SAR, RSC, SSP and mg/ca ratio. The survey of nearby farmers was also carried out to find out the effect of waste water on their health, crops, and animals. From the present study it was observed that the concentration of the water quality parameters is decreases as the distance of the sample location form the factory increases. The study found high concentration of potassium, oil and grease, chromium, COD and BOD making the water unsafe for irrigation and domestic purpose. To cope up with such situation remedial measures are need to be accepted.

Keywords: Sugar factory, physico-chemical characteristics, groundwater

1. Introduction
Water is essential natural resource for sustaining life and environment. Fresh water is the natural resource on which all human activities, food production, and economic stability depends. India is a country of shortage of water resources as a result, many regions are facing serious problem of water scarcity. The surface water is insufficient to meet the need of growing population and industrialization so the demand of groundwater is increasing. Groundwater is a universal resource of a fresh water for world's population. Approximately one third of a global population depends on groundwater for drinking purpose (Peiyue *et al*. 2021) [18]. The quality of groundwater is most important for well-being of environment, society, and the economy.

From last two decades, rapid growth of industrialization has created negative impact on environment. From industrial revolution, industrial wastage has become serious problem. Contaminants are continuously added to the groundwater through various human activities which affects the human health directly or indirectly. Once toxic contents from the waste meets groundwater they will spreads whenever groundwater travels which can make contamination in large extent. The high level of hazardous metals in the groundwater poses considerable risks to the local resource users and to the environment.

India has second rank in the world for sugar production. Sugar industries is agro based industries which gives major contribution in Indian economy. Various chemicals are used in processing of sugar in sugar mill. In most of the sugar factory in India discharge waste effluent of factory into open area without treatment. These effluents contain highly toxic chemicals which infiltrates into ground and contaminate the groundwater. The present research work aimed to study the contamination of groundwater due to discharge of waste water from the factory.

2. Methodology
2.1 Study area
The research work was conducted in the area of sugar factory. Geographically, site has levelled area. The elevation is about 625 m above the sea level.

2.2 Sample collection from industrial drain and surrounding well

From the study it was observed that the flow of water was more at upper reach than towards lower reach. The entire main drain was divided into three zones, such as Drain Point A, Drian Point B, and Drain Point C. Water samples were collected from these drain points for analysis.

At drain point A, three wells were selected such as W1, W2, and W3. The well W1, W2, and W3 were situated at distance of 150 m, 513 m, and 805 m from drain point A. Similarly, from drain point B, well (W4), well (W5), well (W6) were situated at distance 62 m, 402 m, 864 m and from drain point C, well (W7), well (W8), well (W9) were situated at distance 180 m, 416 m, 813 m. Water samples were collected from all the selected wells for study.

2.3 Analysis of sample

Samples were collected from the wells to evaluate the concentration of contaminants with respect to distance from the main drain. For the collection of sample 1 litre plasctic bottles were used. The collected samples were used for the analysis in the laboratory. Physicochemical analysis of samples were done for water quality parameters such as Temperature, pH, EC, TDS, Total hardness, calcium, Magnesium, potassium, sodium, chlorine, Nitrate, Sulphate, COD, BOD, oil and grease, Zinc, and Chromium.

3. Result and Discussion

Physicochemical analysis of water quality parameters is shown in Table 1 and Table 2. All the analysed parameters were compared to standard limit given by BIS and WHO.

Table 1: Physicochemical analysis of main drain water samples

Sr. No.	Parameters	Point A	Point B	Point C
1	Temperature (°C)	29.5	29.5	29.5
2	pH	7.02	7.52	8.55
3	EC (ds/m)	1.67	1.66	0.82
4	TDS (mg/lit)	1300	1176	636
5	Total hardness (mg/lit)	950	921.6	619.2
6	Ca (mg/lit)	93.98	116	34.06
7	Mg (mg/lit)	39.62	44.35	28.8
8	K (mg/lit)	207.22	50.82	0.78
9	Na (mg/lit)	57.02	74.94	62.07
10	Cl (mg/lit)	239.28	327.91	97.48
11	CO_3 (mg/lit)	0	0	24.00
12	HCO_3 (mg/lit)	494.22	341.69	164.74
13	Nitrate (mg/lit)	0.5	0.5	5
14	Sulphate (mg/lit)	1.74	45	88
15	COD (mg/lit)	201	169	57
16	BOD (mg/lit)	69	56	22
17	Zinc (mg/lit)	<0.10	<0.10	<0.10
18	Chromium (mg/lit)	<0.10	<0.1	<0.1
19	Oil and grease (mg/lit)	168	64	61
20	SAR (me/lit)	1.24	1.5	1.89
21	RSC (me/lit)	0.15	-3.84	-0.57
22	SSP (%)	49.46	32.57	40.06
23	Mg/ca ratio	0.7	0.63	1.39

Table 2: Physicochemical analysis of well water samples

Sr. No.	Parameter	W1	W2	W3	W4	W5	W6	W7	W8	W9
1	Temp. (°C)	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5
2	pH	7.58	7.55	7.66	7.76	7.65	7.64	7.95	7.87	7.58
3	EC (ds/m)	0.95	1.28	1.04	1.23	0.97	1.1	0.87	0.83	0.98
4	TDS (mg/lit)	765	1007	855	996	755	878	697	656	794
5	Total Hardness (mg/lit)	540	892.8	568.8	676.8	604.8	828	590.4	626.4	640.8
6	Ca (mg/lit)	61.92	101.99	87.97	87.9	61.92	69.93	51.9	55.91	67.93
7	Mg (mg/lit)	34.76	40.83	30	27.58	32.44	31.23	30.01	35.97	28.8
8	K (mg/lit)	1.17	0	0	12.38	0	1.56	0.78	1.95	1.56
9	Na (mg/lit)	54.95	44.37	39.54	85.52	46.2	72.87	56.09	52.18	57.24
10	Cl (mg/lit)	132.94	212.7	150.66	248.2	150.7	186.1	88.62	70.9	106.3
11	CO3 (mg/lit)	0	0	0	0	0	0	0	0	0
12	HCO3 (mg/lit)	280.67	323.38	244.06	280.67	262.36	268.47	298.97	353.89	311.18
13	Nitrate (mg/lit)	0.5	2.5	5	5	5	5	7.5	7.5	7.5
14	Sulphate (mg/lit)	82	133	86	79	93	99	156	67	88
15	COD (mg/lit)	90	32	36	93	57	90	75	54	147
16	BOD (mg/lit)	28	11	14	31	22	32	28	20	53
17	Zinc (mg/lit)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
18	Chromium (mg/lit)	<0.10	<0.10	<0.1	<0.10	<0.10	<0.1	<0.10	<0.10	<0.10
19	Oil and grease (mg/lit)	104	59	77	72	69	70	51	64	73
20	SAR (meq/lit)	1.39	0.94	0.93	2.04	1.18	1.82	1.53	1.34	1.47
21	RSC (meq/lit)	-1.35	-3.15	-2.86	-2.06	-1.46	-1.66	-0.16	0.05	-0.66
22	SSP (%) (meq/lit)	28.61	18.59	20.05	37.29	25.87	34.63	32.71	28.75	30.52
23	Mg/Ca ratio	0.93	0.66	0.56	0.52	0.86	0.74	0.95	1.06	0.7

W reperents selected well in study area

3.1 Physicochemical water quality parameter

3.1.1 Temperature: In the present study it was observed that the temperature of all samples is same i.e., 29.5°C shown in the Table 1 and Table 2. Ideal water temperature for plant is in the range of 20-26 °C. Therefore, the temperature of water in the study area is slightly warm but not harmful for plant growth.

3.1.2 pH: pH is the indicator of alkaline or acidic nature of water. From the results it was observed that the pH value of samples ranges between 7.02 to 8.55. At point A, pH value is about to neutral which becomes alkaline as flow shifts from A to B and B to C. According to FAO (Food and Agricultural Organization) the normal range of pH is between 6.5 to 8.4. This indicates that all the sample except sample c are suitable

for irrigation purpose and all the well samples are also suitable for domestic purpose.

3.1.3 Electrical Conductivity (EC): From the study it was observed that the maximum EC was found in the sample A and minimum EC was found in the sample C as shown in Table 1.This is because the location of the point A which is near to the sugar factory than the point B and the point C. From Table. 2 it was observed that the higher concentration in well sample was observed in sample W8 and minimum concentration was observed in sample W4. The location of W4 was near to the main industrial drain than W8 therefore, high amount of chemicals mixes with the water at point W4 than all other well samples. According to FAO the range of electrical conductivity of groundwater for agricultural purpose is from 0.7 ds/m - 3 ds/m that means all the water samples are within the permissible range except sample C.

3.1.4 Total Dissolved Solids (TDS): From the Table 1, it was observed that the TDS concentration of sample A, B and C is 1300 mg/lit, 1176 mg/lit and 636 mg/lit respectively. The concentration of TDS decreases as distance increases from the industry. TDS concentration in wells varies between the range 656 mg/lit to 1007 mg/lit as shown in Table 2. The reason behind the fluctuation of TDS concentration in wells is agricultural activities and underground seepage. According to IS 10500-1991 permissible range of TDS concentration is 500mg/lit to 2000mg/lit. Therefore all the drain samples and well samples are beneficial for irrigation purpose and well samples are also safe for domestic purpose.

3.1.5 Total hardness: The maximum hardness was found in the sample A whereas minimum hardness was found in the sample W1 as shown in Table 1 and Table 2. The standard limit for total hardness according to IS 10500:1983 guidelines is 300-600 mg/lit. Sample A, B, C, W2, W4, W5, W6, W8, W9 are above the permissible limit. Only sample W1, W3 and W7 are within the permissible limit of Indian standard so it is beneficial for the drinking and irrigation purpose whereas other samples needs to decrease hardness level in water before use for domestic and irrigation purpose.

3.1.6 Calcium: From the study it was found that the calcium content in the industrial drain varies from 34.06 mg/lit to 116 mg/lit as shown in Table 1. The higher concentration was observed in drain sample B than the drain sample A and C. This might be due to agriculture chemicals or percolated drain water reappear at this location. From the Table 2, it was observed that the fluctuation in the concentration of calcium. This is due to agricultural activities. According to Is 500:2012 standard range of calcium content in water is 75 mg/lit-200 mg/lit. The effect on well water due to main drain water seems to be negligible. Therefore, the drain water is safe for agriculture purpose and the well water is safe for domestic purpose and irrigation purpose.

3.1.7 Magnesium: From the Table 1, it was observed that the higher concentration of magnesium was found in sample B (44.35 mg/lit) and minimum concentration was found in sample C (28.8 mg/lit). Higher concentration of Mg is due to clay minerals which contains Mg content and some organic matter or this might be due to agriculture chemicals or percolated drain water may reappears at this location. The Magnesium concentration varies in between 27.58 mg/lit to 40.85 mg/lit in the open wells as shown in Table 2. According to Indian standard guidelines of water the standard range of magnesium in water is ranges from 30 mg/lit to 100 mg/lit. All the sample are below the permissible limit given by IS. . The effect on well water due to main drain water seems to be negligible. Therefore, drain water is safe to use as irrigation water and well water is safe to use for irrigation purpose as well as for domestic purpose.

3.1.8 Potassium: From the study it was observed that sample A has higher concentration of potassium. As distance increases potassium concentration in the sample decreases. The highest value of potassium in well samples was found in sample W4. This is due to various agriculture activity especially due to inorganic fertilizers applied in the field which percolates and mix with groundwater. According to WHO, maximum potassium limit in drinking water is 10 mg/lit. Therefore, potassium concentration of sample A, sample B, and sample W4 are above the permissible limit as shown in Fig 1. Hence these samples are not suitable for irrigation and domestic purpose.

3.1.9 Sodium: From the study it was observed that the concentration of sodium fluctuates periodically. In the well samples sodium content varies between 39.54 mg/lit to 85.54 mg/lit. The soluble form of sodium infiltrates into ground and mixes with groundwater hence sodium content in the groundwater increases. The effect on well water due to main drain water was seems to be negligible. According to WHO 2004, the permissible limit for sodium concentration in water is 200 mg/lit. Therefore, all the drain samples are safe for irrigation purpose. Also, all the well samples are useful for irrigation as well as domestic purpose.

3.1.10 Chloride: From the Table 1 it was observed that concentration of sample B was more than sample A and sample C because of geological formation of the location of sample B. In the well samples maximum concentration was found in W4 (248.2 mg/lit) and minimum concentration found in W8 (70.9 mg/lit). This is because the distance of point W4 from the industrial drain is less i.e., 62 m than the point W5 (402 m) and point W6 (864 m). According to IS 2012 range of chloride concentration is from 250 mg/lit to 1000mg/lit. concentration of all samples is below desirable limit given by Indian Standard. Therefore, all the samples are safe for irrigation purpose and well samples are also usefull for domestic purpose.

3.1.11 Carbonate: From the study it was observed that only sample C has carbonate content i.e., 24.003 mg/lit. It was clear that the well samples did not contain carbonate content and they are free from the carbonate. The effect of main drain on well water seems to be negligible. According to WHO standard limit of Carbonate content in water is 50 mg/lit therefore all the samples are safe for irrigation purpose and all well samples are safe for domestic use.

3.1.12 Bicarbonate: From the result it was observed that the bicarbonate concentration was higher in sample A than the sample B and sample C. This is because distance between point A and sugar factory was less as compaired to distance of point B and C from the factory. The bicarbonate in the well samples varies in between 244.06 mg/lit to 353.89 mg/lit. The fluctuation of value was due to agricultural activites. The

effect on well water due to main drain water was seems to be negligible. According to WHO 2011 the ideal range of bicarbonate in groundwater is 300 mg/lit to 600 mg/lit. All the drain samples and well samples were below the permissible limit given by WHO. Therefore, drain water is useful for irrigation purpose and well water of all point is safe for irrigation and domestic purpose.

3.1.13 Nitrate: From the study it was observed that nitrate range varies from 0.5 mg/lit to 7.5 mg/lit in drain samples. The higher concentration was found in sample C. Location of sample C was far away from the factory as compared to location of sample B and sample C. Therefore, study revealed that the concentration in drain samples was not affected by industrial effluent. In well samples the higher concentration was found in sample W7, W8 and W9 i.e., 7.5 mg/lit. This is due to fertilizers used for agriculture and animal waste near the well area. According to IS 1050:2012 standard limit of nitrate in water is 45 mg/lit. Hence drain water is beneficial for agriculture purpose and well water is also safe for domestic as well as irrigation purpose.

3.1.14 Sulphate: From the study it was observed that in drain sample the higher sulphate content found in sample C. The point C was away from the industry therefore, industrial effluent not affect the drain sampls in large amount in case of sulphate concentration. In well samples, the sulphate value varies between 67 mg/lit to 156 mg/lit as shown in Table 2. The variation in value was because of sulphate given to the crops in soluble form which then infiltrates and meets to groundwater and increase sulphate content in water. According to BIS 1998 standard limit of sulphate in groundwater is 400 mg/lit. Therefore, all the samples are safe for irrigation purpose and well samples are also useful for domestic purpose.

3.1.15 COD: In the well samples and drain samples the COD concentration was increased as the distance from the location of samples increase from the factory as shown in Table 1 and Table 2. According to WHO, COD concentration in the water is below 10 mg/lit. Therefore, the concentration of COD in all samples was found above the standard limit given by WHO shown in Fig 2. From the study it is clear that the water from the study area it contaminated by COD content. Proper COD removal treatment is required to reduce the COD value of main drain water and well water before use.

3.1.16 BOD: From the result it was seen that higher BOD value was found in sample A than other drain samples. As distance of sample location from the factory increases BOD value decreases. From the Table 2 it was found that higher value of BOD was observed in W8 (53 mg/lit) and lower value of BOD was observed in W2 (11 mg/lit). According to WHO, the BOD value of water is below 0.5 mg/lit that means all the drain samples and well samples excceding the permissible range shown in Fig 3. Hence samples are not safe to use and it is needed to use proper filtration system to reduce BOD value before releasing water to main drain.

3.1.17 Zinc: From the study it was obersrved that the concnetratin of zinc in study samples was found less than 0.10 mg/lit as shown in Table 1 and Table 2. The effect on well water due to main drain water seems to be negligible. According to IS 500-2012 the permissible limit of zinc in water is 10 mg/lit. Hence all the samples are within the permissible limit given by Indian standard. Therefore, drain samples are safe for irrigation and well samples are also safe for irrigation and domestic use.

3.1.18 Chromium: From the study it was observed that the chromium content in drain samples and well samples varies between 0.1 mg/lit to 0.10 mg/lit. Chromium content found in the samples is due to sugar factory which discharge toxic metals in the study area. According to Indian standard guidelines, standard limit of chromium concentration in water is 0.05 mg/lit. Chromium content of all the samples in the study area are above the permissible limit shown in fig 5. Therefore, samples required chromium removal treatment before use for agricultural and other purposes.

3.1.19 Oil and Grease: In all the pollutants, oil and grease is most complicated content to remove. The concentration of oil and grease in the drain sample varies from 61 mg/lit to 168 mg/lit. As distance from the factory increases concentration of oil and grease in the samples decreases. In well samples maximum concentration was found in sample W1 because the location of point W1 was near to sugar factory so maximum oil and grease content of industry mixed in well W1 as compared to other well samples. According to IS 500:2012 the permissible range of oil and grease is 0.2 mg/lit. Therefore, all the drain water samples and well water samples have very high concentration of oil and grease than standard limit shown in Fig 4. Samples need special treatment to remove oil and grease from the water.

3.1.20 Sodium Absorption Ratio (SAR): Sodium Absorption Ratio (SAR) is a property of irrigation water which indicates sodium hazard in water. SAR values ranges from 0.93 meq/lit to 1.89 meq/lit. According to BIS standard limit of SAR is 10 meq/lit that means all the samples in the study area are useful for irrigation purpose.

3.1.21 Residual Sodium Carbonate (RSC): From the study it was observed that the values of RSC ranges from -3.15 me/lit to 0.15 me/lit. According to BIS all the RSC values of samples are within the standard limit. Water having RSC value less than 1.25 me/lit is safe for irrigation. So that water in the study area is safe for irrigation purpose.

3.1.22 Soluble Sodium Hazard (SSP): The SSP less than 50% indicates good quality of groundwater. From the study it was found that SSP values of all the samples ranges from 18.59 to 49.56 shown in Table 1 and Table 2. All the samples are below 50% hence drain water and well water in study area is safe for irrigation.

3.1.23 Mg/Ca Ratio: It is the ratio of magnesium ion to calcium ion. The standard Mg/Ca ratio of groundwater is between 1.5 to 3. From the study it was found that values of mg/ca ratio of all the sample was below the permissible limit so the water is good for irrigation purpose.

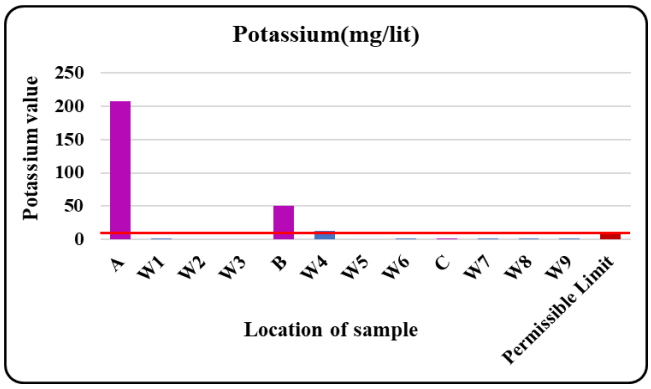

Fig 1: Variation in potassium values according to sample location

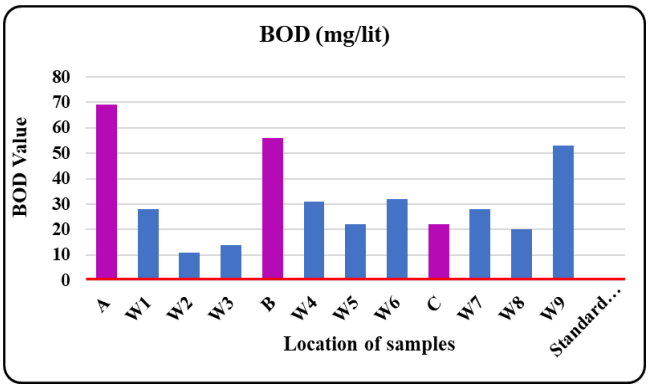

Fig 3: Variation in BOD values according to samples location

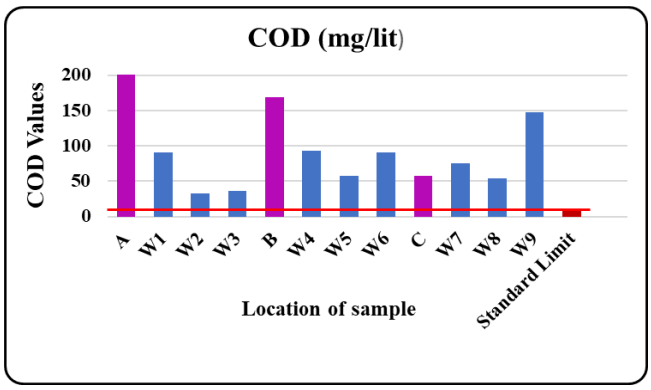

Fig 2: Variation in COD values according to sample location

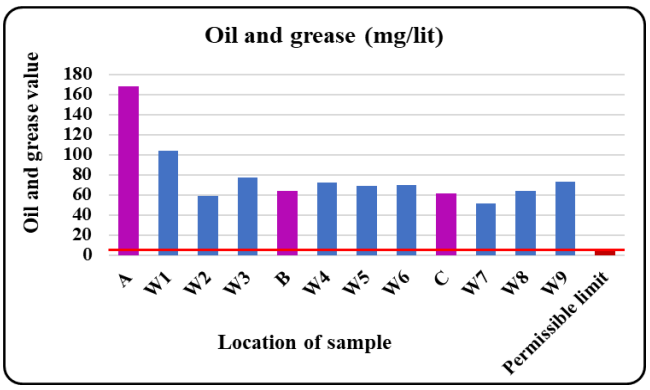

Fig 4: Variation in Oil and grease values according to samples location

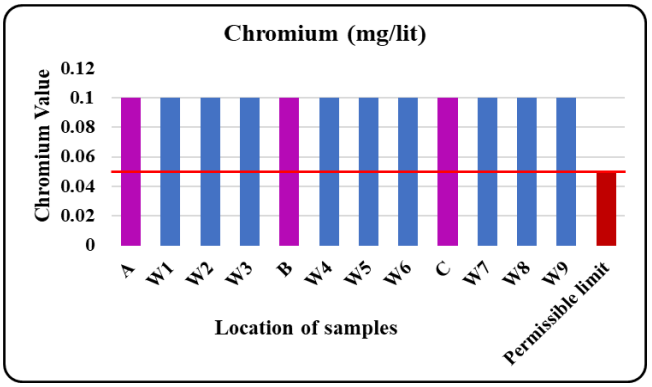

Fig 5: Variation in Chromium Values according sample location

3.2 health hazardous content in groundwater

From the study, following health hazardous content was found in groundwater and main drain samples. These samples are exceeding the norms of standard drinking water guidelines. After comparing groundwater samples with drinking water quality guidelines it was found that following groundwater samples were exceeding the standard limit of drinking water.

Table 3: Health hazardous contents

Sr. No.	Parameters	Standard Range	Location of sample exceeding standard limit
1	Potassium	10 mg/lit	A, B, W4
2	COD	10 mg/lit	A, W1, W2, W3, B, W4, W5, W6, C, W7, W8, W9
3	BOD	<0.5 mg/lit	A, W1, W2, W3, B, W4, W5, W6, C, W7, W8, W9
4	Oil and Grease	0.2 mg/lit	A, W1, W2, W3, B, W4, W5, W6, C, W7, W8, W9
5	Chromium	<0.05 mg/lit	A, W1, W2, W3, B, W4, W5, W6, C, W7, W8, W9

From the Table 3 it was observed that some contents in the samples of the study area exceeding the standard permissible limit given by BIS and WHO. Continuous use of high potassium drinking water can cause several diseases such as digestive and nervous disorder, nausea and breathing problem, vomiting, chest pain etc. High COD and BOD in water is harmful for aquatic life because they may suffocate in polluted water. High chromium level in water causes diarrhoea, cramps, liver and kidney damge and cancer development. Oil and grease in water can gives adverse effects on human health such as eye irritation, Skin irritation, Dizziness, headache. In Extreme cases high gaining of oil and

grease content in body causes death. Therefore, it is suggested not to use this water for drinking purpose.

To remove hazardous content from the water and make the water useful for agriculture and domestic purpose some remedial measures are needed such as chemical oxygen method, electrocoagulation method which remove COD, BOD, and oil and grease from the water. Absorbtion method is also useful to remove chromium content from the water. This methods are suggested to enable the groundwater for agriculture and other purposes.

4. Conclusion

The present study showed variation from the water quality standards indicating contamination of groundwater. Water samples from the main drain and open wells indicating slightly saline nature of water in study area. Hardness level of sample A, B, C, W2, W4, W5, W6, W8, W9 is above the permissible limit given by Indian standard which shows hard nature of water of study area. Comparison of data with water quality guidelines concluded that some water quality parameters such as calcium, magnesium, sodium, chloride, carbonate, bicarbonate, nitrate, sulphate, zinc, and chromium are below the water quality guidelines. The potassium content in Sample A, B and W4 is higher than permissible limit. Therefore, it is not safe for irrigation purpose. The values of COD, BOD, chromium and oil & grease in drain and open well samples are more than the standard permissible limit hence, water of the study area is very toxic for human health. The study concluded that the effluents of the sugar factory deteriorate the quality of groundwater therefore, it is need to install water treatment plant for removal of hazardous contents.

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