STM JOURNALS

Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 11, Special Issue 1, 2023
DOI (Journal): 10.37591/JoPC

http://engineeringjournals.stmjournals.in/index.php/JoPC/index

Research JoPC

Water Quality Index Assessment of the Groundwater of Industrial Area and Absorption by Polymer Composites

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Abstract

Introduction: *Water plays a pivotal role in the existence of human life. Water quality index is an important parameter that helps in improving the quality of drinking and groundwater. Due to anthropogenic activities, the quality of ground and drinking water is decreased.* ***Objective:*** *The main objective of research is to find the water quality index of the groundwater and bore water in selected industrial area of Kakinada and analyse the use of polymer composites for desalination and water treatment.* ***Results:*** *The research results revealed that at sampling sites S-1, S-2 and S-3, water quality index is less than 100, which is considered as poor quality of drinking water. At sites S-4 to S-12, the water quality index is greater than 100, which is not suitable for drinking.* ***Conclusion:*** *The water quality index observed at various stations shows that water at some places is not fit for drinking. Index at sites S-1, S-2 and S-3 is below 100 (very poor quality) and sites S4 to S12 water is more polluted and unfit for drinking. The groundwater needs to be protected from pollution and government need to take necessary measures to improve the quality of groundwater. Cyclodextrin polymer composites are effective for removal of hardness and desalination.*

Keywords: Water, water quality index, groundwater, drinking water, polymer composites

INTRODUCTION

Water is part of the source for human existence on earth. Water plays a crucial role in the domestic, industrial, agriculture and commercial industries. Water quality index (WQI) is an important parameter for assessing the quality of the drinking water. Due to urbanization and industrialization, the quality of water is reduced.

WQI is parameter used to measure changes in quality of water in a particular area and we made comparisons of WQI from different location of Kakinada. This index allows for a general analysis of quality of water in many areas and extent of pollution in the groundwater environment and also helps government to take measures for improving the quality of ground and drinking water. Groundwater quality is impacted by natural processes such as irrigation, urbanization, industrialization, mining, and processes like precipitation, evaporation, ion exchange, and mineral dissolution [1, 2]. To meet their domestic needs, people who live close to industrial areas depend on the quality of the water. The only parameter that evaluates the total quality of the water is the WQI.

The objective of research is to analyse the WQI in different water sample and suggest the measures

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Received Date: December 21, 2022
Accepted Date: March 19, 2023
Published Date: May 18, 2023

Citation: Dasari Sravani, S. Aruna Kumari, K. Mruduladevi. Water Quality Index Assessment of the Groundwater of Industrial Area and absorption by Polymer Composites. Journal of Polymer & Composites. 2023; 11(Special Issue 1): S36–S45.

to increasing the quality of the water through the use of advanced polymer composites for water treatment and desalination.

Polymer composites are made up of two or more natural organic and inorganic materials with high mechanical strength, flexibility, chemical stability and high surface area. These materials are very effective in treatment of water and removal of salts. Among many composites materials the cyclodextrin and amino hyperbranched polymer cotton fibres are more effective for dye removal [3].

Study Area

The water was collected from different areas of the industrial region and rural areas of Kakinada. The coastal region of Kakinada is hub of industries where the usage of water is more for industrial, drinking and domestic purposes (Figure 1).

Figure 1. Map of the study location.

The samples at different location were collected in clean water bottles and stored at room temperature for performing the analysis. To evaluate the water quality at the various stations, many parameters were analysed. The WQI is the best parameter for assessing the purity of water and whether it is fit for drinking. The Bureau of Indian Standards are used to assess the WQI [4].

METHODOLOGY

All the water samples were collected at particular area and analysed for important parameters. The water quality was assessed via various parameter like pH, temperature, electrical conductivity, total dissolved solids (TDS), turbidity, total hardness (TH), total alkalinity (TA), Ca^{2+}, Mg^{2+}, Cl^{-} and dissolved oxygen (DO) with help of conductivity meter, pH meter, turbidity meter, total hardness. Ca^{2+}, Mg^{2+}, and Cl^{-} were analysed by titrimetric method.

RESULTS

For evaluating the quality of the water, a WQI was established for each and every month. Eight significant physio-chemical parameters were taken into account using the Central Public Health Environmental Engineering Organization (CPHEEO), 1991, and Indian Council of Medical Research (ICMR), 1975 standards [5]. Eight crucial factors were taken into consideration when calculating WQI: pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), total alkalinity (Alk), total hardness (Har-T), calcium (Ca), and magnesium (Mg). These factors most significantly impact water quality. The following are the steps for calculating the WQI: Weight factor (3.1): higher legal limit factors are less damaging since they can impair river water quality when present in very high concentrations (Table 1).

Table 1. The physiochemical analysis of water at different sites [5]

Sample	pH	Temperature	EC Ms	TDS ppt/ppm	Turbidity NTU	TH ppm	TA ppm	Ca^{2+} ppm	Mg^{2+} ppm	Cl^{-} Ppm	DO ppm
S-1 TMBW	7.21	29	3.84	0.00000152 ppm	0.05	400	601.5	172.3	55.33	514.84	4.60
S-2 TMMW	7.4	29.2	2.31	872 ppm	0.15	395	545	106.2	70.17	304.9	4.93
S-3 KMBW	7.3	28.7	0.903	335 ppm	1.93	325	590	82.16	59.01	24.99	3.19
S-4 kMMW	6.4	29.1	0.424	150 ppm	0.35	175	167.5	30.06	35.22	14.99	4.94
S-5 PDBW	9.01	29.3	3.29	0.00000121 ppm	0.02	325	750	104.81	53.50	25.99	5.02
S-6 PDMW	7.20	29.1	0.892	315 ppm	0.05	265	250	60.72	49.64	74.97	5.56
S-7 YDWW	7.66	29.1	3.36	0.00000145 ppm	0.28	555	865	148.2	98.85	454.8	4.67
S-8 YDMW	7.50	28.9	0.554	181 ppm	0.15	245	255	60.12	44.92	99.96	4.09
S-9 KDWW	7.20	29.1	1.42	406 ppm	0.04	330	445	86.1	59.26	49.98	4.61
S-10 VKBW	9.20	29.1	1.23	0.00000118 ppm	0.04	730	229	370.74	87.30	524.8	4.32
S-11 PNBW	7.92	28.9	7.45	319 ppm	0.65	225	432	102	98.4	4.52	4.28
S-12 PNMW	7.62	29.1	1.444	641 ppm	0.06	234	540	112	84.5	5.23	3.76

DO, dissolved oxygen; EC, electrical conductivity; TA, total alkalinity; TH, total hardness.

Therefore, a factor's weight and its allowable limitations have an inverse relationship. Consequently, Wi = k/Xi or Wi = 1/Xi where k is the proportionality constant. Wi is the weighting factor. Xi = the maximum allowable limits as determined by the Public Health Environmental Engineering Organization and the Indian Council of Medical Research. k Values were calculated as follows: k = 1. 8 I = 1. (1 Xi) where 8i = 1 (1/Xi) = 1/Xi (pH), 1/Xi (DO), 1/Xi (EC), 1/Xi (TDS), 1/Xi (Alk), 1/Xi (Hart), 1/Xi (Ca), and 1/Xi (Mg) [6] (Table 2).

Table 2. Water quality standards represents the ICMR standards and unit weights

Water quality factors	ICMR Standards Xi	Unit weights Wi
pH	6.5–8.5	0.218176
EC	300	0.00618
TDS	500	0.003708
TH	300	0.00618
DO	5	0.37089
Ca^{2+}	75	0.02472
Mg^{2+}	30	0.0618
Cl^{-}	250	0.007416

DO, dissolved oxygen; EC, electrical conductivity; ICMR, Indian Council of Medical Research; TDS, total dissolved solids; TH, total hardness.

Table 3. Qi rating table of water sample

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
pH	4.0	8.0	6.0	12.40	4.20	4.0	12.0	10.0	4.0	4.40	1.84	1.24
EC	46.8	76.9	9.99	14	106	29.6	110	18.9	47.3	41	248.9	48
TDS	0.05	174.4	67	30	0.004	63	0.029	36.2	81.2	0.03	63.8	128.2
TH	133.3	131.6	108.3	58.3	108.3	88.3	185	81.6	110	243.3	375	78
DO	104.1	100.7	118.5	118.8	349.9	94.1	103.4	109.4	108.9	107.8	82.7	223.9

Ca^{2+}	229.7	141.6	109.54	40	139.7	80.9	197.6	80.1	114.8	493.8	136	149.3
Mg^{2+}	184.3	233.3	196.7	117.3	178.3	165.4	329.5	149.7	197.5	291	329	281.6
Cl^{-}	205.9	121.9	83	46.96	86.63	249.9	181.92	333.2	19.99	209.6	1.8	2.09

DO, dissolved oxygen; EC, electrical conductivity; TDS, total dissolved solids; TH, total hardness.

Note:

pH: pH is crucial for the quality of drinking water. The drinking water's pH ranges from 6.5 to 7 to 8.5 which is slightly acidic in nature. Qi rating is S-1, S-5, S-6, S-9, S-10, S-11 and S-12 are acidic in nature and sites in S-2, S-4, S-7, S-8 are alkaline nature (Table 3).

EC: EC represents the conductivity of ions in water. EC varies from 300 mhos/cm. Qi rating is higher levels are observed in S-11 site next to S-5 and S-7 are detected. The lower levels of Qi rating are analysed in S-4 and S-9. Average levels of conductivity are observed in S-1, S-2, S-3 and S-10, S-12 sites.

TDS: Total dissolved solids are observed in water samples. TDS varies from 500 ppm. Qi rating of water samples observed in the sites S-2 and S-12 are high, whereas least are detected in samples S-1, S-5, S-7, S-10.

TH: The total hardness of water in the parameters are observed as 300 ppm for ground and drinking water respectively. The total hardness of water from S-12, S-11, S-1 respectively. The least hardness of water is observed in S-4.

DO: The dissolved oxygen is found to be standard value 5. In current samples of Qi rating is high is observed as S-5 and S-11.

Ca^{2+}: The calcium content was found to be highest inS-10 and S-1 but other station observed as average S-3, S-2, S-5, S-7,S-9,S-11,S-12. The least calcium content was observed in S-4, S-6, and S-8 sites.

Mg^{2+}: The magnesium content is highest in S-11, S-12, S-10, S-2, S-7 and average in S-1, S-3, S-4, S-5, and S-6 sites

Chloride ions: the Table 4 chloride content is highest is S-7, S-10, S-9, S-1 and average chloride ions S-2, S-6, S-5 and least content in S-3, S-11, and S-12 Show in Table 4.

Figures 2 to 9 provide a graphical representation of WQI rating of different parameter in sample water collected from different sites.

Table 4. Water quality index (WQI) rating table of water sample of different location sites

	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**
pH	8.72	17.44	13.08	270.32	91.56	8.72	26.6	21.8	8.72	95.92	40.1	27.03
EC	0.28	4.61	0.59	0.84	6.36	1.77	6.6	1.13	2.83	2.46	14.9	2.88
TDS	0.0015	5.232	2.01	0.9	0.0012	1.89	0.0887	1.086	2.43	0.0009	1.914	3.846
TH	7.99	7.89	6.498	3.498	6.49	5.29	11.1	4.89	6.6	14.5	22.5	4.68
DO	38.5	37.52	43.84	129.46	129.46	94.1	103.4	109.4	108.9	107.8	82.7	223.9
Ca^{2+}	4.59	2.83	2.19	0.96	2.79	1.61	3.95	2.17	2.15	9.87	2.72	2.98
Mg^{2+}	11.05	13.99	11.8	7.02	10.6	9.92	19.77	8.98	11.85	17.46	19.74	16.89
Cl^{-}	1.43	0.84	0.58	0.32	0.6	1.7	1.2	2.3	0.13	1.4	0.01	0.14

DO, dissolved oxygen; EC, electrical conductivity; TDS, total dissolved solids; TH, total hardness.

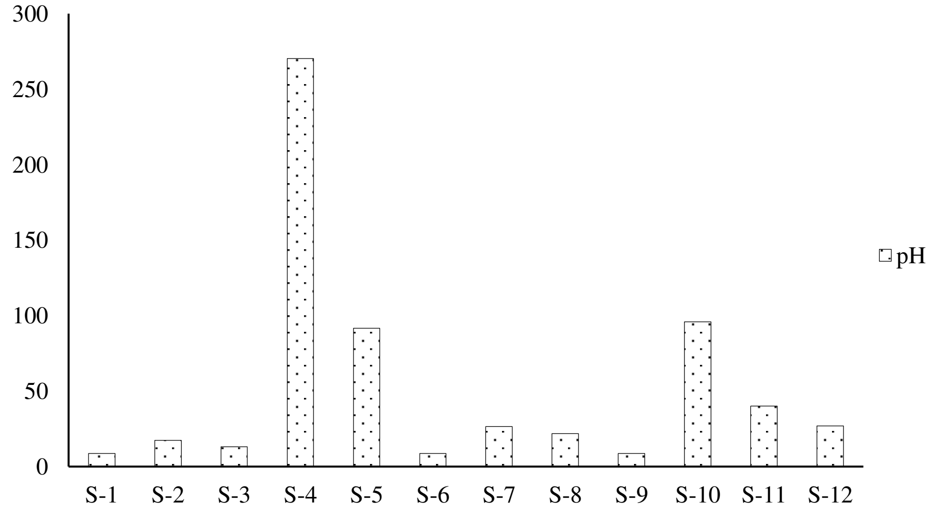

Figure 2. pH.

Journal of Polymer & Composites
Volume 11, Special Issue 1
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

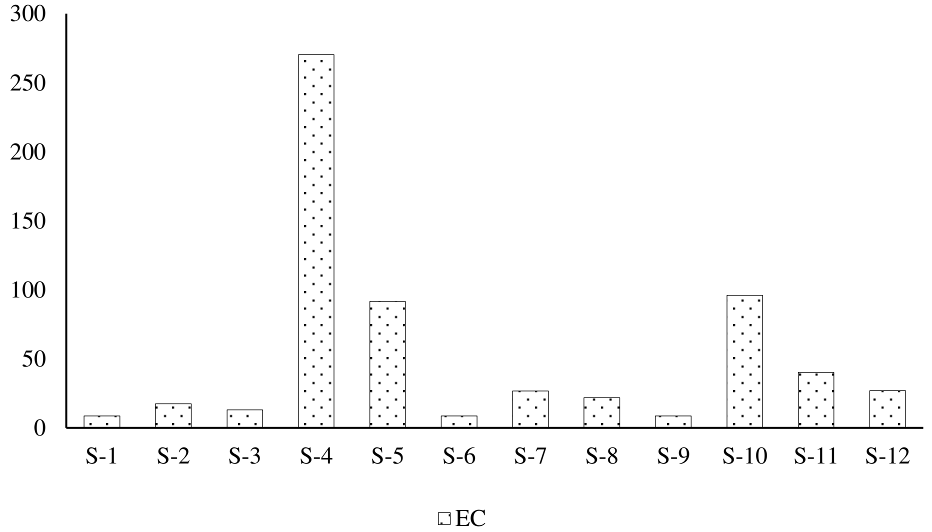

Figure 3. Electrical conductivity (EC).

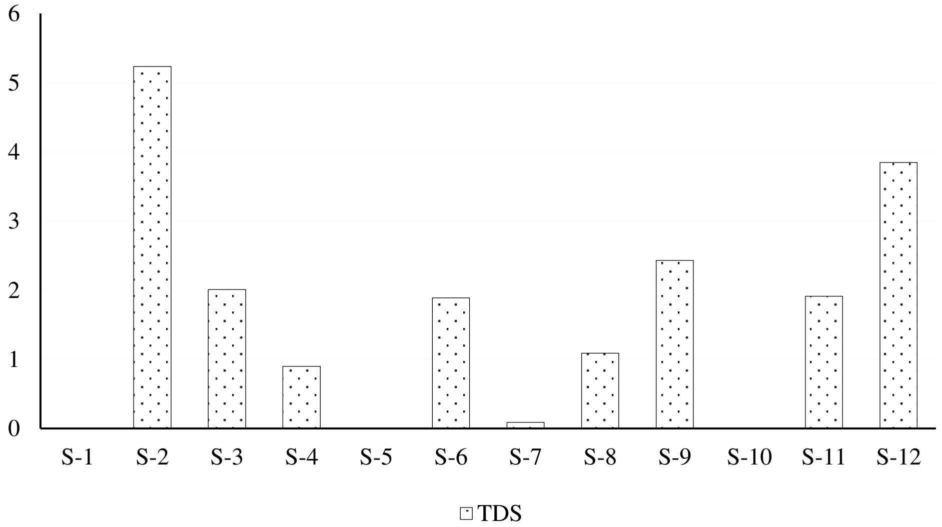

Figure 4. Total dissolved solids (TDS).

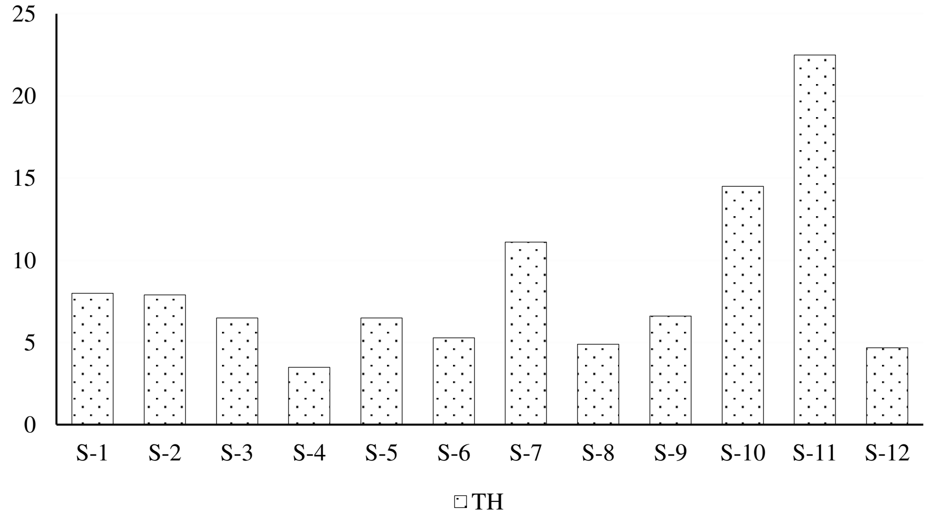

Figure 5. Total hardness (TH).

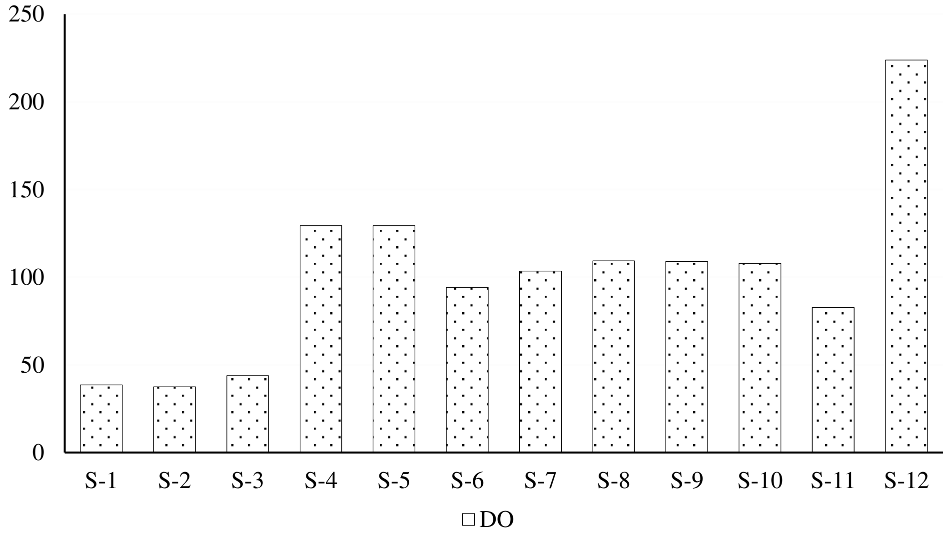

Figure 6. Dissolved oxygen (DO).

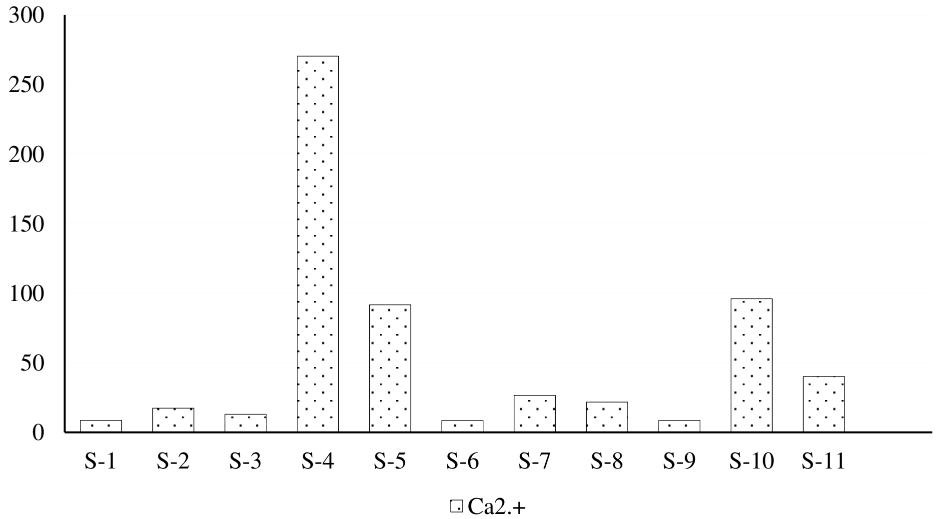

Figure 7. Calcium ions (Ca^{2+}).

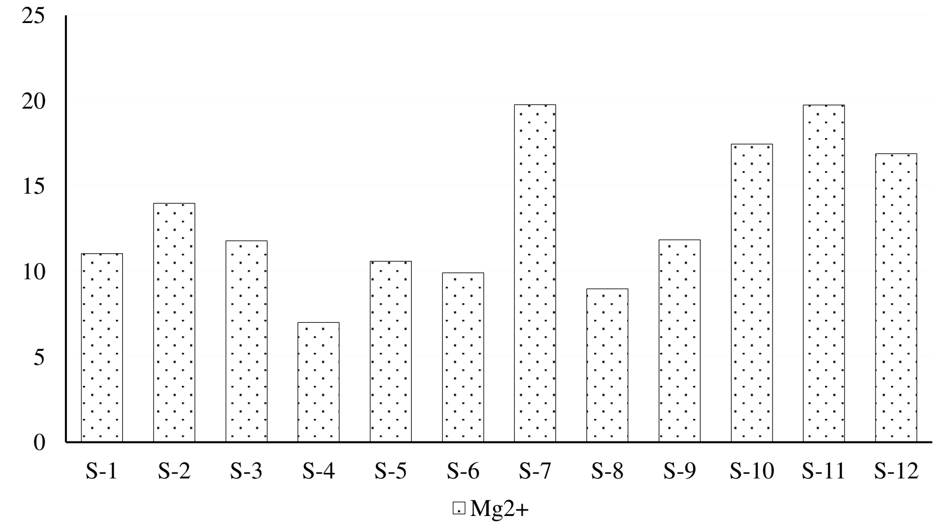

Figure 8. Magnesium ions (Mg^{2+}).

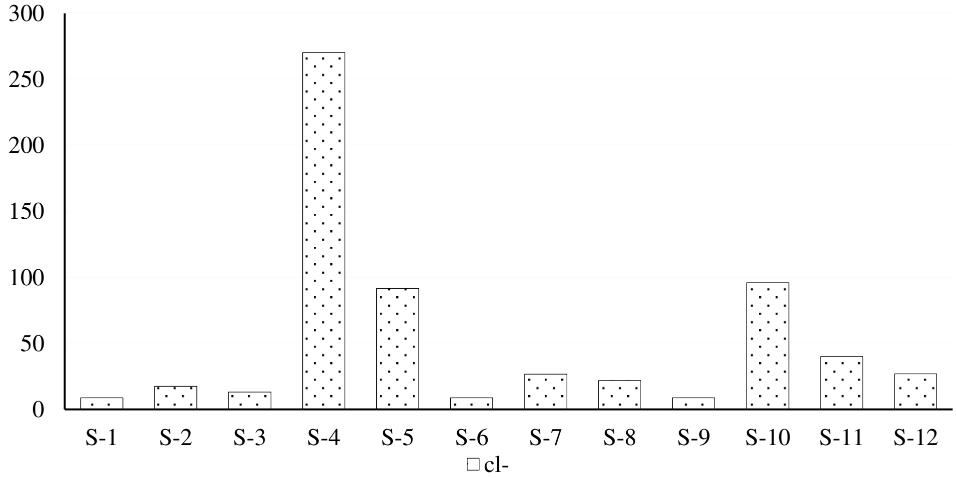

Figure 9. Chloride ions (Cl^{-}).

Table 5. Total water quality index (WQI) at different sites

Sample	Station	WQI
S1	TMBW	72.5
S2	TMMW	90.32
S3	KMBW	80.54
S4	KMMW	419
S5	PDBW	247.8
S6	PDMW	125
S7	YDWW	172.7
S8	YDMW	151.7
S9	PDMW	143.6
S10	VKBW	137.6
S11	PNBW	184.5
S12	PNMW	281.3

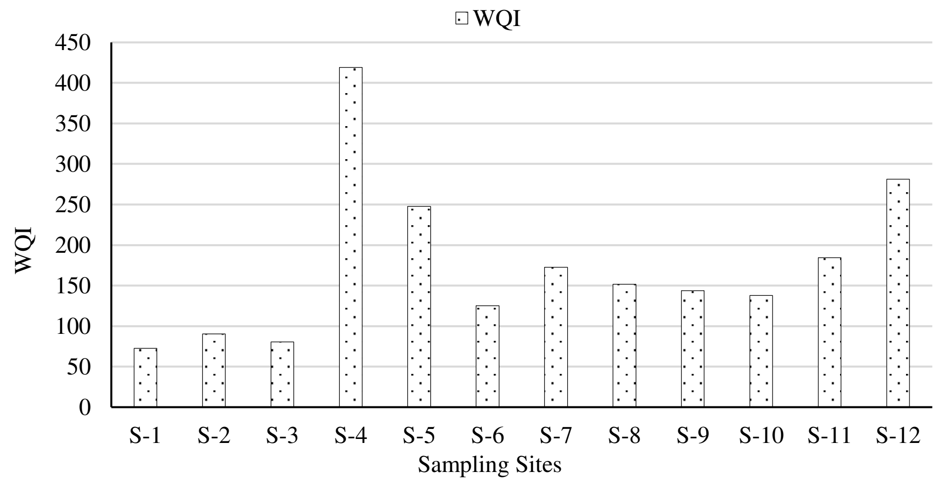

Figure 10. Bar chart representing water quality index (WQI) at the various sites.

The WQI observed at S-1 site is 72.5, at S-2 is 90.5, at S-3 site is 80.5, at S-4 is 419, at S-5 is 247.8, at S-6 is 125, at S-7 is 172.7, at S-8 is 151.7, at S-9 is 143.7, at S-10 is 137.6, at S-11 is 184.5 and at S-12 is 281.2 (Figure 10). Total WQI at different sites is presented in Table 5. The status of water quality based on WQI is presented in Table 6.

Table 6. Status of water quality based on water quality index (WQI) [7].

S.N.	WQI rating	Quality
1	0–25	Excellent
2	26–50	Good
3	51–75	Poor
4	76–100	Very poor
5	100 and above	Unsuitable for drinking

DISCUSSION

The WQI is highest in KMMW, PNMW and KMMW areas, which makes the water in these areas unsuitable for drinking. The WQI at sampling sites of PDMW, YDWW, YDMW, PDMW, VKBW and PNBW are also high and that is why it is not suitable for drinking. The sampling sites S-1, S-2 and S-3 is water quality index is less than 100, which is considered as poor quality of drinking water. At sites S-4, S-5, S-6, S-7, S-8, S-9, S-10, S-11, S-12 the water quality index is greater than 100, which is not suitable for drinking. The groundwater observed in Nigeria is good quality [8, 9]. Several latest methods are developed for assessing the WQI, in which best method is additive regression give best results [10]. Geographical information system is another method for assessing the WQI [11]. Polymer composites are most effective materials for removal of hardness and salts from water. There are different types of polymer composites for removal of salts such as polymer clay composite, polymer-based activated carbon composites, polymer graphene composites and polymer-based adsorbents for dye removal.

Polymer Clay Composite Polymer

Clay is low-cost natural material used for purification of micropolluants. Clay composites draws attention that in water treatment because of wide pores, wide surface area, with high stiffness and stability and regeneration is easier.

Polymer Based Activated Carbon Composites

Activated carbon is powdery solid made up of graphite structure. It is also one of the important materials for purification of water and desalination because it is low cost and easily produced from the agro wastes.

Polymer Graphene Carbon Nanotubes (CNT) Composites

CNT due to high surface area making as effective in water purification and removal of salts and disadvantage of low adsorption capacity.

Polymer Based Adsorbents for Dye Removal

Artificial synthesized dye materials are not effective than natural synthesized polymer composites. Because of their remarkable physiochemical characteristics and voids, cyclodextrin-based composites are particularly effective at removing metals [12–14, 7] (Figure 11).

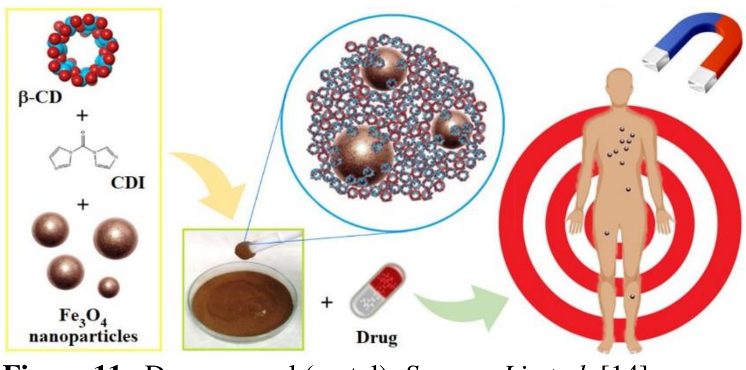

Figure 11. Dye removal (metal). *Source: Li et al.* [14].

Abbreviations

WQI = water quality index, Qi = quality rating, pH = pH scale, EC = electrical conductivity, TDS = total dissolved solids, DO = dissolved oxygen, TH = total hardness, Ca^{2+} = calcium ions, Mg^{2+} = magnesium ions, Cl^{-} = chloride ions.

CONCLUSION

The research results reveal that according to the water quality index observed at various stations, the water at some places is not fits for drinking. WQI at sites S-1, S-2 and S-3 are below 100 so the water quality is very poor and at sites S4 to S12 the water is more polluted and unfit for drinking. The groundwater needs to be protected from pollution, so that people can effectively make use of water resources for the domestic purposes, agriculture and drinking purpose. Beta cyclodextrin polymer is an effective polymer composite for removal of salts and purification of water.

Declaration of Interest

The authors declare there is no conflict of interest in submitted manuscript.

Acknowledgements

We extend my sincere gratitude towards my guide, co-guide and Aditya Educational Institutions and Aditya College of Engineering and Technology in carrying out my research work.

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