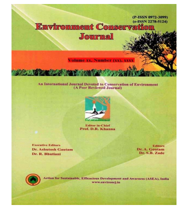
Environment Conservation Journal 23 (3):160-167, 2022

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)



Assessment of groundwater quality from Sahibabad to Modinagar Meerut Uttar Pradesh, India using water quality index

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ARTICLE INFO

Received : 20 February 2022
Revised : 30 March 2022
Accepted : 02 April 2022

Available online: 19 October 2022

Key Words:
Groundwater
Survival
Metroline
Water Quality Index
Pearson Correlation
Radar Chart

ABSTRACT

Groundwater quality and quantity both are important for the survival of human beings on this planet. In the present study an attempt has been made to assess the groundwater quality at mass using points. To fulfil the objectives of the present study, four sites (Sahibabad, Ghaziabad, Muradnagar, and Modinagar) were selected along the metro line construction from Delhi to Meerut. At all these sites, workers of metro line projects are living and working and using the groundwater for drinking purpose. Sampling was carried out from July 2021 to June 2022 using grab method of sampling. The samples were analysed for pH, total dissolved solids (TDS), total hardness (TH), calcium, magnesium, chloride, sulphate, nitrate, and fluoride. The data was processed using water quality index (WQI) and Pearson correlation metrix. TDS at all the study sites ranged from 514mg/l to 549.3mg/l and the values are above the standard limit of BIS (500mg/l). Values of TH, calcium and magnesium were found above the limits prescribed. Concentration of Chloride, nitrate, sulphate, and fluoride were found below the limits prescribed by BIS. However, nitrate is approaching to the standard limit (45mg/l). Correlation metrix shows that calcium is responsible for increasing values of TDS. As per the values of WQI, water quality of site 2 (46.7762), 3 (48.3523) and 4 (48.6281) falls in good category while at site 1 (50.9363) in poor category. There is an urgent need of strict actions to stop the increasing water pollution in the area to prevent the huge population of this area from various water related implications.

Introduction

Water is one of the vital elements necessary for the sustainable development of life on earth. In India, 85% of drinking water and 60% of irrigational water requirements are fulfilled by groundwater (Sajil Kumar, 2017; Agarwal *et al.,* 2019). In the present scenarios, many countries are facing the problem of water scarcity; even the good quality of drinking water is not available for the human society (Gleick, 2000). This situation is wide spreading day by day specially in most of the developing countries such as India, where majority of population depends on the availability of ground and surface water (Srivastava *et al.,* 2012). Physical, chemical, bacteriological and radiological characteristics of water make precious and healthful resource for all biotic and abiotic component of the ecosystem. It is reported that worldwide more than 1.5 billion people directly or indirectly depend on groundwater for drinking purpose (Shen *et al.,* 2008). The efficient use of freshwater resources and their transfer with high quality to the next generation are of great importance in terms of both human health and the ecosystem (Sener *et al.,* 2022). In various regions of the world different

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potable water sources and the associated ecosystems have undergone major modifications; therefore the availability, vitality, and quality of the water assets have been facing the human terrorization (Singh *et al.,* 2015a; Nemcic-Jurec *et al.,* 2019). Both the natural and manmade activities such as population blast, climate change, rapid urbanization and industrialisation, land conversion, extensive agricultural activities, and over abstraction (Singh *et al.,* 2015b; Nemcic-Jurec and Jazbec, 2017; Rawat *et al.,* 2018) contaminate the ground as well as surface water. Groundwater quality also depends on the nature of percolating water and geochemical reactions running in aquifers (Pandey *et al.,* 2020; Dutt and Sharma, 2022). Approximately 28% (1123 BCM-billion cubic meters) of the total water received on the geographical area of India (4000 BCM) is utilizable water resource annually (Central Water Commission, 2020). Groundwater fulfils about 85% of rural water requirement, 50% urban water requirement and more than 60% of countries irrigation water requirement (Sishodia *et al.,* 2016; Adimalla and Venkatayogi, 2017; SubbaRao *et al.,* 2017; Adimalla *et al.,* 2020). In India, the yearly abstraction and consumption of groundwater is highest. The exploitation of groundwater in India (244.92BCM in 2020) is higher than the consumption of both USA and China together (Singh, 2018). Furthermore, a report by the Central Ground Water Board, India reveals that the annual groundwater draft in India is approximately 245 × 109 m^3 (CGWB 2014; Adimalla and Venkatayogi, 2018; Li *et al.,* 2018; Adimalla and Li, 2019). Water quality index (WQI) is a most efficient process to convey the information of water quality concern to citizens and policy makers. WQI is used to by several authors to appraise the water quality of the concerned areas (Bhutiani *et al.,* 2018; Mukate *et al.,* 2019; Rezaie-Balf *et al.,* 2020; Uddin *et al.,* 2021; Ram *et al.,* 2021; Ruhela *et al.,* 2022; Mishra *et al.,* 2022).

Metro line construction activities are going on from Delhi to Meerut {project is named as Delhi–Meerut Regional Rapid Transit System (Delhi-Meerut RRTS)}. A lot of workers are working continuously at all the sites and utilizing the groundwater as the main source for drinking and bathing purpose. There is a need to evaluate the quality along this construction project. Therefore, in the present paper an attempt has been made to evaluate the groundwater quality at the selected sites of Delhi-Meerut Rapid Rail Corridor.

Material and Methods

The samples were collected from the selected sites (Figure 1) once in two months starting from July 2021 to June 2022 in the plastic can of capacity 2 Litre. After collection, the samples were transferred to the laboratory for the analysis of remaining parameters. The samples were analysed using the standard methodologies prescribed in APHA (2012) and CPCB manual (2010).

Figure 1: Showing the map of the study area (Source: Website of RRTS)

Water quality index (WQI)

WQI is an extremely valuable and efficient method which can provide a simple indicator of water quality and it is based on some very important parameters. In this study, WQI was calculated by using the Weighted Arithmetic Index method as described by Cude (2001) and Brown *et al.* (1970). In this method unit weight (Wi) and quality rating (Qi) was calculated first and then sub index of each parameter was calculated by multiplying the unit weight (Wi) and quality rating (Qi). The overall WQI was calculated by aggregating the sub index of each parameter by using the following equation:

$$WQI = \frac{\Sigma QiWi}{\Sigma Wi}$$

Where,

- Qi = Quality rating
- Wi = Relative weight

Results and Discussion

The average and comparative values of all the parameters are given table 1. pH is the negative log of hydrogen ion values. It measures the acidic and basic strength of the particular solution. Usually, pH values have no direct impact on human health but it alters the other characteristics (it promotes corrosivity inside the pipes which has a direct impact on human health) which affect the human health (Wu *et al.,* 2020). pH of groundwater depend on the certain factors like geology, atmospheric precipitation and anthropogenic activities in that area. During the study period, highest pH was observed at site 4 (7.7±0.04) and at the remaining site, same pH (7.6) was observed with different standard deviation. pH was observed within the limit of BIS (6.5 to 8.5). A strong negative correlation was observed between pH and chloride (-0.726) while a very week positive correlation with fluoride (0.050). Agarwal *et al.* (2019) observed the pH in the range of 7.31 to 8.97. The author also observed the anthropogenic activities in the area which are continuously altering the pH of the groundwater. Singh and Tripathi, (2016) also reported the pH between 7.1 and 7.9 in the same study area. Total dissolved solids (TDS) are the total of dissolved ions in the groundwater primarily calcium, magnesium, potassium, sodium, carbonates, sulphates, bicarbonates and chloride. As the TDS is directly correlated with electrical conductivity (EC) therefore an increase in TDS results in an increase in the EC of water. During the study period, minimum TDS (514.0 mg/l±3.94) was observed at SS-4 and maximum TDS (549.3mg/l ±9.89) was observed at SS-2. At all the studied sites, TDS was found above the standard limit of BIS (500mg/l). The obtained results are lesser than the obtained range (514.0–549.3 mg/l) from the report of Singh and Tripathi (2016) and Agarwal *et al.* (2019) for the NCR region. A strong negative correlation was observed between TDS and calcium (+0.742) indicating that calcium is the major ions responsible for increased TDS level in the area. Suitability of groundwater samples for domestic, industrial and irrigation purposes depends on the values of total hardness; therefore total hardness is considered as an important parameter (Farid *et al.,* 2022). The hardness in water is because of the presence of the carbonates and bicarbonates of calcium, magnesium, chloride and sulphate (Bhutiani *et al.,* 2021a&b). During the study period, minimum total hardness (358.4mg/l±3.37) was observed at SS-4 and maximum total hardness (380.7mg/l ±12.64) was observed at SS-1. Hardness was found above the standard limit of BIS (200 mg/l) at all the studied sites. All the samples fall in hard water category. Increased level of hardness is the causes of many stomach problems and reduced amount of minerals in human body (Rawat *et al.,* 2018). Therefore there is a need of water treatment before consumption in the study area. Prolonged use of hard water can cause urolithiasis (Agarwal *et al.,* 2019). Ahmad and Khurshid, (2019) observed the average values of hardness as 301.53mg/l in Hindon River basin area of Ghaziabad. Hardness was found moderately positively correlated with chloride (+0.629) and strongly correlated with sulphate (+0.954). TH was found moderately negatively correlated with calcium (-0.610) and weekly positively correlated with magnesium (+0.388). The results of correlation show that TH was highly influenced with chloride and sulphate in spite of their low quantity. However, concentration of calcium and magnesium were high but their impact was low. During the study period, minimum calcium (116.7mg/l±1.62) was observed at SS-4 and maximum calcium (124.6mg/l ±3.05) was observed at SS-2. Calcium was found above the

Table 1: showing the average values of physicochemical characteristics of the all the selected four sites (All the values are in mg/l except pH)

Parameters /Month	SS-1	SS-2	SS-3	SS-4	Standard (BIS, 2012)
pH	*(7.43-7.76) 7.6±0.11	*(7.43-7.62) 7.6±0.07	*(7.53-7.68) 7.6±0.05	*(7.69-7.79) 7.7±0.04	6.5-8.5
TDS	*(510.7-567.9) 527.6±21.02	*(539.8-567.9) 549.3±9.89	*(538.1-549.1) 542.8±4.80	*(511.5-521.9) 514.0±3.94	500
Total Hardness	*(360.3-394.3) 380.7±12.64	*(362.5-374.2) 367.9±4.13	*(345.9-376.2) 363.9±10.36	*(353.8-362.1) 358.4±3.37	300
Chloride	*(66.2-79.7) 74.3±4.94	*(75.2-83.9) 78.9±2.93	*(55.2-65.2) 59.9±3.53	*(55.8-67.3) 62.9±4.11	250
Magnesium	*(75.2-79.3) 77.8±1.57	*(72.8-77.8) 75.0±1.82	*(75.2-79.3) 77.8±1.57	*(70.4-74.1) 72.1±1.49	30
Calcium	*(113.7-123.5) 117.7±3.65	*(121.2-129.5) 124.6±3.05	*(115.8-128.2) 121.4±4.39	*(114.4-119.3) 116.7±1.62	75
Sulphate	*(27.2-34.5) 30.3±2.70	*(34.5-39.8) 37.9±2.08	*(28.5-31.5) 29.9±1.12	*(27.6-29.5) 28.9±0.67	200
Nitrate	*(29.3-33.5) 31.1±1.65	*(31.7-39.2) 34.6±2.75	*(31.3-34.9) 33.8±1.33	*(29.8-30.7) 30.1±0.33	45
Fluoride	*(0.24-0.32) 0.28±0.03	*(0.21-0.28) 0.24±0.03	*(0.23-0.28) 0.26±0.02	*(0.24-0.32) 0.21±0.27	1

***=range (n=06)**

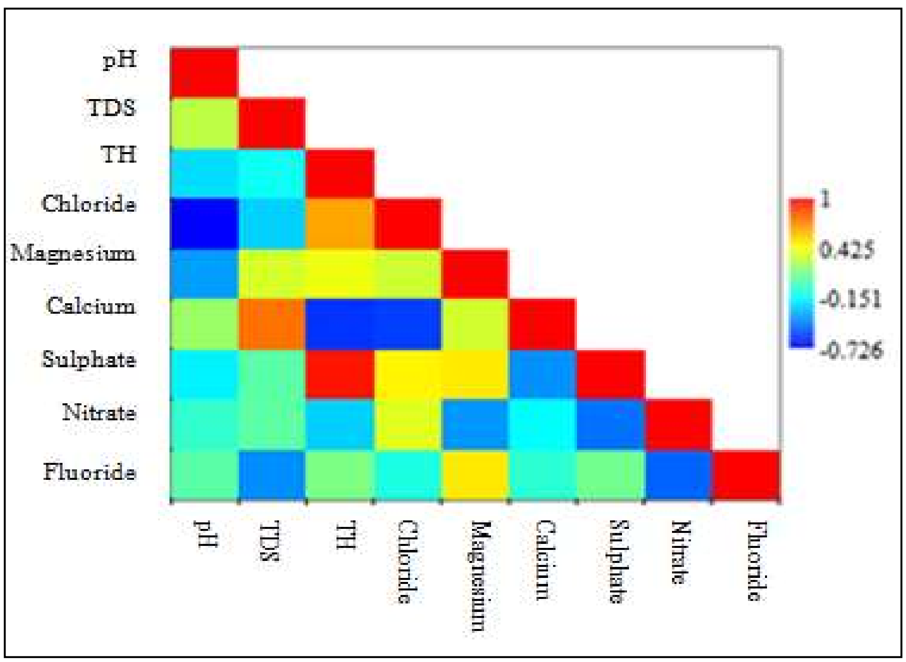

Figure 2: Showing the correlation between average values of physicochemical characteristics.

standard limit of BIS (75 mg/l) at all the studied sites. During the study period, minimum magnesium (72.1mg/l±1.49) was observed at SS-4 and maximum magnesium (77.8mg/l ±1.53) was observed at SS-1 and SS-3. Magnesium was found above the standard limit of BIS (30 mg/l) at all the studied sites. Chloride is considered as an indicator of sewage contamination in water. Higher quantity of chloride is responsible for salty taste and bleaching property of water (Sadat-Noori *et al.,* 2014). The higher concentration of chloride ion is responsible for salinity problem in ground water.

During the study period, minimum chloride (59.9mg/l±3.53) was observed at SS-3 and maximum chloride (78.9mg/l ±2.53) was observed at SS-2. Chloride was found within the limit of BIS (250 mg/l) at all the studied sites. Occurrence of sulphate in groundwater is due to nature of rocks present there, nature of fertilizers used and solid and liquid industrial waste dumped in the area. Sulphate beyond the permissible limit is harmful to plumbing structures. During the study period, minimum sulphate (28.9mg/l±0.67) was observed at SS-4 and maximum sulphate (34.6mg/l ±2.75) was observed at SS-2. Sulphate was found within the limit of BIS (200 mg/l) at all the studied sites. Sulphate was found strongly positively correlated with TH (+0.954) and moderately positively correlated with chloride (+0.448) and magnesium (+0.472). Sources of presence of nitrate in groundwater are nitrogen-based fertilizers, atmospheric precipitation, residues of crops (Shakerkhatibi *et al.,* 2019), and septic tanks (Nakagawa *et al.,* 2017). Increased quantity of nitrate in water (beyond the permissible limit) causes blue baby syndrome (Logeshkumaran *et al.,* 2015). During the study period, minimum nitrate (30.1mg/l±0.33) was observed at SS-4 and maximum nitrate (34.6mg/l ±2.75) was observed at SS-2. Nitrate was found below the standard limit of BIS (45mg/l) at all the studied sites. Similar lower concentrations of nitrate ion have also been found by Lone *et al.* (2021). A week negative correlation of nitrate was found with TH (-0.258), magnesium (-0.152), and moderately negative with sulphate (-0.468). Both the natural and anthropogenic factors are responsible for fluoride occurrence in groundwater. A minimum quantity of fluoride is a dietary requirement for strong bones (Aravinthasamy *et al.,* 2020) while in excess quantity it causes bones fluorosis (whether teeth or skeletal) and different other implications. During the study period, minimum fluoride (0.23 mg/l±0.02) was observed at SS-4 while maximum fluoride (0.28mg/l ±0.03) was observed at SS-1. Fluoride was found within the limit of BIS (1.0 mg/l) at all the studied sites.

Water quality index (WQI)

Standard values, ideal values and unit weight used in the calculation WQI are given in table 2 while the values of WQI at all the sites are given in table 3. The WQI is a widely acknowledged method for determining the fitness of groundwater for human use. Twelve water quality parameters (Cl^-, pH, Ca^{2+}, Mg^{2+}, TDS, SO_4^{2-}, NO_3^-, and F^-) were involved in estimating the integrated groundwater quality by the WQI method. Standard values recommended by Bureau of Indian Standard (BIS) for drinking water were used as reference for WQI calculation. Water quality was categorized based on Chaterjee and Raziuddin (2002) classification, as (I) excellent, (WQI is 0-25); (II) good (26–50); (III) poor water (51–75); (IV) very poor water (76–100); (V) unsuitable for drinking, when WQI is >100. At all the studied sites magnesium was considered as criteria pollutant due to highest value quality rating (Qi). The value of WQI at site 2, 3 and 4 ranged from 46.7762 to 48.6281. Therefore, groundwater at these sites falls in second category i.e. good. At site 1, the value of WQI was found as 50.9363, therefore, groundwater quality at this site falls in third category i.e. poor. Values of WQI at all the sites indicate that water quality is continuously degrading in the area. Therefore there is a need of awareness among the society and stake holders regarding the water quality and its impacts on human health.

Table 2: Showing the standards value, ideal value and unit weight of each parameter used for the calculation of WQI.

Parameters	Standard value	Ideal Value	Unit weight
pH	7.5	7	0.0844
TDS	500	0	0.0013
TH	300	0	0.0021
Chloride	250	0	0.0025
Ca	75	0	0.0084
Mg	30	0	0.0211
Sulphate	200	0	0.0032
Nitrate	45	0	0.0141
Fluoride	1	0	0.6330

Conclusion

The present study was conducted at the selected sites along the metro line construction from Delhi to Meerut. The objective of the present study was to evaluate the water quality in terms of physicochemical parameters. The groundwater in study area was found slightly acidic in nature. Values of dissolved solids were found beyond the

Table 3: Showing the values of sub-index of each parameter and WQI at all the sites

Parameters/Site	SS-1		SS-2		SS-3		SS-4	
	OV	WiQi	OV	WiQi	OV	WiQi	OV	WiQi
pH	7.6	10.7469	7.6	9.3965	7.6	10.0155	7.7	12.4349
TDS	527.6	0.1336	549.3	0.1391	542.8	0.1374	514.0	0.1302
TH	380.7	0.2677	367.9	0.2587	363.9	0.2560	358.4	0.2521
Chloride	74.3	0.0752	78.9	0.0799	59.9	0.0607	62.9	0.0637
Ca	77.8	0.8749	75.0	0.8436	77.8	0.8749	72.1	0.8108
Mg	117.7	8.2759	124.6	8.7600	121.4	8.5408	116.7	8.2102
Sulphate	30.3	0.0479	37.9	0.0600	29.9	0.0473	28.9	0.0457
Nitrate	31.1	0.9732	34.6	1.0805	33.8	1.0555	30.1	0.9409
Fluoride	0.28	17.8295	0.24	15.4030	0.26	16.2470	0.23	14.5590
∑WiQi	39.2250		36.0214		37.2351		37.4475	
WQI	50.9363		46.7762		48.3523		48.6281	

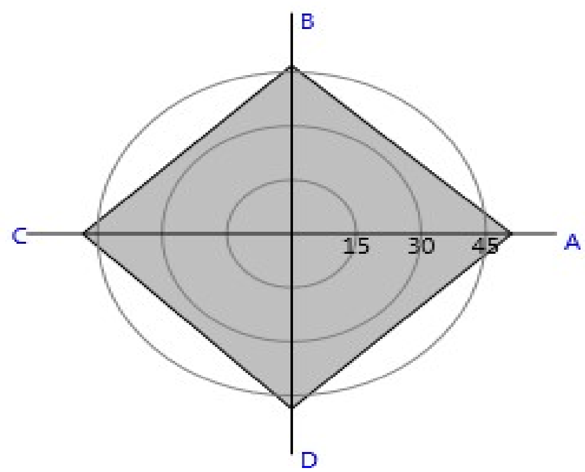

Figure 3: Radar chart showing the values of WQI at all the sites.

permissible limits at all the sites showing the problem of salinity in the study area. Values of hardness, calcium and magnesium were found beyond the limits but the values of chloride and sulphate was found below the permissible limits showing that the temporary hardness is present in the groundwater. Therefore, there is a necessity to spread the awareness among the workers to use the water after proper boiling otherwise various abdominal implications will happen in long term use of this water. Fluoride was also observed below the standard limit. Similarly, the values of nitrate was also observed below the standard limit but the values are approaching towards limit, therefore there is a necessity to spread the awareness among the farmers regarding the use of nitrogen based fertilizers. Values of WQI indicate that water quality in the area falls from good to poor category. Therefore, there is an urgent necessity to take the appropriate steps to protect the water quality as well as quantity in the study area.

Acknowledgement

The authors are thankful to the KEC International Limited for providing facilities of water monitoring and Arihant Analytical Laboratory for performing monitoring and analysis of water samples. The authors are also thankful to the Department of Environmental Engineering (SITE), Swami Vivekanand Subharti University, Meerut for providing necessary facilities during the completion of this project.

Conflict of interest

The authors declare that they have no conflict of interest.

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