Hydrogeochemical Investigation and Groundwater Quality Assessment in Patancheruvu Area Sangareddy District, South India

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ABSTRACT

The current research was conducted to assess the groundwater quality in the Patancheruvu area of Sangareddy District, South India. To analysis physicochemical parameters, 16 groundwater samples were collected for the month of May and November, 2020. The chemical analysis results show that the ground water nature in the study area is alkaline to basic and is classified very hard water. High TDS concentrations in the study area is due to various industries and anthropogenic activities. In both seasons, the order of major cations and major anions is in the following order: $Na > Mg > Ca > K$ and $Cl > SO_4 > HCO_3 > NO_3 > F$ respectively. The majority of the EC, TDS, Na, TH, Mg, Ca, Cl, HCO_3, and SO_4 samples exceeded the desirable limit, and some samples also exceeding the permissible limit. In both seasons, the dominant hydro chemical facies identified by the Chadha diagram were $Na-K-HCO_3$ and $Ca-Mg-HCO_3$. Water quality analysis said that most of the data in both seasons fell into poor to very poor category. The research tells that around Patancheruvu groundwater quality is poor, thisis attributed due to both anthropogenic factors and geogenic processes.

Keywords: chemical analysis; groundwater; Patancheruvu; physicochemical; water quality.

INTRODUCTION

Water is the most essential part for every living organism which is also a main fragment of earth's rivulet, lagoons, and oceans. Water is completely tasteless, odourless and free from any chemical constituents but yet it is vital for all known animal kingdom, starting from fairy flies to leptotyphlops. Although 71% of total earth's surface is covered by water yet 96.5% of these are hold by the oceans and for the remaining 2.5%, two-third is frozen (Mtoni et al., 2012). So ultimately there is not much fresh water left for civilization uses currently. Taking the world's total population as 7.5 billion, so it is a vital matter of concern to use the total accessible water wisely and effectively with minimum wastage. It is only the 8% of the planet's fresh water those are used for domestic purpose and rest 80% are being used for cultivation and industrial purposes (Aher et al., 2019). Due to the scarcity of fresh water, over a billion people deficits to clean drinking water. Currently, surface and groundwater quality issues are much more severe in densely populated, heavily industrialised areas, excessive use of pesticides and fertilisers in rural areas, and shallow ground water tablets (Alphayo and Sharma, 2018). There is no substitute for the drinking water sources therefore, it is highly recommended to have a disciplined management if available water and timely

monitoring of water quality is also required (Ali, 2010). In India, the availability of surface water resources is insufficient which ultimately results in the dependency of most of the urban and semi urban people on the ground water resources (Bradford et al., 2014). Currently, surface water bodies and aquifers that store groundwater are changing greatly in terms of their quality. This is happening due to domestic, agricultural and industrial activities on surface and on atmospheric (Graham and Polizzotto, 2013). These actions are changing water quality and directly impacting adjacent human health and socioeconomic aspects. In order to scientifically develop and manage water resources, it is necessary to evaluate and predict surface and groundwater quality (Dzwairo et al., 2006). Anthropogenic activities change groundwater levels and flow conditions through pumping, which promotes the interaction between groundwater and aquifer rocks, while industrial drainage is discharged into surface water systems, thereby affecting the hydrogeochemical processes of the entire water system change (Miraji and Zheng, 2019).

Studying physio-chemical, and biological estimation of water resource is important for government and policymakers. The quantity of nutrients and suspended sediment (SS) in surface water plays an essential role in aquatic ecosystems and contribute safety to water quality (WQ) (Anwar and Aggarwal, 2016). Most of the catchments and rivers are affecting from anthropogenic stress. Therefore, studying long-short term responses of changing land use and land cover (LULC) with respect to water quality is essential for effective management of surface water and ground water (Ibraheem and Mazhar, 2017). Surface water quality (SWQ) has supreme importance in controlling domestic as well as aquatic ecosystems (Jain and Vaid, 2018). Ground water quality impacts both drinking water resources and agricultural uses. Landscape characteristics are the dominant factors that have a substantial effect on water quality (El Ouadrhiri et al., 2022; Sunadji et al. 2022). For better understanding the water quality changing trend in surface and ground water, studies must be including the correlation between industrial, urban and agricultural Land uses with respect to water quality parameters (Bradford et al., 2014). Many researchers have identified the alterations in LULC and WQPs, for example, a higher extent of agricultural and urban land leads to an increase in concentrations of Nitrate (N) and Phosphate (P) into the freshwater ecosystem (Graham and Polizzotto, 2013). The reason behind this is the mixing of fertilizers into the surface water through runoff from different land uses. If water quality studies have done with both point source (PS) pollution studies as well as Non-point Source (NPS) pollution can improve in understanding and analysing water planning and management. PS pollutants are not dependent on flow, while NPS is primarily dependent on flow and further altered by several site-specific factors (Dzwairo et al., 2006). Therefore, WQ in wet season indicates the collective impact of NPS and PS pollution while, in the dry season, it is derived mainly from PS pollutant (Mtoni et al., 2011).

The different water quality parameter can be conventionally studied by conducting laboratory experiments on field samples and applying advance techniques to these samples (Mjemah et al., 2009). Conventional sampling point methods are fit for identifying the Spatial-temporal variations of WQ and for checking different water quality standards. They are expensive, time-consuming, and limit the assessments (Miraji and Zheng, 2019; Olasoji et al., 2019). Finding loads of nutrients like nitrogen (N), phosphorus (P) and suspended sediment (SS) is complicated because of data non-normality, infrequent monitoring of data and of missing data (Dwivedi et al., 2016). To enhance the security and operating performance of WQ management, it is necessary to establish a computer decision-making system, which can play a similar role in WQ evaluation, prediction, planning and protection (Haddeland et al., 2014). Majority of studies have addressed the importance of accurately acquiring the information of water components for WQ monitoring by using Remote Sensing (RS) (Korajkic et al., 2018). Since from the 1970s, a large number of satellites have been launched with multi-sensors on board, which are continuously providing data (Nnadi and Fulkerson, 2002). Satellite RS is promising tool for the assessment of spatial and temporal variations in land use and land cover, handling the complex heterogeneous and dynamic behaviour of coastal, inland and estuaries (Kalita et al., 2021). Remote sensing data has a tremendous role in water quality analysis (Dhere and Jagnnath, 2016). A proper assessment enables policymakers and water resource managers to understand the behaviour of watershed for current and future land-use practices.

STUDY AREA

The area taken up in the present study is situated in Patancheruvu which is in the north western part of Hyderabad and is geographically located between North latitude 17.53° and 78.27° EastLongitude. The survey of India topo sheets 56 O/5 and 56 O/2 cover the entire watershed area. The total geographical area of watershed covers parts of both Sangareddy block. The villages covered by the study are area Ameenapur (CT), Bachuguda, Bhanur, Indresham, Patelguda, Sultanpur and Wadakpalle. The study area along with water quality points is shown in Figure 1.

MATERIALS AND METHODOLOGY

The research was done by collecting available physicochemical information from various public and private institutions located in the study area. Subsequently, the quality of the data was verified considering: i) reasonable reported chemical and physicochemical values, ii) transcription errors and, iii) analytical errors in the ionic balance less than or equal to 10%.To determine the water quality and chemical composition of groundwater graphic, descriptive and multivariate statistical methods are used. These methods are combined and correlated with the geological and hydrogeological knowledge of the study area.

In the current study, 16 well water data were collected for the months of May, 2020 and November, 2020. Here, May and November are considered as Pre-monsoon season (Dry season) and Post monsoon season (Wet season) respectively and analysed physicochemical parameters of groundwater using the APHA (2005) procedures.

Groundwater samples were collected in 1000-ml polyethylene bottles, after flushing the well assembly with water for 5-10 minutes to remove stagnant water. Before collecting the water form well, the bottles were cleaned with distilled water. The electronic OTT dip metre was used to measure the water level. At the time of the field visit, pH and conductivity metres were calibrated with standard buffers of the respective parameters for determining, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and pH. To remove solid sediments, the samples were filtered in a vacuum filtration unit using 0.45-m Millipore filter paper. The GPS was used to determine the locations points of collected well data. For collected water data physicochemical parameters analysis was done for the both periods of 2020 year. Standard analytical method is used to calculate the total hardness (TH), magnesium (Mg), calcium (Ca), sodium (Na), bicarbonate (HCO_3), potassium (K) carbonate (CO_3), sulphate (SO_4), chloride (Cl), and fluoride (F)(APHA 2005). The volumetric technique was used to determine the concentrations of Total hardness, HCO_3, Mg, Ca, and Cl. Titrimetric ally standard EDTA titration is
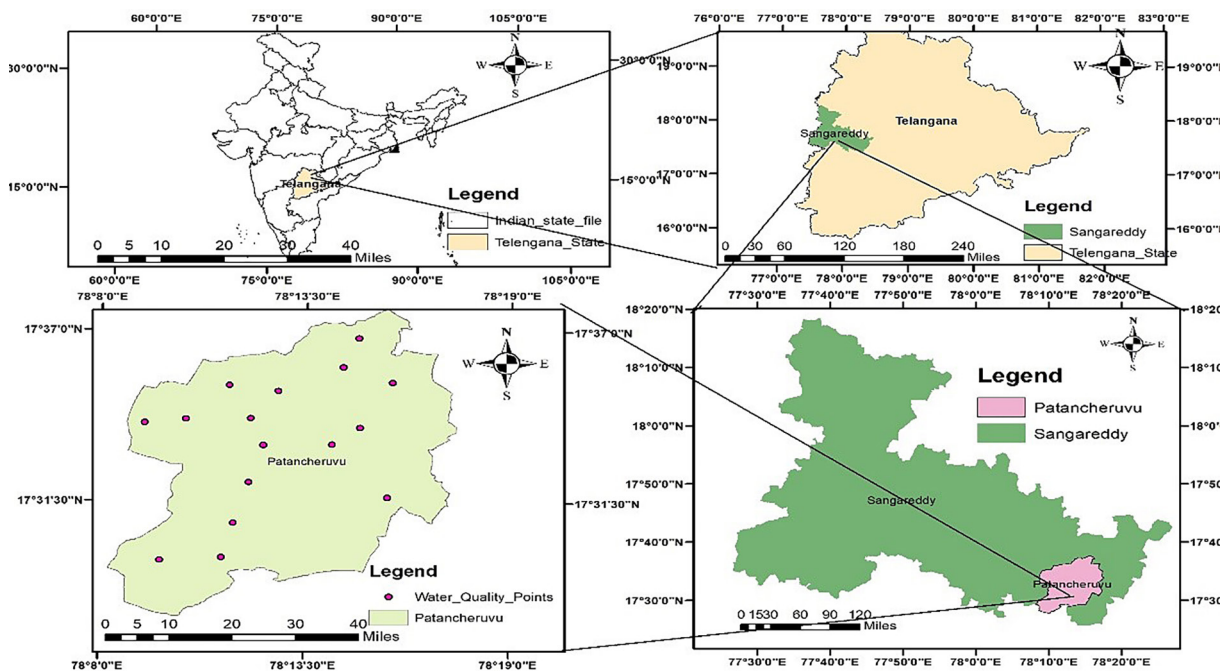

Figure 1. Study area with water quality sample points

used to determined Ca and Mg concentrations. Titration of HCO_3 to a methyl in the presence of phenolphthalein and methyl orange indicators. Titration with $AgNO_3$ solution was used to determine chloride. Flame emission photometry was used to determine Na and K. SO_4, NO_3, and F were measured using a spectrometer and various buffer solutions. The data were statistically analysed, and mean, standard deviation calculated by excel 10. These parameters provide useful information about the processes that control groundwater in the study area. In the present study, it was considered that the data have quality assurance and control at the time of sample collection and analysis. However, the data was examined to verify that the compiled characterisations had the relevant quality for the development of this investigation. During this data review, errors such as: samples with uncertain locations or with inverted coordinates, no recording of depths, inconsistent units of measure (all concentration values were converted to mg/L format). The error of Ion balance calculation given in Eq. (1).

The accuracy of the data determined by using Ionic balance error.

$$\text{Error of Ion balance} = \frac{\sum \text{Cations} - \sum \text{Anions}}{\sum \text{Caions} + \sum \text{Anions}} \times 100 \tag{1}$$

For accuracy of the results it should be ± 10. The ionic balance error is within ± 10, excluding few samples which are above ± 10 in both the seasons.

Water quality index (WQI)

Globally Water Quality Index (*WQI*) method is used to assess the appropriateness of water quality for domestic purposes. Water quality for drinking purposes around the study area is calculated with the help of WQI method and compare the WQI values with the BIS (2012) standards. WQI is calculated by using 9 parameters. Three steps were used to compute WQI. In the first step weight (w_i) assign to the nine parameters (Hardness, pH, Cl, TDS, SO_4, Ca, F, Mg and NO_3) (Table 1). In the next step Eq. (2) is used to estimate the relative weight (W_i).

$$W_i = \frac{wi}{\sum_{i=1}^{n} wi} \tag{2}$$

where: w_i–weight of the respective parameter;
n– number of parameters.

Final step is assigning quality (q_i) of respective parameter which was calculated by Eq. 3

$$q_i = \frac{(C_i - C_{i_0})}{(S_i - S_{i_0})} \times 100 \tag{3}$$

where: C_i–Measures value of respective parameter;
S_i – normal allowable value was given in BIS, 2012 for each parameter in mg/l and
C_{i_0} is the ideal value.

WQI is calculated with the sub index (SI_i) with the help of Eq. 4

$$SI_i = W_i \times q_i \tag{4}$$

Final WQI is computed by sum of SI_i of each groundwater samples data as follows Eq. 5

$$WQI = \sum SI_i \tag{5}$$

RESULTS AND DISCUSSIONS

Specific parameters were analysed spatially and statistically for collected groundwater samples of Patancheruvu. The parameters were

Table 1. Relative weight of chemical parameters

Chemical parameters	Bureau of Indian Standards (BIS, 2012)	Weight (*wi*)	Relative weight $W_i = wi/\sum_{i=1}^{n} wi$
TDS	500	4	0.13333
pH	6.5–8.5	4	0.13333
Hardness	300	2	0.06667
Ca	75	2	0.06667
Mg	30	2	0.06667
Cl	250	3	0.1
SO4	200	4	0.13333
NO3	45	5	0.16667
F	1	4	0.13333
		$\sum wi = 36$	$\sum Wi = 1$

determined are pH, TDS, electrical conductivity, chlorides, calcium, sodium, potassium, magnesium, alkalinity, nitrates, sulphates, fluorides, and total hardness. Tables 2 shows the Average, Maximum (Max), Minimum (Min), and standard deviation (St.D) values of physicochemical indicators for May and November 2020. The maximum and minimum values of the cations and anions reflect the degree of chemical heterogeneity of the groundwater as a result of the different geochemical processes present in the study area.

For the month of May pH ranges from 7.1 to 8.4, while for the month of November pH ranges from 8 to 9.5. In the May and November months, the normal pH is 8.8 and 8.6, respectively. It tells that the pH nature of the water in study area slightly having alkaline side. All collected data were found that within the adequate range as mentioned in BIS, 2012. In the month of May, the electrical conductivity (EC) range from 485 to 5408 S/cm and while in the month of November it is ranged from 385 to 5308 S/cm. These ranges are happening with and average value of 1715 S/cm and 1615 S/cm for the month of May and November respectively. The EC values show that the concentration of EC decreases from May to November, which could be due to dilution during the month of November. The presence of salts such as Na, Cl, and HCO3 in groundwater explain the high EC value.

The major cations and anions are added together to form total dissolved solids (TDS). In this study, TDS ranges from 320 to 3569 mg/l for May month with a mean value of 1132 mg/l and for November month it is range from 220 to 3469 mg/l with a mean value of 1032 mg/l. According to BIS, 2012 permissible limit and desirable limit of TDS are 2000 mg/l and 500 mg/l respectively. From the results, it is observed that the average TDS value is above the desirable limit. Approximately 70% and 60% of samples data are exceed the desirable limit in the month of May and November respectively. Aside from the desirable limit, 39% and 35% of the samples data exceeded the permissible limit. High concentration of TDS in the region may be due the presence of various industries and anthropogenic activities are major concern. The quality of groundwater in the region based on TDS and Total hardness (TH) for both the months are shown in following Figures. From the Figure 2, it is noted that majority of the samples was fresh water in nature. High TDS in the region may be due the presence of salts like Na, Cl, SO_4 and HCO_3 (Das and Mahanta 2019).

May month TH variety from 236 to 1637 mg/l with a mean value of 667 mg/l, whereas for the month of November TH varies from 156 to 1558 mg/l with a mean value of 644 mg/l. From the TH results, it is identified that a greater number of water samples date range from hard to very hard type. It is also observed that average hardness value exceeds the desirable limit.

Calcium (Ca) concentrations varies from 45 to 360 mg/l in the month of May, and in the month of November it varies from 33 to 348 mg/l. The mean Ca value in the May month is 105 mg/l and

Table 2. Physico-chemical statistical analysis of various parameters for May and November 2020

Physico chemical indicators	Bureau Indian Standard (BIS, 2012)		May				Nov			
	Desirable limit	Allowable limit	Min	Max	Ave	St.D	Min	Max	Ave	St.D
pH	6.5	8.5	7.1	8.4	7.8	0.4	7.0	8.5	7.6	0.4
EC	-	-	485	5408	1715	1239	385	5308	1615	1239
TDS	500	2000	320	3569	1132	818	220	3469	1032	818
TH	300	600	236	1638	667	363	156	1558	644	389
Ca	75	200	45	360	105	68	33	348	102	72
Mg	30	100	30	214	98	50	18	214	95	55
Na	-	-	25	545	213	154	54	489	179	140
K	-	-	5	259	49	46	13	247	40	45
Cl	250	1000	175	850	299	201	265	811	255	192
SO_4	200	400	125	1145	230	228	211	1130	224	9
HCO_3	200	600	92	620	227	126	199	600	221	123
NO_3	45	No relaxation	23	1050	202	241	20	989	198	7.6
F	1	1.5	0.25	2.50	0.96	0.56	0.10	2.35	0.81	0.56

in November it is 102 mg/l. Ca concentrations decrease from May to November, possibly due to dilution in rain season happen before November. In terms of drinking purposes, the average value of Ca is above the desirable limit (i.e. 75 mg/l). Furthermore, approximately 75% and 69% of water samples data in May and November month exceeded the allowable BIS requirements of 200 mg/l. A high Ca concentration in water may have a negative effect on heart diseases.

The concentrations of Magnesium (Mg) varies from 30 to 214 mg/l and 18 to 214 mg/l in the month of May and November respectively. The average rate of Mg concentrations is 98 and 95 mg/l in the month of May and November respectively. It is observed that the average Mg value is above the desired limit. Approximately 87% of samples in the May and 73% of samples in November month exceeded the desirable limit of BIS standards. A high Mg intake may lead to Kidney failure.

The concentrations of Sodium (Na) varies from 25 to 545 mg/l in the month of May, with an average rate of 213 mg/l. In the month of November Na range from 18 to 214 mg/l, with a normal rate of 95 mg/l. Concentrations of Potassium (K) in May month range from 5 to 259 mg/l (mean 49 mg/l) and in November month it varies from 13 to 247 mg/l (mean 40 mg/l). The concentrations of large quantity of K in groundwater could be formed due to irrigation activities. There is no prescribed limits of Na and K, but having high quantity of NA in water is a source to be salty water.

In the month of May Chloride (Cl) concentrations varies from 175 to 850 mg/l, and in the month of November the concentrations vary from 265 to 811 mg/l. The mean value of Cl in May and November months are shown as 299 and 255 mg/l respectively. The average concentration of CI is beyond the desirable value of 250 mg/l. It is observed that collected data are under the allowable limit of 1000 mg/l (BIS, 2012). High chloride concentrations may result from sewerage waste pollution and ion leaching from landfill sides.

Concentrations of bicarbonate (HCO_3) varies from 92 to 620 mg/l, and 199 to 600 mg/l in the month of May and November respectively. The average HCO_3 concentration is given as 227 mg/l and 221 mg/l for two seasons respectively. Desirable limit of HCO_3 is given as 200 mg/l (BIS, 2012). The results shown that, the average concentration of HCO_3 is higher than the desirable limit.

Concentrations of Sulphate (SO_4) varies from 125 to 1145 mg/l and 211 to 1130 mg/l in the month of May and November respectively. Average Sulphate (SO_4) is 230 mg/l and 224 mg/l for two seasons, respectively. The average SO_4 concentration is exceeds the desirable limit of 200 mg/l. Aside from the desirable limit, approximately 45% and 38% of samples higher than the allowable range of 400 mg/l. High SO_4 concentrations caused due to breakdown of organic materials in weathered soils, as well as anthropogenic and agricultural activities (Craig and Anderson 2017). Due to high magnesium in drinking water, laxative effect happens and led to unstable of water and harm to human system.
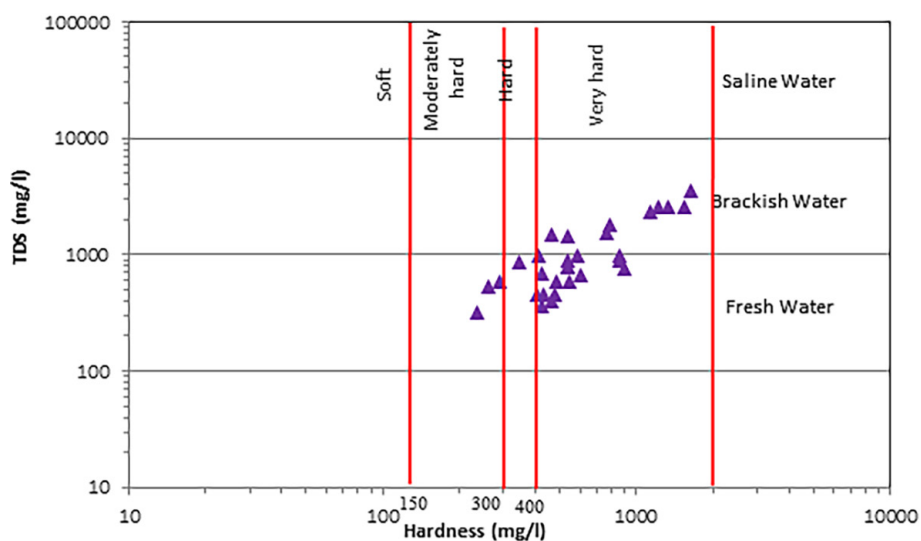

Figure 2. Classification of groundwater base on TDS and Total hardness (TH) in May 2020
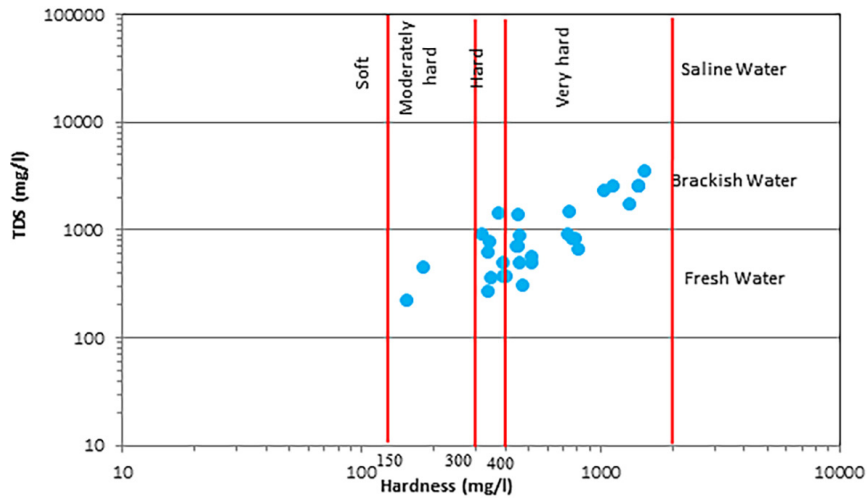
Figure 3. Classification of groundwater base on TDS and total hardness (TH) in November 2020

The concentration of Nitrate (NO_3) around the study area ranged from 23 to 1050 mg/l, with a normal value of 202 mg/l. NO_3 diverse from 20 to 989 mg/l during November month, with an average of 198 mg/l. The average NO_3 concentration exceeds than the allowable value of 45 mg/l. In terms of nitrate contamination, the majority of the data is higher than the allowable limit (BIS, 2012). The concentration of NO_3 is high in the study area could be led to a faulty sewage system and poor waste disposal management.
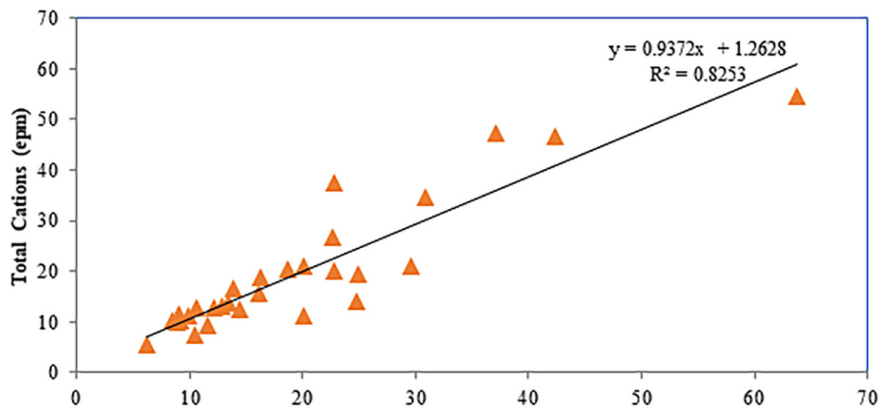

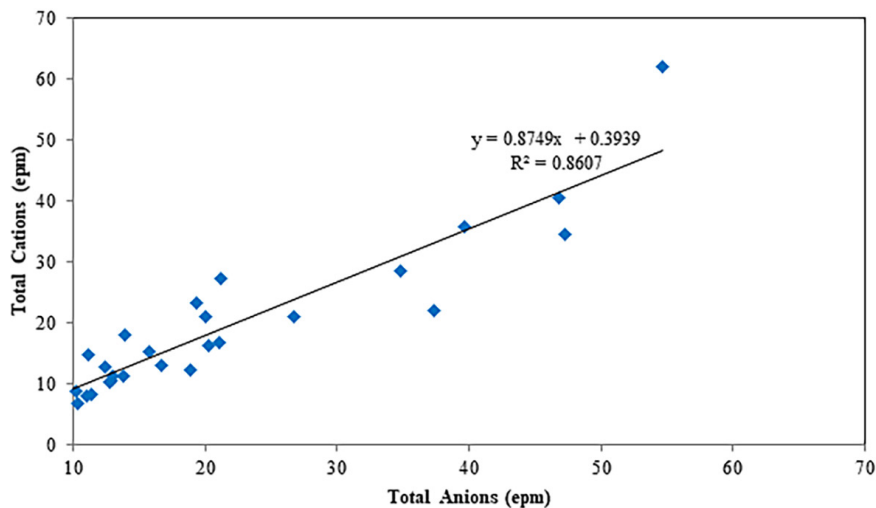**Figure 4.** Plot of total cations vs total anions in May

Figure 5. Plot of total cations vs total anions in November

Fluoride (F) concentrations varies from 0.25 to 2.5 mg/l and 1.10 to 3.35 mg/l, with a mean value of 0.96 mg/l and 0.81 mg/l in the month of May and November respectively. Approximately 47% and 39% of the water data were found beyond the allowable value of 1.5 mg/l.

Total cations and total anions

A plot was made between the total cations and total anions in milliequivalent for the May and November month to check the accuracy of the results. The majority of sample points fall along an equiline, indicating that the total cations and anions are balanced (Figure 4, 5). This graph depicts the precision of the chemical analysis data. This result was also supported by the ionic balance ratio.

Hydro chemical facies of groundwater

Groundwater hydrogeochemical lithologic investigation is a useful method to defining the pattern of flow and chemical characteristics of

origin in groundwater. For the month of May and November, chemical data in milliequivalent percentage was plotted in a Chaddah diagram (Chadha, 1999). The Chadha diagram, shown in figure 6.a, b, identified six facies. According to the graph, the most of the water data samples fall into classes 6 and 4. Class 6 and 4 have alkaline earths (Ca+Mg) that outnumber alkali metals (Na+Cl) and strong acidic anions (HCO_3+CO_3) that outnumber weak acidic anions ($Cl+SO_4$), respectively. In both seasons, the dominant hydro chemical facies identified by the Chadha diagram were Ca-Mg-HCO_3 and Na-K-HCO_3.

Kriging water quality index (KWQI)

From the results it is observed that WQI extended from 74 to 508 mg/l with an average value of 201 in May 2020, and from 59 to 474 mg/l with a mean value of 184 mg/l in November month. Table 5 represents the water in the study area and its categorisation based on WQI values. According to the WQI classification, approximately 15% and 21% of samples in the May and November
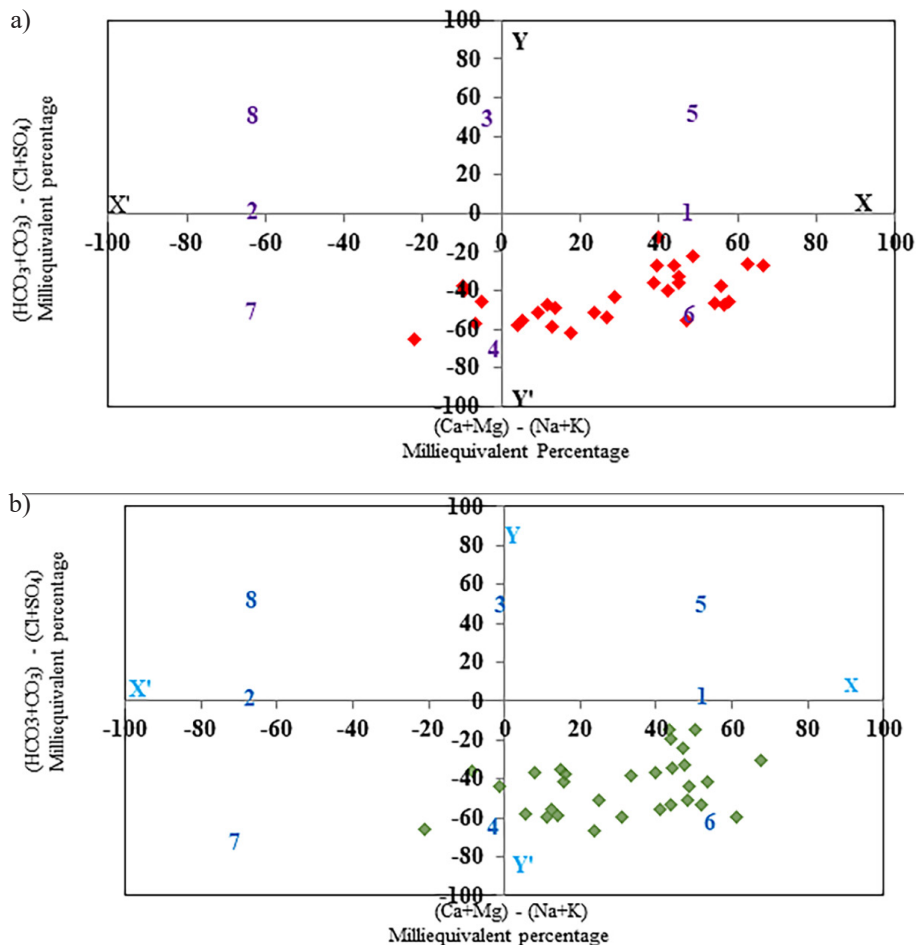

Figure 6. Chadha diagram for month of May (a) and November (b)

Table 3. Groundwater quality classification based on WQI

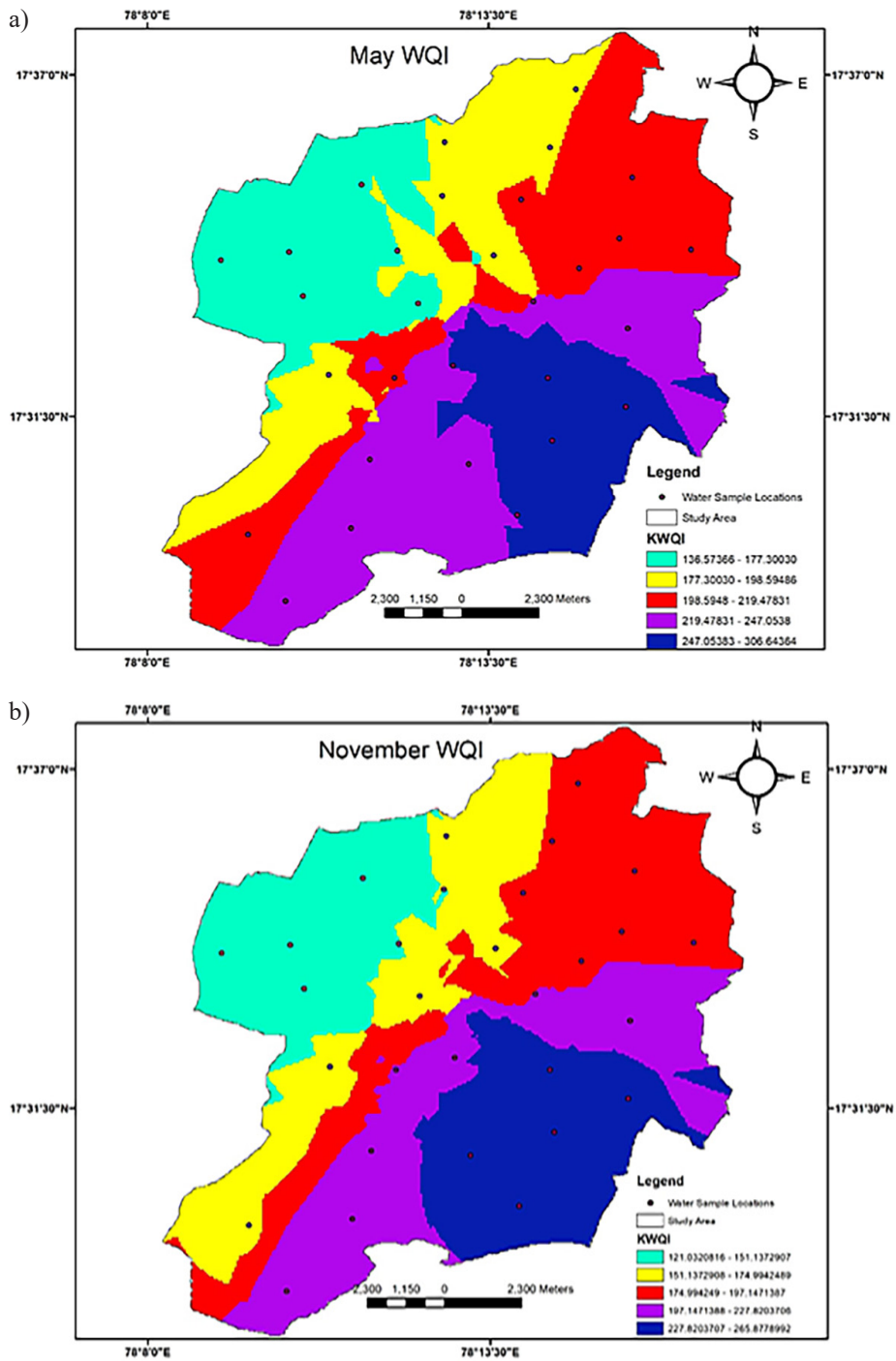| WQI (mg/l)	Water quality	% of samples	
		May 2020	May 2020
<120	Excellent	-	-
121–150	Very Good	15	21
151–174	Good	40	45
175–200	Poor	30	20
201–250	Very Poor	5	6
>251	Not acceptable for drinking purposes	10	8

Figure 7. (a) Kriging water quality index for May and (b)November

Table 4. Correlation among various ground water quality parameters

Parameters	PH	EC	TDS	TH	Ca	Mg	Na	K	Cl	HCO$_3$	SO$_4$	NO$_3$
PH	1											
EC	0.02	1										
EC	0.01	0.09	1									
TDS	0.01	0.32	0.81	1								
TH	0.05	0.62	0.01	0.62	1							
Ca	0.02	0.03	0.82	0.53	-0.52	1						
Mg	-0.13	-0.01	-0.05	-0.06	-0.42	-0.02	1					
Na	-0.11	-0.12	0.01	-0.01	-0.01	-0.62	0.09	1				
K	0.51	0.02	0.02	0.03	0.04	0.02	-0.12	-0.09	1			
Cl	2.08	-0.4	0.01	0.02	-0.01	0.06	-0.32	-0.06	0.38	1		
HCO$_3$	-0.42	0.01	0.04	0.35	-0.42	0.91	0.01	-0.04	-0.01	0.04	1	
SO4	0.45	0.02	0.02	-0.03	-0.06	-0.22	0.45	-0.15	0.27	-1.12	-0.24	1

month respectively, belong to the very good water quality. From the WQI results it is observed that most of samples, approximately 40% and 45% are exhibit the Poor water type in the month of May and November respectively. Interestingly, it is observed that round 10% and 8% of the samples data are not acceptable for drinking purposes. Kriging interpolation is performed on the five buffer zones of the study area as shown in Figure 7 (a, b). From Figure 7 (a, b), we can clearly see the spatial distribution trend of water quality for May and November months. The Kriging Water Quality Index (KWQI) map shows depicts six classes of water quality, namely excellent: white colour (range <120), very good: Beryl green colour (121–150), good: yellow colour (range 151–174), poor: red colour (175–200), very poor: purple colour (range 201–250), and not acceptable for drinking: blue colour (range >251). Study area falls in the good category during two seasons and there are no major seasonal variations in the study area. Through semi-variance function and Kriging interpolation, it is found that the overall characteristics of each water quality index are telling that at south east side water is not acceptable for drinking purposes and in west north side water is very good condition. We can also see that in north east and south west side water is range from poor to good condition. From spatial analysis we can say that in south east side more significances precautions should be taken.

Correlation

In the present study, the correlation coefficient indicates that PH has a positive and significant correlation with EC, TDS, TH, Ca, Mg, Cl, HCO$_3$, NO$_3$ and negative correlation with Mg, Na, and HCO$_3$. Electrical Conductivity has a positive correlation with TDS, TH, Ca, Mg, Cl, SO$_4$ and NO$_3$, negative correlation with Mg, Na, and Cl. TDS has a bad correlation with Mg and positive correlation with the rest of elements. Total hardness has a negative correlation with Mg, Na and SO$_4$ and remaining chemicals are positively correlated with TH. Ca has a negative correlation with all the chemicals except to its own. Mg has a negative correlation with Mg, Na, and SO$_4$ and positively correlated with HCO$_3$, Na has a positive correlation with HCO$_3$, SO$_4$ and negative correlation ship with Cl and HCO$_3$. Na has a negative correlation with all the chemicals. As shown in the Table 4, the significant or positive correlation and negative correlations are estimated with respect to the each other parameter and the empty cells represent existing relations vice versa.

CONCLUSIONS

Present study was undertaken to measure the groundwater quality of Patancheruvu, one of the most polluted cities in Medak District, South India. The entire study area is characterised by high pollution load in terms of almost all the physiochemical as well as heavy metals. Most of the measured variables exhibited random distribution in the groundwater samples and the correlation study showed mutual associations among various parameters.

The average TDS value exceeds the desirable limit of 500 mg/l (BIS, 2012). Approximately 39% and 35% of the samples exceeded the permissible limit of the BIS standard for drinking.

The majority of the samples were discovered in nature as fresh water. The presence of salts such as Na, Cl, SO_4 and HCO_3 may contribute to the region's high TDS. The presence of various industries and anthropogenic activities may result in high TDS concentrations.

The arrangement of major cations is in the following order: Na > Mg > Ca > K. In two months, the major anions are Cl > SO_4 > HCO_3 > NO_3 > F. Most of the data exceeded the desirable limit for TDS, EC, TH, Na, Mg, SO_4, CL, HCO_3 and Ca. In both months, the dominant facies identified by the Chadha diagram are Ca-Mg-HCO_3 and Na-K-HCO_3.

WQI ranged from 74 to 508 mg/l with a mean value of 201 in May 2020, and from 59 to 474 mg/l with a mean value of 184 in November. According to the WQI classification, the most of the data in both seasons fell into the Poor to Very Poor water category.

The high concentration of TDS, Cl, and HCO_+ in the region may be contributing to the high concentration of WQI. About 70% groundwater sample belonged to the hard water category. It is observed that groundwater quality in this area is poor, which may be attributed to both anthropogenic factors such as septic tank leakage, untreated domestic discharge, fertilisers from irrigation, and waste come from various industries.

To sum up all results, it is conclusion that necessary to carry out the research on the spatial distribution characteristics of ground water quality in the study area. The change of its characteristics on the spatial scale will be helpful for in-depth analysis of the characteristics of groundwater quality.

REFERENCES

1. Aher, K.R., Deshpande, S.M., Varade, A.M. 2019. Groundwater quality assessment studies in Yeola Block of Nashik District, Maharashtra. Journal of Geosciences., 4(1), 11–22.

2. Ali, S.I. 2010. Alternatives for safe water provision in urban and peri-urban slums. Journal of Water and Health,. 8(4), 720–734. https://doi.org/10.2166/wh.2010.141

3. Alphayo, S.M., Sharma, M.P. 2018. Water quality assessment of Ruvu River in Tanzania using NSFWQI. Journal of Scientific Research and Reports., 20(3), 1–9. https://doi.org/10.9734/JSRR/2018/44324

4. Anwar, K.M.,Aggarwal, V. 2016. Studies on seasonal variation in groundwater quality: a statistical approach. Journal of Environmental Research and Development., 11(1), 123–131.

5. BIS 2012 I.S.D.W.S. 2012. Bureau of Indian Standards, New Delhi, 2–3.

6. Bradford, S.A., Wang, Y., Kim, H., Torkzaban, S.,Simunek, J.2014. Modeling microorganism transport and survival in the subsurface. Journal of Environment Quality., 43(2), 421–440. https://doi.org/10.2134/jeq2013.05.0212

7. Das, A.K., Mahanta, N. 2019. Evaluation of premonsoon groundwater quality of pallahara block, Angul district, Odisha, India. Magnesium. Journal of Emerging Technologies and Innovative Research., 6(5), 465–470.

8. Dhere, A.M., Jagnnath, B.D. 2016. Recent status of groundwater pollution of municipal solid waste disposal site at Urali-Devachi Village in Pune City. IOSR Journal of Environmental Science.,10(9), 56–61.

9. Dwivedi, D., Mohanty, B.P., Lesikar, B.J. 2016. Impact of the linked surface water-soil water-groundwater system on transport of E. coli in the subsurface. Water, Air, and Soil Pollution., 227(9), 351. https://doi.org/10.1007/s11270-016-3053-2

10. Dzwairo, B., Love, D., Hoko, Z., Guzha, E. 2006. Assessment of the impacts of pit latrines on ground. Physics and Chemistry of the Earth., 31, 779–788. https://doi.org/10.1016/j.pce.2006.08.031

11. El Ouadrhiri, F., Elyemni, M., Adachi, A., Hmamou, A., Bendaoud, A., Chaouch, M., Lahkimi, A. 2022. Investigation of the physico-chemical quality of the wastewater in fez city (morocco) using a multivariate statistical method. Ecological engineering and environmental technology., 6, 15–25.

12. Graham, J.P., Polizzotto, M.L. 2013.Pit latrines and their impacts on groundwater quality: a systematic review.Environmental Health Perspectives., 121(5), 521. https://doi.org/10.1289/ehp.1206028

13. Haddeland, I., Heinke, J., Biemans, H., Eisner, S., Flörke, M., Hanasaki, N., Konzmann, M., Ludwig, F., Masaki, Y., Schewe, J. 2014. Global water resources affected by human interventions and climate change. Proceedings of the National Academy of Sciences., 111(9), 3251–3256. https://doi.org/10.1073/pnas.1222475110

14. Holcomb, D.A., Stewart, J.R. 2020. Microbial Indicators of Fecal Pollution: Recent Progress and Challenges in Assessing Water Quality. Current Environmental Health Report., 7, 311–324. https://doi.org/10.1007/s40572-020-00278-1

15. Ibraheem, A.M., Mazhar Nazeeb Khan., S.M. 2017. Suitability assessment of groundwater for irrigation purpose in Veppanthattai block, Perambalur district, Tamil Nadu. World Scientific News., 81(2), 81–93.

16. Jain, C.K., Vaid, U. 2018. Assessment of groundwater quality for drinking and irrigation purposes

using hydrochemical studies in Nalbari district of Assam, India. Environmental Earth Sciences., 77(6), 1–14.

17. Kalita, P.J., Gogoi, C., Maunash, S. 2021. Hydro chemical assessment of groundwater in North-Eastern Region of India: a case study of Western Suburb of Jorhat Town of Assam, India. Current World Environment., 16(1), 18–33.

18. Korajkic, A., McMinn, B., Harwood, V. 2018. Relationships between microbial indicators and pathogens in recreational water settings. International Journal of Environmental Research and Public Health., 15(12),2842.https://doi.org/10.3390/ijerph15122842

19. Miraji, M., Liu, J., Zheng, C. 2019. The impacts of water demand and its implications for future surface water resource management: the case of Tanzania's Wami Ruvu Basin (WRB). Water., 11(6), 1280. https://doi.org/10.3390/w11061280

20. Mjemah, I.C., Camp, M.V., Walraevens, K. 2009. Groundwater exploitation and hydraulic parameter estimation for a Quaternary aquifer in Dar-es-Salaam Tanzania. Journal of African Earth Sciences., 55(3), 134–146. https://doi.org/10.1016/j.jafrearsci.2009.03.009

21. Mtoni, Y.E., Mjemah, I., Msindai, K., Van Camp, M., Walraevens, K. 2012. Saltwater intrusion in the Quaternary aquifer of the Dares Salaam region, Tanzania. Geologica Belgica., 15(1–2), 16–25. https://doi.org/10.1007/978-3-642-19902-8_35

22. Mtoni, Y., Mjemah, I.C., Camp, M.V.,Walraevens, K. 2011. Enhancing protection of Dar es Salaam quaternary aquifer: groundwater recharge assessment. In: Advances in the Research of Aquatic Environment. Springer, Berlin, Heidelberg., 299–306. https://doi.org/10.1007/978-3-642-19902-8_35

23. Sunadji, S., Mahmudi, M., Lusiana, E.D., Tobuku, R. 2022. Use of Harmful Algae Presence to Assess Water Quality in Lake Ranu Grati, Indonesia. Ecological Engineering & Environmental Technology., 23(6), 118–127. https://doi.org/10.12912/27197050/152950

24. Nnadi, F.N., Fulkerson, M. 2002. Assessment of groundwater under direct influence of surface water. Journal of Environmental Science and Health, Part A., 37(7), 1209–1222.

25. Olasoji, S.O., Oyewole, N.O., Abiola, B., Edokpayi, J.N. 2019. Water quality assessment of surface and groundwater sources using a water quality index method: A case study of a peri-urban town in southwest, Nigeria. Environments., 6(2), 23.