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Hydrogeochemical Assessment of Groundwater of Taluka Chachro, Thar Parker, district, Sindh, Pakistan

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Abstract: The study was conducted to evaluate the hydrogeochemistry of groundwater. Twenty-six groundwater samples were analysed for the groundwater quality of Chachro Taluka. The EC and TDS contents in most of the water samples were above WHO (2011) recommended limits. Almost all water samples collected from dugwells located in the study area have elevated concentrations of Na and Cl exceeding the WHO guidelines. Results of Ca, and Mg show that 92% and 96% of groundwater samples were within the prescribed limit respectively. Whereas, HCO_3, SO_4, and NO_3 contnets of 88%, 77%, and 69% respectively are also above the guidelines. Statistical results revealed a dominating trend among the cations of $Na^+>Ca^{+2}>Mg^{+2}>K^+$ and anions occur in the order of abundance, as $Cl^->HCO_3^->SO_4^{-2}>NO_3$, respectively. The water quality index (WQI) shows that 15% groundwater samples belong to poor category, and 35% water samples were found belonging to very poor category.While, remaining 50% wells were found unsuitable for drinking purpose.

Keywords: Thar desert, Chachro, groundwater, hdrogeochemistry, drinking water quality.

Introduction

Groundwater is considered a valuable freshwater resource worldwide for domestic, industrial, and agricultural uses in arid and semi-arid areas (Boufekane and Saighi, 2019; Oyeyemi et al., 2020). Groundwater demand has increased due to overpopulation, urbanization, and increased industrialization (Oyeyemi et al., 2020; Umar et al., 2013). Natural processes like precipitation and dissolution of minerals, ion exchange, and anthropogenic activities were found to be the primary contaminant sources to deteriorate groundwater quality (Chen et al., 2019; Liu et al., 2020). Naturally contaminants in groundwater above permissible limit, badly affect the ecology and lead to reduction in crops yield, and the fertility of the soil (Khanoranga and Khalid, 2019; Mumtaz, 2017; Umar et al., 2013).

Groundwater quality is evaluated with diverse techniques, like water quality index, ionic ratios, multivariate statistical techniques, and geospatial tools, (Karroum et al., 2017; Singh et al., 2017). Water quality index (WQI) generally explains quality groundwater resources by various parameters using mathematical approach (Barakat et al., 2020). Among several water quality indices, the drinking water quality index was developed to classify water resources for human utilization (Barakat et al., 2020). Due to low annual rainfall and high temperature, the evaporation rates in arid and semi-arid areas are significant factors contributing to salinity and sodicity (Boufekane and Saighi, 2019; Giday Adhanom, 2019; Zakaria et al., 2020). In the south eastern part of Pakistan, Thar desert is suitable for agriculture, however, due to water scarcity and salinity of groundwater, cultivation is limited to the monsoon season. At the same time, Thar desert groundwater quality's lateral variation is significant. The Engro Coal Mining and Qasbo village's modal agriculture farm is irrigated by groundwater available in Tharparkar district.

Several studies were carried out to assess water resources in Tharparkar district, (Leghari et al., 2007). Rafique et al. (2009) reported the elevated fluoride contents in the dug well water. The groundwater quality of district Tharparkar is characterized as moderately to highly saline, from moderately hard to very hard with high fluoride contamination. Rashid et al., (2012) studied water quality for arsenic contamination in the groundwaters of Thar Parkar district. Brahman et al., (2013) reported that the groundwaters of Chachro and Dahili sub-districts or Talukas of Tharparkar district were highly polluted with arsenic and fluoride. Soomro et al. (2017) suggested that anthropogenic activities were the primary factor for high nitrate contamination of groundwater in the study area. Kumar et al., (2020) also found the groundwater quality of Islamkot subdistrict of Thaparkar, as unsutiale for drinking purpose. The main objective of this study was to determine main geological factors that affect the quality of the dug well water geochemistry in the area.

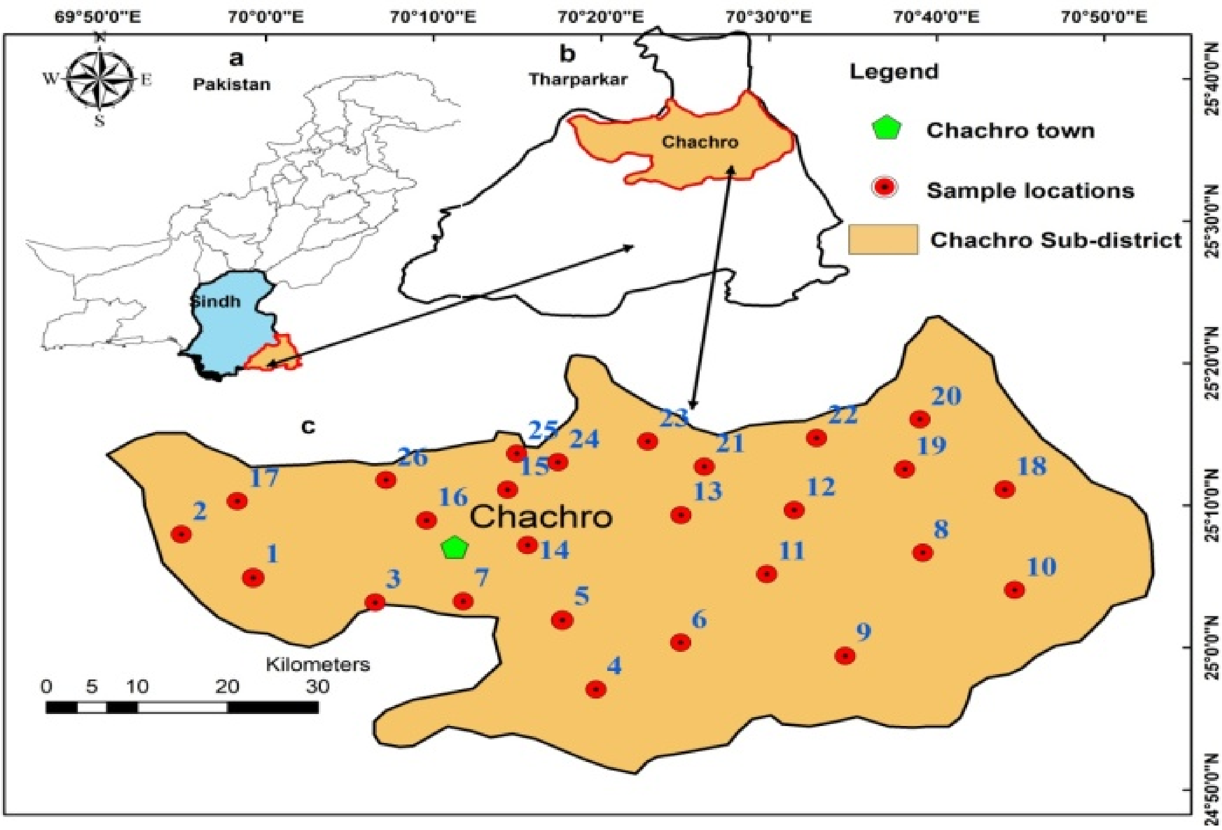

Fig. 1 Groundwater sample locations a) Pakistan, b) Tharparkar district, c) ChachroTaluka.

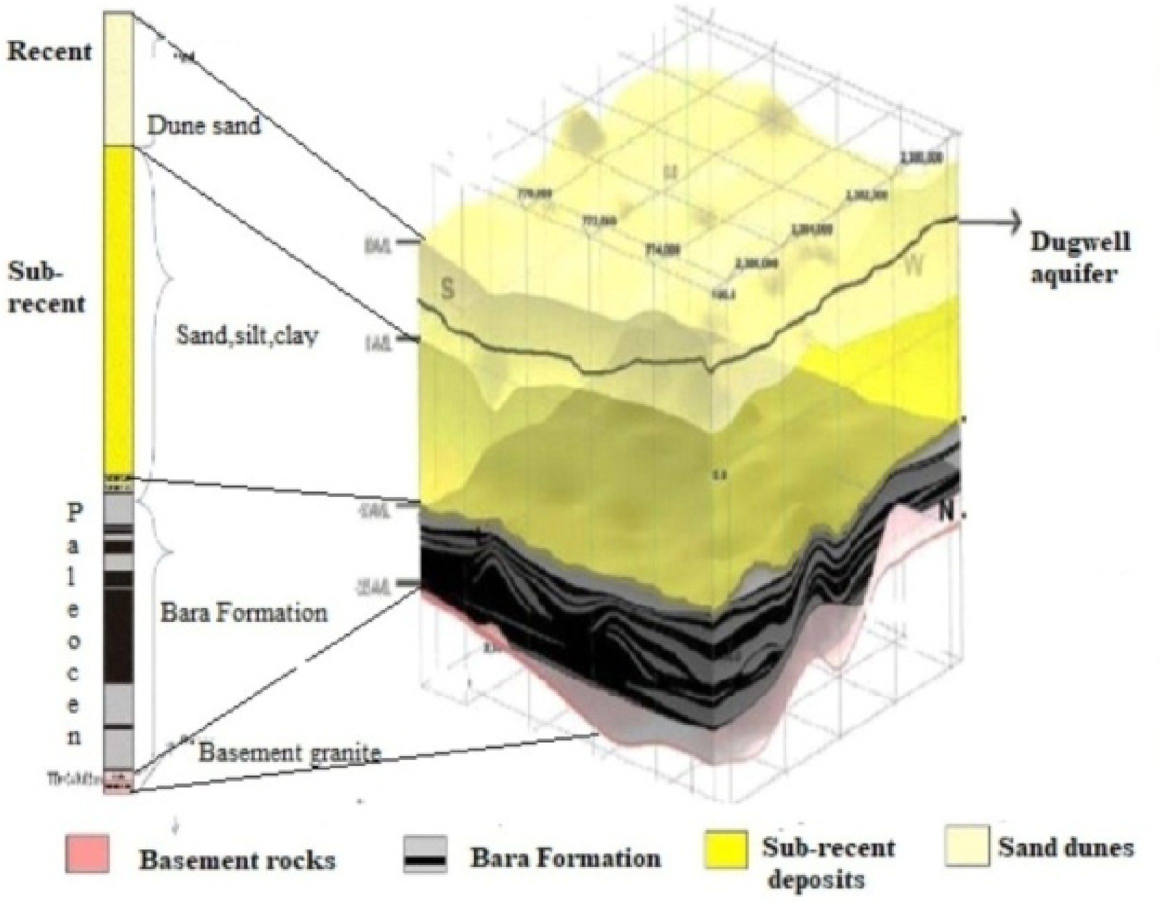

Fig. 2 The 3D geological model and general lithology of Tharparkar district (Butt, 2018; Munir et al., 2018).

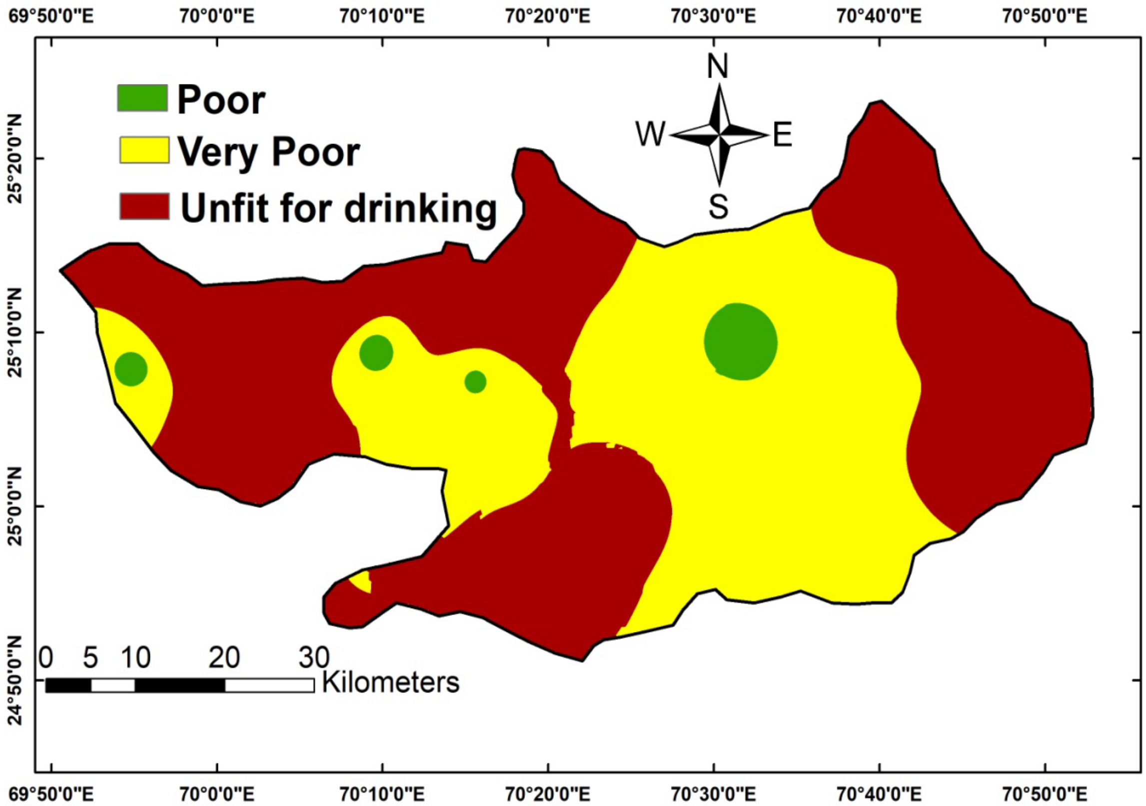

Fig. 3 Spatial distribution of drinking water quality (WQI) in the study area.

Table 1.Weight (wi), relative weight (Wi) of chemical parameters, and WQI of well water samples from the study area.

Parameters	WHO guidelines	Weight (wi)	Relative Weight (Wi)	S.ID	WQI	Remarks	S.ID	WQI	Remarks
EC (µS/cm)	1500	3	0.076923	1	311.9485	Unfit	15	380.3231	Unfit
pH	6.5-8.5	3	0.076923	2	175.0969	Poor	16	150.2457	Poor
TDS (mg/l)	1000	3	0.076923	3	329.9319	Unfit	17	493.916	Unfit
Ca (mg/l)	150	2	0.051282	4	369.4037	Unfit	18	406.0984	Unfit
Cl (mg/l)	250	3	0.076923	5	288.1215	Very Poor	19	200.0963	Very Poor
Mg (mg/l)	100	2	0.051282	6	348.4542	Unfit	20	395.7175	Unfit
Na (mg/l)	200	3	0.076923	7	220.1498	Very Poor	21	268.4879	Very Poor
HCO_3 (mg/l)	300	2	0.051282	8	230.54	Very Poor	22	265.6173	Very Poor
K (mg/l)	12	2	0.051282	9	237.1063	Very Poor	23	333.2845	Unfit
SO4 (mg/l)	250	3	0.076923	10	357.0769	Unfit	24	637.3908	Unfit
NO3 (mg/l)	12	4	0.102564	11	216.1681	Very Poor	25	373.8024	Unfit
		∑wi=39	∑Wi=1						

Materials and Methods

The study area of Taluka Chachro lies between latitudes 24.8521° and 25.389° north, and longitudes 69.8421° and 70.8815° east. It has total area of 4103 sq.km and population of 351263, based on the 2017 Census. The groundwater is available in the dug wells of Chachro at depths of 30 to 45 m (Zaigham, 2003). This area like oter parts of Tharparkar district has semi-arid to an arid climate, with low and irregular precipitation, averaging approximately <100 mm per annum. This district of Thar region is devoid of perennial rivers, streams, canals, and thus heavily depends on the monsoon rains during June to September. Small agriculture fields, and livestocks like camels, cattle, goats, and sheep are the main sources of livelihood for the prople of district Tharparkar.

Geologically, Thar desert consists of dunes (Recent deposits) and outcrops of Precambrian rocks of igneous and metamorphic origin constituting

Nagarparkar igneous complex (de Wall et al., 2018; Mastoi et al., 2019). This area is rich in mineral reources including kaoline deposits, huge reserves of pink and grey granite, and coal, bssides occurrences of salt. The recharging source of groundwater is only rainwater. Geologically, four lithological types comprising dunes (Recent sediments), sub-Recent (alluvial deposits), Bara Formation of middle Palaeocene age, and igneous rocks of Precambrian age also occur in Tharparkar area (Fig. 2); (Fassett and Durrani, 1994; Khuhawar et al., 2019; Rafique et al., 2009; Zaigham, 2003; Zaigham et al., 2000).

Sampling and Analysis

Twenty-six groundwater samples were collected from wells from several villages of Chachro area (Table 2). The sample locations were marked using GPS (Fig. 1). The standard GIS methodology of APHA (2012) was applied during the sample collection. The chrome metal container secured with a fibre cord was used for collecting water samples in plastic bottles. Before sampling these bottles were washed with de-ionized water several times. The field parameters such as electrical conductivity, temperature, TDS, and pH were measured at the site with a portable TDS/EC/PH meter (Hana HI 8921-4). Bicarbonate and chloride ions were determined by volumetric titration method. The major ions i.e., NO_3^- and SO_4^{2-}were analysed with an ultraviolet-visible (VU-VIS) spectrophotometer. Before analysis, the instrument was calibrated. The major cations, i.e., Na^+ and K^+ were determined by flame photometer (PFP7, Cambridgeshire) after calibration with 5, 10, 50, and 100 ppb standard solutions. Ca^{+2} and Mg^{+2} values wre obtained by volumetric titration using ethyl diamine tetraacetic acid (EDTA). Statistical analysis of the results of chemical data is shown in Table 2.

Results and Discussion

The pH values of groundwaters from Chachro area varies from 7.0–8.3, with an over of 7.565. The EC concentration varies between 2593 to 18950 µS/cm with the mean value of 8904.154µS/cm. Almost all samples have a higher EC concentrations than standard limit. The overall dissolved salts (TDS) concentration ranges between 1659 and 2128 mg/L, with an average concentration of 5698.70mg/L which is much higher than WHO limit of 500 mg/L. According to Freeze and Cherry (1979) classification of water-based TDS, the current study samples mostly fall in the TDS 1000 to 10000 mg/L range and categorized as brackish water, and two groundwater samples from the study area contained TDS value higher than 10000 mg/L, classified as saline water.

The concentration of Ca and Mg ranges between 36 - 288 mg/L and 17 to 272 mg/L, respectively, with average values of 118 mg/L and 108 mg/L, respectively. Results of Ca and Mg show that 92% and 96% groundwater samples are within the WHO guidelines, respectively. Sodium and potassium ions average concentrations were found as 1588 mg/L and 26 mg/l, respectively. Results reveal that only 3.85% water samples contained potassium within the

Table. 2 Physio-chemical parameters of groundwater samples, while X and Y represent the Eastern and Northern values of sample location.

S. No	X	Y	pH	EC (µS/cm)	TDS (mg/l)	Mg (mg/l)	Ca (mg/l)	Na (mg/l)	K (mg/l)	Cl (mg/1)	CO_3 (mg/l)	HCO_3 (mg/1)	SO_4 (mg/1)	NO_3 (mg/1)
1	69.987	25.081	8	9460	6054	160	160	1670	28.4	2638	Nil	380	330	19.37
2	69.916	25.132	7.6	4670	2989	41	68	834	16.5	1187	Nil	390	158	6.66
3	70.108	25.053	7.4	10240	6554	109	92	1938	22.5	2340	Nil	1150	360	18.77
4	70.328	24.951	7.4	11820	7565	165	184	2140	17	3440	Nil	350	320	7.831
5	70.294	25.032	7.2	8870	5677	102	116	1610	19	2460	Nil	360	310	13.21
6	70.412	25.006	7.6	10780	6899	106	120	2010	21	2979	Nil	390	395	10.2
7	70.196	25.054	7.4	6590	4218	53	72	1260	14	1767	Nil	440	172	13.41
8	70.652	25.111	7.5	6690	4282	68	80	1184	14.5	1765	Nil	300	286	18.27
9	70.575	24.990	7.6	6230	3987	68	64	1130	15.5	1554	Nil	360	292	41.39
10	70.744	25.067	7.7	10700	6848	126	116	1944	18.7	3079	Nil	390	340	33.63
11	70.497	25.086	8	5380	3443	69	78	875	15.5	1347	Nil	220	162	59.63
12	70.525	25.161	7.9	2593	1659	24	36	450	10.5	539	Nil	210	79	47.42
13	70.412	25.155	7.3	6590	4218	70	100	1160	16.5	1793	Nil	240	257	20.14
14	70.260	25.120	7.7	3235	2070	88	104	420	74.5	603	Nil	340	260	46.09
15	70.240	25.185	7.7	9370	5997	129	108	1630	29.6	2257	Nil	450	465	102.54
16	70.159	25.149	8.3	3850	2464	17	44	770	9.5	555	Nil	850	170	11.19
17	69.971	25.171	7.3	14590	9338	170	224	2620	101	4078	Nil	320	870	10.25
18	70.734	25.185	7.2	10240	6554	131	156	1730	18	2640	Nil	330	285	117.13
19	70.634	25.209	7.3	5280	3379	53	84	870	12.7	1264	Nil	350	232	44.38
20	70.649	25.267	7.6	12640	8090	129	140	2340	22.4	3540	Nil	430	370	20.64
21	70.435	25.212	8.2	7350	4704	97	112	1290	19	1867	Nil	260	355	47.13
22	70.547	25.245	7.4	8150	5216	112	132	1360	20.8	2257	Nil	310	360	19.09
23	70.379	25.241	7.5	9360	5990	114	148	1580	23	2321	Nil	410	476	63.81
24	70.290	25.217	7.4	18950	12128	272	288	3280	28	5738	Nil	340	580	17.21
25	70.249	25.227	7.5	11550	7392	92	108	2260	32.6	3356	Nil	390	295	15.73
26	70.119	25.196	7	16330	10451	248	132	2940	48	4752	Nil	370	580	11.69
Mean values			7.565	8904.15	5698.70	108.19	117.92	1588.27	25.72	2389.1	-	397.21	336.88	32.18
WHO standard			**6.5 to 8.5**	**1000**	**1000**	**150**	**200**	**200**	**12**	**250**	**150**	**250**	**150**	**10**

recommended WHO limit for safe drinking water. About 69.% wells were found to have potassium concentration within limit (12-25 mg/l), but about 27% groundwater samples exceeded the standard limit. The major cations revealed by statistical results as Na^+>Ca^{+2}>Mg^{+2}>K^+ in the order of abundance.

HCO_3^- concentration in samples varied between 210-1150 mg/l. About 88% of samples exceeded the permissible limit (WHO 2011). The Cl^- SO_4^{-2} contents of 539 to 5738 mg/l and 79 to 870 mg/L also exceeded standard limits in about 88% and 33% groundwater samples, respectively. High sulfate concentration in samples may be due to sulfate-containing minerals and halite (Talib et al., 2019).

The NO_3 average contents vary from 6.66 to 117.13 mg/L with average of 32.185 mg/L. Livestock waste, fertilizer, geological factors, and domestic wastewater percolation were the most important sources of NO_3 pollution in groundwater (Bourke et al., 2019; Chen et al., 2019; Soomro et al., 2017). About 69% of the water samples were found highly contaminated with nitrate in Chachro area. Statistical results revealed abundance pattern among the major anions as Cl^- >HCO_3^->SO_4^{-2}> NO_3^-.

Water Quality Index (WQI)

The WQI is significant process for determinig the general quality of water for domestic uses (Adimalla, 2020; Talib et al., 2019). It is calculated in four steps by taking into account the major physiochemical parameters like pH, EC, TDS, HCO_3, Cl, SO_4, NO_3, Ca, Mg, Na, and K. The results revealed that four dug well samples in the area belonged to poor category with water quality index ranging between 100-200. Whereas, 9 water samples were of very poor quality with WQI 200-300, and 13 wells water was found unfit for drinking purpose due to > 300 WQI (Fig. 3).

A graphical tri-linear diagram was used to isolate groundwater phase variation and origin of geochemical parameters by plotting bivariate diagrams showing the concentrations of significant cations and anions (Liu et al., 2020; Saravanan et al., 2016; Talib et al., 2019). The significant cations plot of sodium and potassium shows dominance over major anions i.e. calcium and magnesium. However, these two groundwater samples fall in mixed-type categories and one sample in calcium-type water. The anion triangle Cl^- is dominant over SO_4^{-2}, HCO_3^- + and CO_3^- anions. Thus, these two well samples fall in the bicarbonate category. The diamond shape indicates that most of the groundwater samples are NaCl type. In addition to this, 2 well samples represent the mixed category, and $CaHCO_3$ type groundwater. The study area results reveal that NaCl water is dominant in the area.

Conclusion

Hydrogeochemical assessment of groundwater quality of Chachro taluka was carried out to determine groundwater suitability for drinking purpose. Statistical data analysis illustrates the abundance pattern of Na^+> Ca^{+2}> Mg^{+2}>K^+ for cations and Cl^- >HCO_3^->SO_4^{-2}>NO_3^- trend for anions. Almost all samples have higher concentrations of EC and TDS than the recommended limit of WHO (2011), and thus, groundwater unsafe for drinking purpose. The water quality index (WQI) of the study area shows that four well samples were found to have poor quality water, nine samples belonged to very poor category, and thirteen groundwater samples were of unsuitable category for drinking purpose.

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