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Management of Ground Water Hazard: A Case Study from Thar Coal Mines, Pakistan

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Abstract: This study covers the Thar coal field block-II located in the southeast of Sindh, Pakistan. The aim of present study is to identify the impacts of ongoing coal mining activity on ground water quality and water table in community wells of villages in Thar coal mine block-II. The ground water samples from 58 community wells (located in 21 villages of block-II) were collected and analyzed for the water quality parameters like water table (depth), electrical conductivity/TDS, and pH. The groundwater samples from community wells and Gorano pond were analysed to assess water quality. The reserved area of Gorano pond is about 1500 acres, wherein water discharged from aquiufers in coal mining area of block-II is being accumulated. The extracted ground water is being disposed off in multiple depressions near villages Gorano, Kathar and Dhukar Shah

Keywords: Ground water hazard, Thar coal, TDS, dewatering, Pakistan.

Introduction

The discovery of Thar coal deposit is estimated to be over 175 billion tons, which has uplifted Pakistan's coal resources to more than 184 billion tones giving it the eleventh position in the list of 12 major coal producing countries of the world (Abbas and Atique, 2005; GSP report, 2002). The district Tharparkar lies in south-eastern arid zone of Sindh (Pakistan) which comprises two sub-divisions; Mithi and Chachro and four sub-districts (Talukas) of Mithi, Nagarparkar, Diplo, and Chachro. Thar coalfield encompasses about 9,600 sq. km (140 kilometers (N-S) and 65 kilometers (E-W)), of Sindh desert. Spatially distributed Thar coalfield is divided into twelve blocks (Fig. 1). The type of coal found in the Thar coal fields is invariably lignite, which is a low-grade pyritic coal that is generally used in modified industrial furnaces to generate heat for boilers, coke oven heaters, brick kilns, etc. The average quality parameters of the lignitic coal are: avg. 7% ash, 1.4 % sulphur, 48% moisture (in-situ) at heating value 5140 Btu/lb. In current scenario only Thar coal block-II was allocated for open pit mining. Therefore, block-II was selected for research study.

The study area has the characteristics of a desert and has no regular or permanent surface water bodies. In the absence of proper water resources, sometimes the water can be found in small level trails or depressions, which host the rain water. Primarily, the ground water is recharged by rainfall. The rainwater precipitates through top cover of sand dunes and desert's topography to recharge the ground water resources of Thar. There are multiple aquifers present above the coal zone, called coal roof aquifer. These aquifers are forming two to three levels consisting of compact sand horizons with thickness in few meters, (Fig. 2). Several artificially dug depressions are usuall built of silty clay and caliche material (Zaigham et al., 2009).

This study aimed at identification of ground water hazards and impacts of ongoing coal mining activity on ground water quality and water table in mining areas (Fig. 3). The dewatering of groundwater likely to pose moderate to major hazards at and during the pre-mining, mining and post-mining stages. The presence of aquifers at the coal roof level and basal level may produce major hazards during/after the mining operation (Nergis et al., 2018).

Geology the Study Area

The sedimentary column succession diminishes from west to east and has a thickness of around 250 m in the Thar coal field (GSP report, 2002). The core samples demonstrated that coal-bearing strata of Paleocene-Eocene dregs un-conformably overlie the Precambrian rocks of volcanic composition (Zaigham et al., 2009). The generalized stratigraphic sequence of Thar coalfield area is given in Table 1. It comprises Basement complex, coal-bearing Bara Formation, alluvial deposits and sand dunes (Zaigham et al., 1996 a, b). The coal beds have variable thickness from 0.20 to 36 m (GSP report, 2002). The coal is dark or grayish dark in color. The overburden comprises three types of materials: hill sand, alluvium and sedimentary succession. The aggregate overburden is around 150 to 230 meters (IBRD, 2001).

Materials and Methods

The study is based on ground water samples collection and temporal analysis to carry out qualitative and quantitative assessment of ground water quality in boreholes of nearby villages in block-II and Gorano pond discharge area. Water samples were collected from community wells located in villages of block-II, and

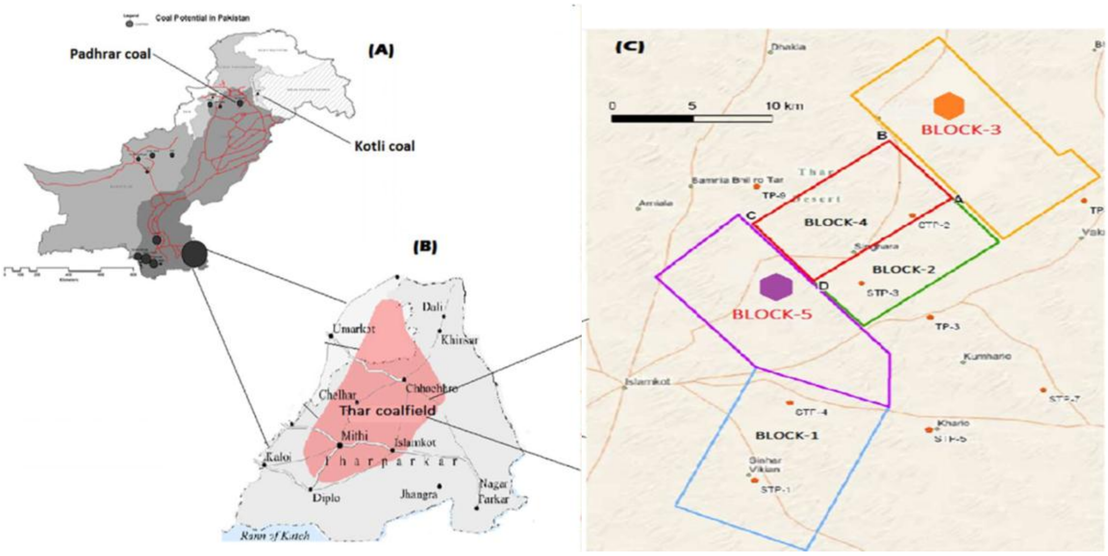

Fig. 1 The location map of Thar coalfield and under study Blocks-2 (modified after Munir et al., 2018).

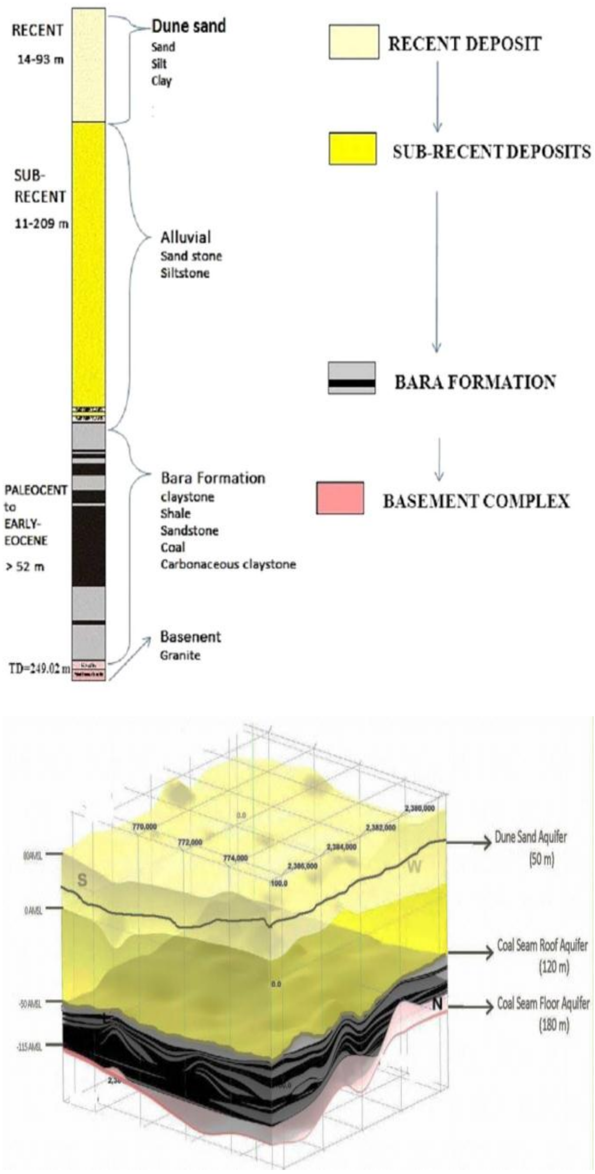

Fig. 2 Subsurface model of Thar coal field with three aquifer zones and general stratigraphy (after Munir et al., 2018) .

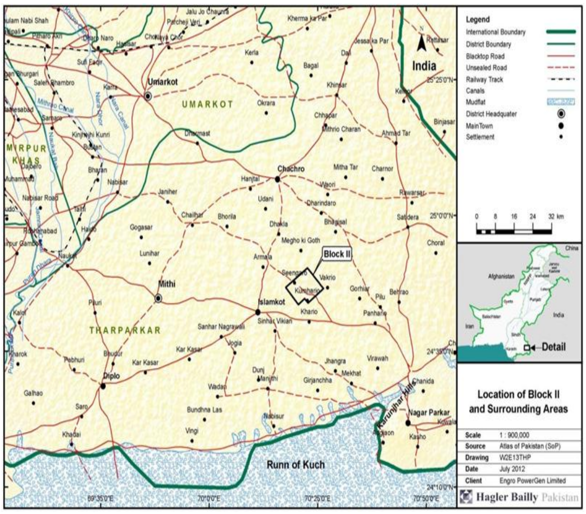

Fig. 3 The location of Thar coal field, block-II, Thar.

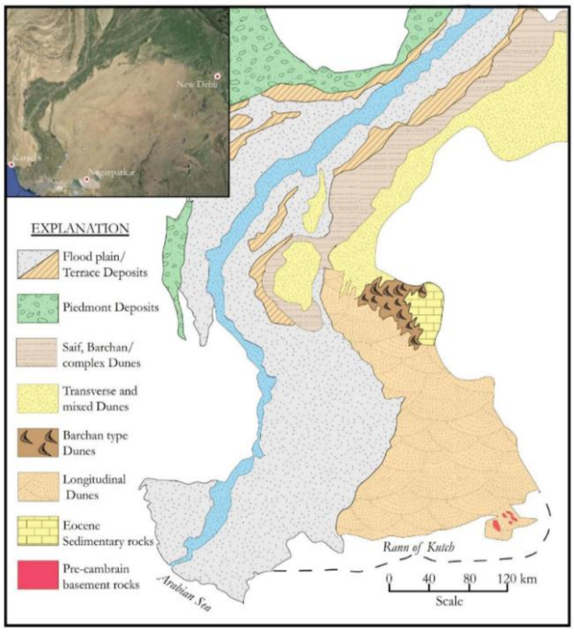

Fig. 4 Geomorphology of the study area (GSP, 2002).

near the Gorano pond. Moreover, one sample was collected from dewatering outlet of Gorano pond (main surface water reservoir) (Table 2).

Table 1. Stratigraphic sequence in the Thar coalfield.

Formation	Age	Thickness	Lithology
Dune Sands	Recent	14m to 93m	Sand, Silt, Clay
Unconformity			
Alluvial Deposits	Sub Recent	11m to 209m	Sandstone, Siltstone, Claystone, mottled.
Unconformity			
Bara Formation	Paleocene to Early Eocene	52 meter	Claystone, Shale, Sandstone, Coal, Carbonaceous Claystone
Unconformity			
Basement Complex	Pre-Cambrian		Granite, Quartz and Diorite

Table 2. Summary of water samples collection.

Sr.No	Ground Water from Wells		Surface Water of Reservoir
1	Villages	Wells	Gorano Pond
2	21	58	1

Results and Discussion

The study area is classified into three categories.

A- Ground water from villages in Block-II (2015, 2016, 2017)
B- Dewatering sample from Gorano Pond (2016)
C- Ground water samples from villages in surrounding of Gorano Pond (2015, 2016, 2017)

Wells Monitoring in Surroundings of Block-II

40 wells were monitored in the vicinity of mining area in 13 villages of block-II. Purpose of monitoring was to analyze the impact of dewatering on community wells in all these villages and georeference it on the map (Fig. 5). Wells were monitored with respect to water tale depth, TDS level and pH.

The water depth (water table) is not uniform in the study area in surrounding villages of block-II. The community well descends up to first coal roof aquifer. The graph (Fig. 6) illustrates that the water table depth (along vertical axis) varies from 48 to 90 m in depth.

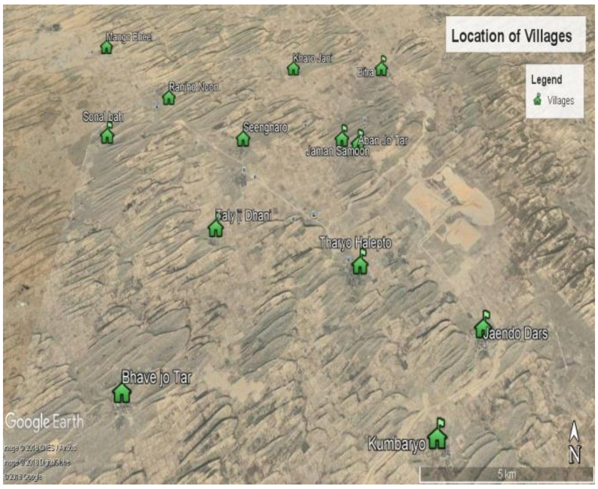

Fig. 5 Location of villages (field sample collections) from villages in surroundings of block-II, Thar.

However, the water level in the community wells was lowered over three years (2015-17) in all the community wells located in the coal mines.

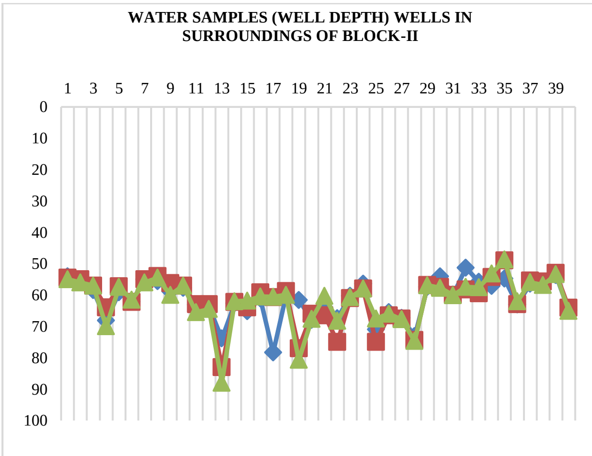

Fig. 6 Water samples (water table depth) from villages in block-II, Thar, Data of March 2015 (blue color), March 2016 (orange color) and March 2017 (gray color).

Over three years (2015-17) the TDS level is showing erratic change. The spatial variations in the graphs for 2015, 2016 and 2017 are defining the temporal variations in water quality. The graph illustrates the water quality in terms of TDS level (along vertical axis) various from 1000 mg/l to 9000 mg/l (Fig.7). It was found that the TDS levels in some of the wells were much above the National Environmental Quality Standard (NEQS) for drinking water.

Wells Monitoring around Gorano Pond

The Gorano pond is a surface water reservoir reserved for collection of aquifers discharge. The water samples were taken from the community wells located in six villages in vicinity of the Gorano pond (Fig. 8) and examined.

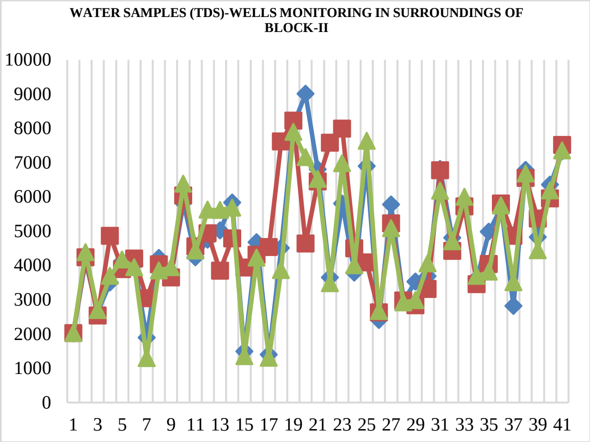

Fig. 7 Water sample (TDS) from villages in surrounding of block-II, Thar. Data of Mar 2015 (Blue color), Mar 2016 (orange color) and Mar 2017 (gray color).

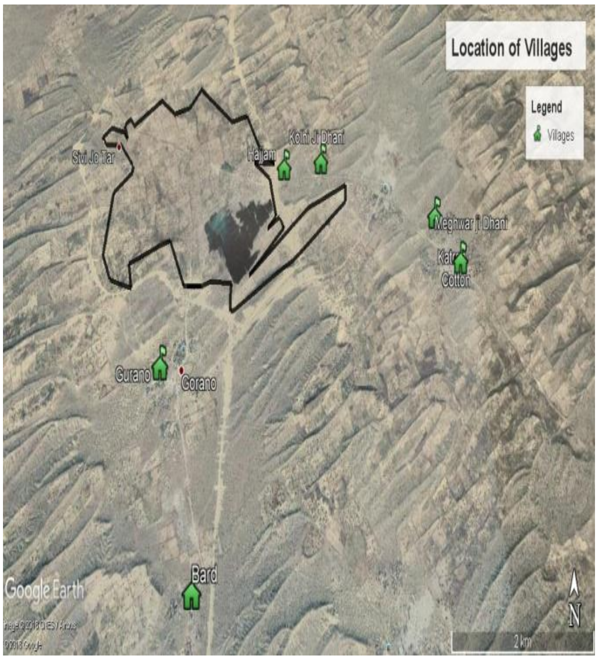

Fig. 8 Locations of villages around Gorano pond, Thar.

Figure 9 illustrates the water table depth in community wells in the vicinity of Gorano pond. The water samples depth (water table) in the wells near Gorano pond did not remain uniform in three years (2015-17). The graph (Fig. 9) illustrates that the water table depth (along vertical axis) varies from 11 to 21 meters. The ground water is being used by the villagers for drinking and domestic purpose from first aquifer of the area.

The Figure10 shows the water quality in terms of TDS level and shows that it varies from 480 mg/l to 6320 mg/l. It was found that the TDS levels in some of the wells were much above the National Environmental Quality Standard (NEQS) for drinking water. Over three years (2015-17) the TDS level varies widely with respect to distance between the community well and proximity to the Gorano pond. The water quality is controlled by top aquifer type (perched aquifer, sand lens aquifer, i.e. Kansas), and seasonal recharge.

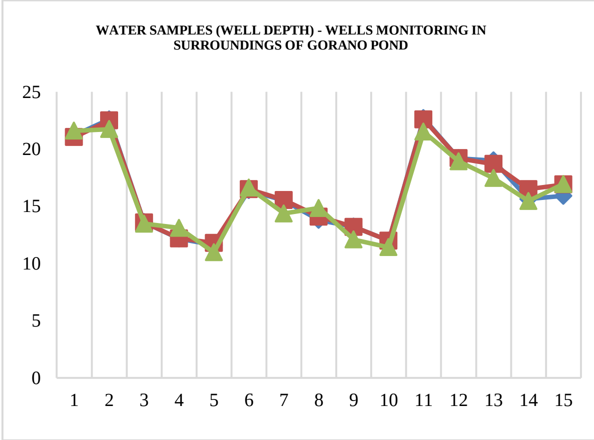

Fig. 9 Field water sample (water table depth) from villages in surroundings of Gorano pond, Thar. Data of March 2015 (blue color), Mar 2016 (orange color) and Mar 2017 (gray color).

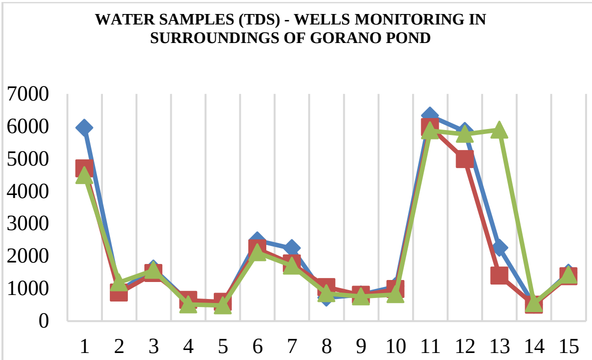

Fig. 10 Field water sample (TDS) from villages in surroundings of Gorano Pond, Thar. Data of Mar 2015 (blue color), Mar 2016 (orange color) and Mar 2017 (gray color).

Groundwater Study near Gorano Pond

The outline boundary of land reserved for dewatering pond (Fig. 11) which covers 15-20% of reserved area that is covered (visible in black shadow area). Gorano pond comprises 1500 acres land. Depending on the actual situation (evaporation, percolation) even pond area might be sufficient for dewatering throughout mine operation. Water is being discharged at the rate of 3600 m^3/hr by means of multiple pumping wells.

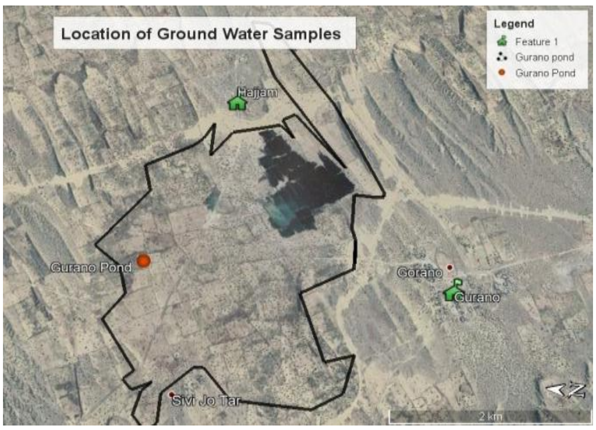

Fig. 11 Well sample locations, Gorano pond, Thar.

The discharged water was collected from Gorano pond in 2016 and water quality of the discharge is given in Table 3.

Table 3. Quality of discharged water in the Gorano pond (2016).

Sr. No.	Parameters.	Unit	SSDWQ	Results
1	pH vlaue	…..	6.5-8.5	7.65
2	Odour	….	Non Objectionable/ Acceptable	Non Objectionable
3	Taste	….	Non Objectionable/ Acceptable	Non Objectionable
4	Colour	Pt Co	<15	<5
5	Total dissolved solids	mg/l	<1000	5478

The ground water samples were collected from two nearby villages Hajam and Gorano. Composite samples were collected from both villages and the results are mentioned in Table 4, 5. The village Gorano is lying at the boundary of the reserved land for discharge pond area.

Table 4. Results of a community well in the village Hajam.

S.No.	Parameters.	Unit	SSDWQ	Concentration
1	pH vlaue	…..	6.5-8.5	7.60
2	Odour	….	Non Objectionable/ Acceptable	Non Objectionable
3	Taste	….	Non Objectionable/ Acceptable	Non Objectionable
4	Colour	Pt Co	<15	<5
5	Total dissolved solids	mg/l	<1000	5891

It was found that the TDS levels in some of the wells were much above the National Environmental Quality Standard (NEQS) for drinking water. Total dissolved solids in 95% of the wells, exceeded 2,000 mg/l, which is higher than 1,000 mg/l, generally acceptable level for human consumption. Qualitative and quantitative study span over three years (2015-17) found that the existing boreholes of villages in block-II will help to mitigate future hazards e.g. quality of the drinking water in community wells.

Table 5. Results of a well in village Gorano.

S.No.	Parameters	Unit	SSDWQ	Concentration
1	pH vlaue	…..	6.5-8.5	7.70
2	Odour	….	Non Objectionable/ Acceptable	Non Objectionable
3	Taste	….	Non Objectionable/ Acceptable	Non Objectionable
4	Colour	Pt Co	<15	<5
5	Total dissolved solids	mg/l	<1000	1390

General chemical analysis of water samples collected indicated that the samples from open wells near the Gorano Pond can be classified as fresh water (WHO standards). Gorano village water is much better than the Gorano outlet water, which is associated with first coal roof aquifer. Community opinions were also taken regarding water quality changes. Majority of villagers (in the villages adjacent to Gorano pond) inform that they did neither notice any change in water or quality observed early mining impacts. However, seasonal monitoring of dewatering pond should be carried out and documented. The government should develop a comprehensive plan for water management in Thar coal mines. Compensation plan should be developed for those areas, where dewatering can negatively affect. The area reserved for the pond will not be suitable for any type of agricultural activities.

It is recommended that the impacts of dewatering on soil, ground water, flora and fauna, physical local environment and local geomorphical features should be studied. The geophysical surveys (electrical resistivity techniques VES, ERT, etc.) may also be planned to monitor the infiltration of brackish water (outlet water) back in the aquifers.

Conclusion

The groundwater is being dewatered from roof aquifers (above coal) in block-II mining area. It was found that TDS levels in some of the wells were much above the WHO and NEQS limits for drinking water. The total dissolved solids in 95% of the community wells were found to have more than 2,000 mg/l. The discharged water has TDS about 5478 mg/l, which makes it brackish in nature. The water quality is controlled by aquifer type, seasonal recharge and with TDS of water > 2,000 mg/l and ground water extraction rate etc. Future decline in water table in community wells can be predicted therefore a mitigation plan needs to be implemented for local community.

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