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Research Article

ASSESSMENT OF GROUNDWATER QUALITY FOR HOUSEHOLD, AGRICULTURAL, AND INDUSTRIAL USE IN MUNUGODE

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Abstract

The study's main goal is to assess the physical and chemical quality of ground water in Munugode for household, agricultural, and industrial use. Dissolved elements and their characteristics affect water quality. Chemical water analysis based on ion or ion group connections. Graphs relate chemical processes as groundwater movers and water groups with comparable evolutionary histories. Physical and chemical water qualities can aid with these concerns. Several computer programmes and software exist to plot and analyse water appropriateness. Piper's trilinear diagram comprises three fields: two triangular and one diamond-shaped. Lower left triangle shows ppm% values for calcium, magnesium, sodium, and potassium. Wilcox's diagram is used to identify irrigation water by graphing sodium percentage versus electric conductivity. Wilcox's graphic classifies bore and excavated well samples into four classes.

Keywords Ground water, piper's trilinear diagram, wilcox's diagram, calcium, magnesium, sodium, and potassium

1. Introduction

Water is vital for life and development. Exploited water resources may become scarce or inaccessible. Globally, agriculture, home industries, and rural supply programmes are using more groundwater. Increasing water demand from urban, industrial, and agricultural needs and unpredictable precipitation from meteorological changes degrade water sources (Kourgialas. 2021; Lv et al, 2020; Ahmed et al, 2016). Water is used domestically, industrially, and agriculturally. Industrialization and growth are increasing water consumption. In developing countries like India, groundwater is crucial to life and sustainable development, and its overexploitation is a big issue (Ramaiah & Avtar, 2019).

Nearly 1/5 of the world's water comes from groundwater, so protecting it is a primary management issue. Water is available on earth as water, vapour (clouds), fresh water lakes, ice bergs and sea water, glaciers (Khyade & Swaminathan, 2016).

People in the study region use groundwater for agriculture. Hydro geochemistry of the study area, notably fluoride contamination, has not been studied in detail (Rashid et al, 2018). This prompted the U.S. to investigate the geochemistry of the ground water and sods due to the area's proximity to Nalgonda.

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This study compares the basin results of the Munugode study area with those of the nearby Munugode vagu for a regional outlook on quality, availability, and distribution. The proposed land is near Nalgonda's suburbs and is generally industrial-free.

The study's main goal is to assess the physical and chemical quality of ground water in the area for household, agricultural, and industrial use.

Geographical Location:

Munugode Study Area is 35 kilometres from Nalgonda, near SH-2. Munugode mandal, Nalgonda district (Madhnure, 2022). The current study region is in Survey of India Toposheet No. 56 O/8. Below is a table with sample locations for 12 settlements and 5 main tanks in the study area.

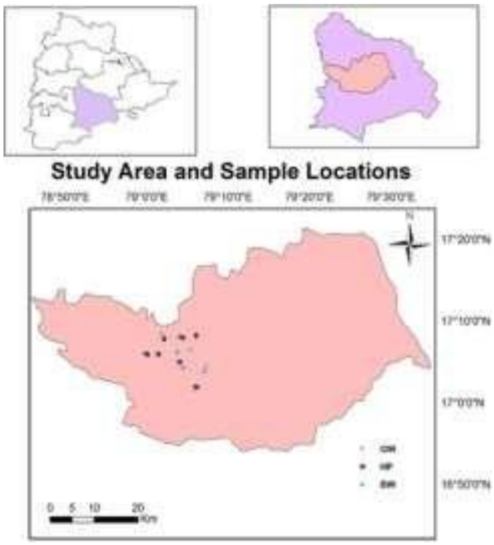

Figure 1: Study area of sample locations

Twenty well and tank samples from the research region were obtained (fig. 1.). All samples were analysed using APHA- 1995 procedures; the results were used in this investigation (Abbasnia et al, 2022).

Table 1: Villages and tanks in study area

Sample Number	Village Name	Latitude	Longitude
BW-1	Koratikal	17.07377778	79.12155556

HP-1	Koratikal	17.032048	79.100581
BW-2	Ookondi	17.01722222	79.09788889
BW-3	Kaslapuram	17.01780556	79.10475
BW-4	Munugode	17.072639	79.074667
BW-5	Cheekatimamidi	17.100944	79.021306
BW-6	Kompalle	17.13705556	79.06663889
BW-7	Gudapur	17.13802778	79.08
HP-2	Ookondi	17.13608333	79.10036111
HP-3	Rathipalle	17.10436111	79.05738889
HP-4	Munugode	17.082694	79.066972
HP-5	Cheekatimamidi	17.098111	79.024333
HP-6	Palivela	17.09811111	79.02433333
HP-7	Kompalle	17.10094444	79.02130556
OW-1	Gudapur	17.13686111	79.02988889
OW-2	Koratikal	17.017806	79.10475
OW-3	Singaram	17.14936111	78.99766667
OW-4	Ookondi	17.10036111	78.99363889
OW-5	Palivela	17.14102778	79.02988889
OW-6	Kompalle	17.10036111	78.99363889

GEOLOGY

The study region has Archaean granites. They're firm, compact, and fine to coarse. Mineral content and structure change this state. Pink and grey granites predominate (Kumar et al, 2020). They're coloured by a mineral. The two granites are hard to distinguish. Light bands are rich in quartz and feldspar, while dark bands are predominantly mica and hornblende. Pink granites contain microcline, orthoclase, acid plagioclase, hornblende, mica, and epidote. Porphyritic granites are pink (Abdulkarim et al, 2021).

Gray Granites

Low-relief rocks. Fine to medium-grained. They comprise of 2 to 3 mm hornblende and biotite enclaves grouped in parallel plains to form lineation and strong gneissic banding. Mafic enclaves are 5 cm long and 2-3 cm broad.

The rock consists of light grey and blue quartz grains. Light brown potash feldspar crystals and white or light grey plagioclase grains. Hence, grey granites. Quartz and epidote veins crisscross the rock. Quartz-feldspathic veins also appear (Vazquez et al, 2016).

Grey granites are also even-grained, with some coarse and fine areas. Dark-colored finegrained rocks. Feldspars are white, greyish white, or pale pink. Gray, smoky, or pale green quartz. Feldspar crystallises irregularly (Pellant & Pellant, 2021).

Pink granites

This location has pink granites. Pink granites are heterogeneous rocks that are pink. These granites and their grey analogues have the same texture and mineralogy. The single criterion is prominent pink or flesh-colored feldspar. Some are crimson to pink. Variable grain size. Porphyritic and gritty (Ossian, 2019). In the fields, the rock slopes into county rock. It's worn and has noticeable feldspar crystals (Jackson, 2015).

METHODOLOGY

Bore wells, excavated wells, tanks, lakes are sampled with plastic bottles. Before sample collection, plastic bottles were washed and open-dried. The bottle should be 1l (Bwambale & Kalema, 2018). Glass bottles aren't suggested since they break easily and several minerals in ground water react with glass, altering sample chemistry. Before collecting well samples, pump the well to guarantee a representative sample. Make sure the groundwater sample has no solid particles (McCarthy, 2018).

The bottle should be closed tightly after the sample is collected. Temperature, negative logarithm of hydrogen ion concentration (pH), electrical conductivity (EC), location of well, well inventory data and other physical parameters such as color of water, turbidity and odor should be recorded there itself (Al Omari et al, 2016). Shorter the time gap between collection of samples and analysis greater the accuracy. If samples are to be preserved long time, suitable treatment should be given. They are analyzed for pH, EC and total dissolved solids as per slandered procedures (Ali et al, 2016).

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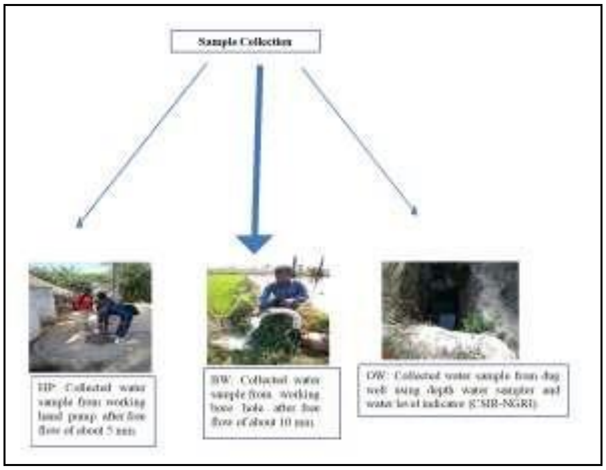

Figure 2: Collection procedure

CHEMICAL ANALYSIS

- Collection of water samples in pre-cleaned bottles of 1 liter each.
- pH, EC, total dissolved solids (TDS) were measured in situ using portable pH meter MCP pocket digital pH meter.
- The chemical analysis of Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, NO_3^{-}, CO_3^{-2}, Fe^{+2}, Fe^{+3}, Cl^{-}, PO_4^{-3}, SO_4^{-2}, F^{-} using ion chromatography in CSIR-NGRI. **Analysis of ground water Physical tests:**

Ground water aesthetics. It measures ground water turbidity, colour, and odour (Nyakundi et al, 2020).

Chemical tests:

Analysis determines the amount of chemicals and pollutants in ground water. Chemical analysis expresses substances as ions, cations and anions (Yang et al, 2016). Cations are positively (+Ve) charged ions which include calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+},) and potassium (K^{+},). Anions are negatively (-Ve) charged ions which include carbonate (CO_3^{-2}), bicarbonate (HCO_3^{-}), chlorides (Cl^{-}), sulphates (SO_4^{-2}), nitrates (NO_3^{-}), etc.

The lab test measures groundwater components. Water testing include:

1. In-situ
2. Chemical Analysis (CSIR-NGRI)

HYDROGEOCHEMISTRY

Physical properties

Ground water is clean, colourless, odourless, and relatively consistent temperature, unlike surface water. In most hydrological settings, ground water can be used without treatment (Mchome, 2017). Ground water from caverns and other huge openings may contain suspended debris and contaminants. Physical quality may restrict water's use for specific purposes. Physical and chemical water quality must be assessed. Color, odour, turbidity, and temperature are important for beneficial usage of water (Omer., 2019).

Colour:

Color is an important water quality factor. Minerals or chemical substances can colour groundwater. Organic substances and iron can tint. Coloring drinking water isn't recommended (Iwuozor, 2019).

Odor:

Gases, organic molecules, and minerals give ground water its odour and taste (Omer, 2019). **Turbidity:**

Turbidity measures suspended particles and microorganisms in water. Light path through water is used to measure turbidity (Boyd, 2015).

Carbonate and Bicarbonate:

These two anions contribute to the alkalinity or acid neutralising power of water. Rainwater is the main source of carbonate and bicarbonate in groundwater. As it reaches the soil, it dissolves more CO_2, increasing temperature or pressure reduces CO_2 solubility in water, and organic matter releases CO_2 for dissolution (Vesala et al, 2017). Bicarbonate concentrations between 50 and 400 ppm are prevalent in ground water (Towfik & Hammadi, 2020).

Determination of carbonates:

Using several indicators and sulphuric acid as a standard solution, these two radicals are volumetrically titrated (Ngibad & Pradana, 2019). ***Reagents:***

1. H_2SO_4 (0.02 N) solution
2. Phenolphthalein indicator: 0.5 g. of phenolphthalein diluted in 50 ml ethyl alcohol and 50 ml distilled water.
3. Methyl orange indicator: 1.05 g. of methyl orange, diluted in 100 ml distilled water. **Procedure:**

CO_3, add 2 to 3 drops of phenolphthalein indicator to 20 ml of water in a conical flask and titrate with 0.02 N H_2SO_4 until the pink hue just vanishes. Note the volume of acid necessary for titration (Patel & Vashi, 2015).

$$CO_3 \text{ mg/l} = \frac{\text{Ml of acid X 1000 X eq. wt. of } CO_3 \text{ X Normality of } H_2SO_4}{\text{Ml of sample Taken}}$$

If water sample pH is above 8.3, carbonate determination is required. Two to three drops of methyl orange indicator are applied to 20 ml of HCO_3 in a conical flask. Then titrate with 0.02 N H_2SO_4 drop wise until the orange yellow colour turns pink, and note the acid value required for titration.

$$HCO_3\ mg/l = \frac{Ml\ of\ Acid\ X\ 1000\ X\ Equal\ weight\ of\ HCO_3\ X\ Normality\ of\ H_2SO_4}{Ml\ of\ Sample\ Taken}$$

Chemical Properties

Total Dissolved solids (TDS)

Munugode mandal has 821-1676 mg/l total dissolved solids.

Table 2: Classification of water based on TDS

CATEGORY	TDS O"0[1]0
Fresh water	0-1000
Brackish water	1000-10.000
Saline water	10,000-10,0000
Brine water	More than 10,0000

pH: pH measures water's acidity or alkalinity by its hydrogen ion concentration. pH is the logarithm of Hydrogen ion concentration (Schockman & Byrne, 2021). I. Pure water pH-7.

2. Acidic pH below 7
3. Alkaline is above 7 pH.

Ground water pH is 5-8 mol/l. Ideal pH range is 7-8.

Electrical Conductivity (EC):

Specific conductance is groundwater's electrical conductivity. Total ionized water ingredient concentration significance (Logeshkumaran et al, 2015).

Hardness:

Hardness is an important hydrogeochemical property for drinking and industrial water. Hardness is caused by dissolved calcium, magnesium, chlorides, nitrates, and sometimes iron and aluminium (Fatlawy & Yas 2015). Calcium carbonate ppm or mg/l.

$$Water\ hardness\ (mg/l) = 2.5\ ca\ (mg/l) + 4.1\ Mg(mg/l)$$

Table 3: Classification of water according to total hardness concentration in (mg/l) as $CaCO_3$

Water Classification	Total hardness concentration in (mg/l) as $CaCO_3$
Soft	0-50
Moderately soft	50-100
Slightly hard	100-150

Moderately hard	150-200
Hard	200-300
Very hard	>300

RESULTS AND DISCUSSION

Hydrogen Ion Concentration (pH):

The pH value of ground water indicates alkalinity or acidity (basic interaction of number of its mineral and organic compounds). Geochemical equilibrium or solubility calculations rely on quality (Deutsch, 2020). pH range of ground water is 6.52 to 8.5. All samples had acceptable pH levels. The pH suggests an alkaline atmosphere (all pH values are above 7).

Electrical Conductivity (EC):

Conductivity shows ionic concentrations. Temperature, concentration, and ion types matter (You et al, 2020). The study area's ground water EC ranges from 525.4 to 2566 µS/cm at 250. 500-1500 µS/cm is the maximum EC in drinking water (WHO, 1983). The research area's water samples have EC salinities above 250 S/cm. 3,5,14 are medium salinity samples.

Total Hardness:

Hardness is a requirement for home, drinking, and industrial water sources (Gauri & Soni, 2016). The study area's ground water hardness ranges from 32.8 to 926.7 mg/l. Total water hardness cannot exceed 300 mg/l.

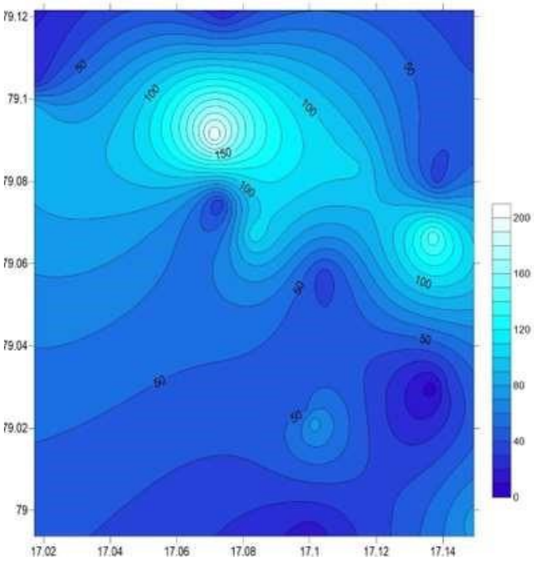

Figure 2: Total hardness of the ground water in the study area

Magnesium:
Magnesium (Mg) content is 2.5-123.4 mg/l. Drinking water Mg limit is 30 mg/l. 18 samples (1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19 and 20) surpass the limit.
Calcium:
Ground water contains 9 to 272 mg/l of calcium. Ca drinking water limit is 75 mg/l. 6 samples (1, 8, 9, 10, 11, and 15) surpass limits.
Table 4: Sample codes with calcium and megnisum concentration in drinking water

Sample Code	Name	Mg	Ca
BW-1	Koratikal	65.9	17.4
BW-2	Ookondi	39.7	86.8
BW-3	Kaslapuram	155.1	23.7
BW-4	Munugodu	167.7	203.5
BW-5	Cheekatimamidi	112.1	102.1
BW-6	Kompalle	74.4	149.8
BW-7	Gudapur	157.7	35.3
HP-1	Koratikal	58.8	68.1
HP-2	Ookondi	38.3	46.2
HP-3	Rathipalle	42.6	34
HP-4	Munugodu	11.3	28.1
HP-5	Cheekatimamidi	97.3	107.3
HP-6	Palivela	15.3	46.1
HP-7	Kompalle	83	76.5
OW-1	Gudapur	35.5	4.1
OW-2	Koratikal	22.5	23
OW-3	Singaram	51	75.4
OW-4	Ookondi	35.6	12.5
OW-5	Palivela	32.8	29.5
OW-6	Kompalle	57.1	55.5

Sodium and Potassium:

From 38.4 to 241.8 mg/l, sodium content varies. Na is limited to 200 mg/l in drinking water. 2 study samples (13 and 15) surpass limits. Potassium levels range from 1 to 147 mg/l. No drinking water limits.

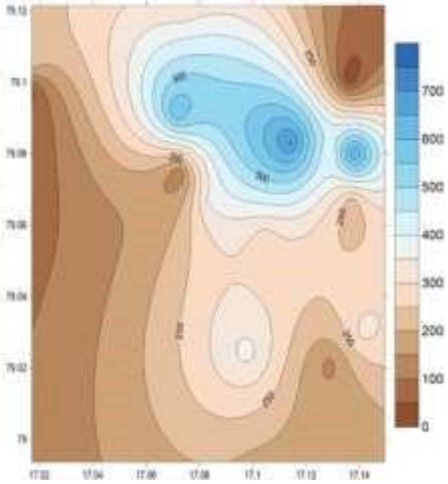

Figure 3: Sodium and potassium concentrations of ground water

Sulphate:

Ground water sulphate (SO_4) ranges from 0.02 to 153.6 mg/l. Drinking water sulphate limit is 150 mg/l. All samples pass. 1 and 10 study samples surpass limits.

Chloride:

Ground water chloride ranges from 48.1 to 664.2 mg/l. Drinking water Cl limit is 250 mg/I. 11 research area samples (1, 2, 8, 10, 11, 12, 13, 15, 17, 18 and 19) exceed limits.

Fluoride:

Ground water fluoride content ranges from 0 to 2.2 mg/l. Drinking water F limit is 1.5 mg/l. The table below indicates fluoride levels in the study region that are too high.

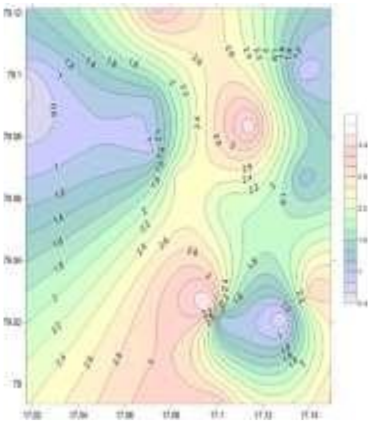

Figure 4: Fluoride concentrations of ground water **Table 5:** Fluoride concentrations of ground water

Sample Code	Name	F
BW-1	Koratikal	3.3
BW-2	Ookondi	0.5
BW-3	Kaslapuram	1
BW-4	Munugodu	1.1
BW-5	Cheekatimamidi	3.6
BW-6	Kompalle	1.3
BW-7	Gudapur	1.7
HP-1	Koratikal	2.2
HP-2	Ookondi	0.9
HP-3	Rathipalle	2
HP-4	Munugodu	1
HP-5	Cheekatimamidi	2.5

HP-6	Palivela	3.7
HP-7	Kompalle	1
OW-1	Gudapur	2.4
OW-2	Koratikal	0.6
OW-3	Singaram	2.8
OW-4	Ookondi	3.2
OW-5	Palivela	3
OW-6	Kompalle	1.5

Bromide:

Ground water bromide content ranges from 0 to 2 mg/l. 4.5 mg/l is the Br drinking water limit.

Nitrate:

Ground water nitrate concentrations range from 1.1 to 417.3 mg/l. Six samples (1, 2, 4, 6, 8 and 10) from the study region exceed the 50 mg/l NO_3 limit for drinking water.

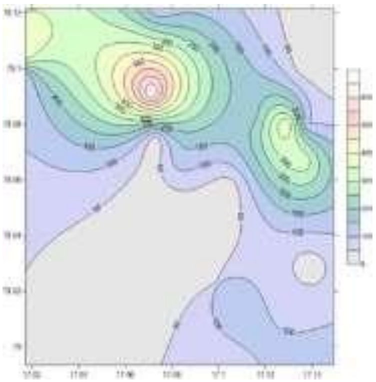

Figure 5: Nitrate (NO_3) concentrations of the ground water

Phosphate (PO_4):

No boundaries. This study doesn't measure phosphate.

QUALITY CRITARIA FOR GROUNDWATER USE

Water quality requirements indicate constituent concentrations that, if not exceeded, are suitable for usage. Water quality parameters meant to produce direct water use and safeguard water-dependent life (Sasakova et al, 2018). Acceptability of groundwater for a specific use is largely determined by its chemistry. Physical, chemical, and biological water parameters compared to criteria define water quality (Faust & Aly, 2018). Groundwater quality depends on dissolved chemicals and the traits and features they confer (Lipczynska-Kochany, 2018).

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Analysis and interpretation of geo-chemical characteristics of groundwater

Graphical and numerical interpretation of chemical water analysis based on ion or ion group relationships. Graphs compare and emphasise similarities in recognising chemical processes as groundwater movers and water groups with comparable evolutionary histories (Shry & Reiley, 2016). Many strategies and methods based on water's physical and chemical properties can help with these problems. Several computer programmes and software have been created in the recent decade to plot and analyse water suitability (Macrae et al, 2020).

Table 6: Quality criteria for groundwater

Sample Code	Name	Latitude	Longitude	pH	EH	COND	TDS	Na	K	Mg	Ca	Cl	SO_4	HCO_3	CO_3	NO_3	F	Br	Na + K	DEPTH
BW-1	Koratikal	17.07377778	79.12155556	8.12	-83	1710	910	298.2	3.3	65.9	17.4	175.8	108.9	470	60	100	3.3	3.5	301.5	48.72
BW-2	Ookondi	17.017222	79.09788889	7.97	-75	910	480	40.	1.9	39.7	86.8	144.	43.2	70	20	118.	0.5	0	42.2	26
		22						3				5				6				
BW-3	Kaslapuram	17.01780556	79.10475	8.01	-77	2280	1220	211.5	3.1	155.1	23.7	304.4	88.4	470	40	388.2	1	1.1	214.6	27.432
BW-4	Munugodu	17.072639	79.074667	7.8	-66	4190	2260	588.7	5.4	167.7	203.5	935.1	250.3	380	0	664.4	1.1	3.8	594.1	30.8
BW-5	Cheekatimamidi	17.100944	79.021306	7.99	-76	3660	1970	710.2	6.6	112.1	102.1	764.3	527.8	480	40	172.4	3.6	2.5	716.8	54.864

BW-6	**Kompalle**	17.13705556	79.06663889	7.43	-46	2320	1240	210.2	7.3	74.4	149.8	384.9	149.3	370	0	334.1	1.3	2.5	217.5	36.8
BW-7	**Gudapur**	17.13802778	79.08	8.22	-88	3540	1910	638.3	30.5	157.7	35.3	889.1	208	550	60	100.6	1.7	2.1	668.8	38.5
HP-1	**Koratikal**	17.032048	79.100581	8.8	-118	2170	1160	383.5	14.7	58.8	68.1	263.6	140.2	350	80	408.9	2.2	0	398.2	42.672
HP-2	**Ookondi**	17.13608333	79.10036111	8.49	-101	610	325	17.1	1.7	38.3	46.2	8.8	5.2	280	60	19	0.9	0	18.8	28.4
HP-3	**Rathipalle**	17.10436111	79.05738889	8.02	-77	1680	900	274.5	3.4	42.6	34	299.4	94.5	370	20	13.7	2	1.3	277.9	40.4
HP-4	**Munugodu**	17.082694	79.066972	7.65	-58	597	318	105.1	3.2	11.3	28.1	12.6	15.7	310	0	11.6	1	0.3	108.3	28.2
HP-5	**Cheekatimamidi**	17.098111	79.024333	8.22	-87	2370	1260	279.5	73.7	97.3	107.3	424.9	152.1	420	40	132.3	2.5	1.7	353.2	44.8
HP-6	**Palivela**	17.09811111	79.02433333	8.09	-80	1510	800	369.3	2.5	15.3	46.1	64.9	110.5	610	40	13.3	3.7	0	371.8	60.96
HP-7	**Kompalle**	17.10094444	79.02130556	8.45	-100	2370	1270	286.7	47.3	83	76.5	470.9	158.6	320	60	152.	1	2.1	334	27.4

																6				
OW-1	**Gudapur**	17.13686111	79.02988889	8.54	-104	1220	650	264.4	2	35.5	4.1	62.4	37.3	500	80	27.6	2.4	0	266.4	11.4
OW-2	**Koratikal**	17.017806	79.10475	8.07	-79	880	470	131.7	2.4	22.5	23	89.9	61.9	180	20	71.3	0.6	0.8	134.1	9.9
OW-3	**Singaram**	17.14936111	78.99766667	7.77	-64	1600	860	171.5	2.4	51	75.4	242.1	126.4	230	20	131	2.8	0	173.9	18.288
OW-4	**Ookondi**	17.10036111	78.99363889	8.45	-99	979	519	182.8	2.5	35.6	12.5	40.4	39.1	330	60	73.6	3.2	0.8	185.3	21.336
OW-5	**Palivela**	17.14102778	79.02988889	8.24	-89	1530	820	306.2	12.7	32.8	29.5	138.5	124	430	60	31.7	3	0	318.9	20.4
OW-6	**Kompalle**	17.10036111	78.99363889	8.08	-81	1350	720	152.9	7.1	57.1	55.5	85.6	75.2	290	20	221.3	1.5	0.6	160	10.7

Piper's trilinear Diagram

Piper's trilinear Diagram (fig.6) is used to determine the origin and source of dissolved salts, specify the hydro-geological processes that affect groundwater quality, and classify distinct water types (Palmajumder et al, 2021).

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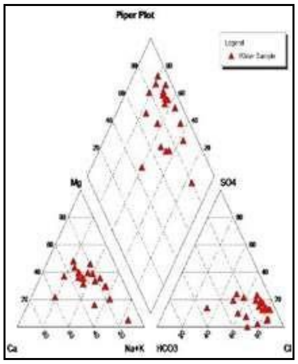

Fig. 6: Piper's Diagram for chemical classification of water samples

Two bottom triangular fields and a centre diamond-shaped field make up Piper's trilinear diagram. Ca+, Mg+, Na+, and K+ are plotted in ppm% in the lower left triangle. The primary anions in ppm% are CO3+, F-, CO3-, Cl-2, and SO-2. The plots in two triangle fields are projected onto a quadrilateral or centre diamond-shaped field to determine groundwater kinds. Different types of groundwater can be differentiated based on plot placements in the diamond-shaped field. Piper's trilinear diagram and diamond-shaped field (Gnanachandrasamy et al, 2015). Pipers trilinear figure shows the concentration of main elements in pre-monsoon groundwater samples (Singh et al, 2015).

Evaluation of groundwater for drinking purpose

Todd BIS 1991 and WHO 2006 set the limitations (Adimalla, 2019). All drinking water programmes follow these requirements. Maximum Contaminant Level (MCL) and acceptable Level (PL) of WHO and BIS standards were used to evaluate groundwater for drinking (Adimalla & Qian, 2021). Table 6 shows the concentrations of major, secondary elements, EC, TDS, pH, and TH along with the location of samples over PL and MCL. In majority of the groundwater samples collected during a field, the average concentration values of major (HCO_3^{+1}, Cl^{-1}, SO_4^{-2}, Na^{+1}, Ca^{2+}), secondary (CO_3^{-2}, F^{-1}, NO^-, K^{+1}), are above the permissible limits for drinking purpose. Some of the graphical representation of some of the major ion concentration at different locations

To know the effect of geo-chemical constituents on human health, the health aspects of the most important geo-chemical constituents of groundwater for drinking are highlighted. The concentration of secondary elements shows that many ionic concentrations are well within the BIS and WHO permissible limits (Singh et al, 2022).

Evaluation of groundwater for irrigation

Evaluation of groundwater for irrigation depends on dissolved salts, relative proportions of bicarbonate to calcium and magnesium, sodium to calcium on both the plant and soil, prevalent meteorological conditions, irrigation techniques, and drainage system (Shabbir & Ahmad, 2015). In Munugode Study Area, SAR, Na % was used to evaluate groundwater for irrigation. Groundwater for irrigation is classified graphically (Ghazaryan et al, 2020).

Sodium Adsorption Ratio (SAR)

SAR measures Na absorption by soil components during water percolation. This ratio is useful as a sodium or alkali water hazard index. Higher SAR damages soil structure. High SAR promotes alkali danger in soil; calcium-magnesium-rich water reverses it (Rao & Latha, 2019). Sodium Adsorption Ratio computed using equation.

$$\mathbf{SAR = Na/[(Ca + Mg^2)/2]^{1/2}}$$

Meq/1 for all ions.

According to the table, 7 samples are outstanding, 10 are good, 3 are dubious, and 7 are inappropriate for irrigation based on SAR.

Table 7: Irrigation classification of groundwater according to SAR values (Richards, 1954).

SAR	Water class	No. of samples
<10	Excellent	12
10-18	Good	5
18-26	Doubtful	3
>26	unsuitable	Null

Wilcox's Diagram (1955).

Wilcox's graphic plots sodium percentage against electric conductivity for irrigation water categorization. Wilcox's graphic (fig. 7) shows that all field-collected groundwater samples fit into four classes: excellent to good, good to permissible, permissible to questionable, and doubtful to inappropriate (Vincy et al, 2015).

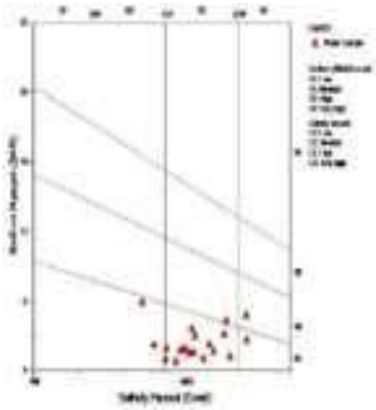

Fig. 7: Wilcox's Diagram showing the irrigation water classification **Table 8:** Irrigation water classification based on Wilcox's diagram

Sl. No.	Water class	Description	Suitability
1	C2-S1	Medium Salinity and low alkali hazards	Good to excellent
2	C3-S1	High salinity and low alkali hazards	Permissible salinity and excellent alkali
3	C4-S1	Very high salinity and low alkali hazards	Doubtful salinity and excellent alkali
4	C3-S2	High salinity and medium alkali hazard	Permissible to good
5	C3-S3	High salinity and high alkali hazards	Permissible to doubtful
6	C3-S4	High salinity and very high alkali hazards	Permissible to unsuitable
7	C4-S2	Very high salinity and medium alkali hazards	Doubtful to good

SAR and electrical conductivity values of all pre-monsoon drilled and dug well samples are plotted on Richard's (1954) fig. 7. All water samples fall into seven categories: 1. C2-S1 (low alkali hardness), 2. C3-S1 (high salinity/low alkali), 3. C4-S1 (high salinity/low alkali), 4. C3-S2 (high salinity, medium alkali), 5. C3-S3 (high salinity/high alkali), 6. C3-S4 (high salinity/alkali hazard) and 7. C4-52 kinds (high salinity, medium alkali) Tables 8 and 9 show irrigation-suitable water.

Table 9: Irrigation suitability of water

Irrigation suitability	No. of samples
Excellent to good	4
Good to permissible	13
Doubtful to good	2
Permissible to doubtful	Null
Permissible to Un doubtful	Null
Un doubtful to Good	1

CONCLUSION

Basin lithology is primarily granitic (grey and pink granites, granite gneisses). Part of PreCambrian Eastern Dharwar Craton. Groundwater is alkaline. Alkaline conditions enhance fluoride absorption. 0.5 to 3.7 mg/l fluoride in samples. 41% of samples had >1.5mg/l of fluoride. 11.6 to 664.4 mg/l nitrate content. 56% of the samples have high Nitrate concentrations (>50mg/l), and 12% are unsuitable for irrigation. All significant ion concentrations, excluding fluoride and nitrate, are within WHO 2004 guidelines. Fluoride, Nitrate, Magnesium, and Chloride levels are also high. So, drinking requires safeguards.

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