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Physico-chemical analysis of groundwater covering the parts of Padmanabhanagar, Bangalore Urban District

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Abstract: *The present study evaluated the ground water quality and physico-chemical characteristics of the water samples collected from 15 bore wells in the study area which is situated in Rangappa Layout which is located in the Ittamadgu Village of Uttarahalli Hobli which falls in the Bangalore South taluk of the Bangalore Urban district. Physico-chemical characteristics of the collected water samples, various parameters like pH, Temperature, Total Suspended Solids, Turbidity, Total Dissolved Solids, Total Hardness, Electrical Conductivity, Sodium, Potassium, Ca, Mg, Cl, HCO_3, CO_3, NO_3, F, SO_4, PO_4, Cr^{+6}, Fe, Cu, Pb, Ni, Zn are analyzed. Spatial variation maps are prepared to understand the distribution. The variation in elevation, overburden thickness, fractures, rate of discharge are determined. Hill piper, Wilcox and USSL have been obtained to determine the percentage of salinity and alkalinity of water. The quality of water found suitable for drinking purpose.*

Keywords: *Physico-chemical characteristics, spatial variation maps, Hill Piper, Wilcox, USSL*

I. Introduction

Water is the most essential and one of the prime necessities of life. No one can live without water (Khanna et al., 2007). Unplanned urban development has posed gigantic problems of environmental pollution. Due to this, water of natural bodies is getting polluted at an alarming rate (Shastri et al., 2008). Physico-chemical parameters play a vital role in determining the distributional pattern and quantitative abundance of organism's inhabitating a particular aquatic ecosystem (Singh et al., 2009). Groundwater quality is being threatened by agricultural, urban & industrial activities, which leach or inject the polluted water directly into underlying aquifers. Quality of water is an important criterion for evaluating the suitability of water for irrigation and drinking. The study of underground contamination will be of immense help to researchers and environmental regulators to evolve and initiate mitigative measures. Long and sustained industrial activity in any given area can often lead to soil and ground water contamination. Improper waste disposal practices might contaminate the soils and gradually the entire ground water in the area, impairing ground water quality for many applications including drinking. The present investigation involves the analysis of water quality in relation to physico- chemical parameters.

II. Study Area

In order to study the ground water development and the quality of the ground water, a sample study area (Fig. 1) the Rangappa Layout which is located in the Ittamadgu Village of Uttarahalli Hobli which falls in the Bangalore South taluk of the Bangalore Urban district has been chosen. It falls between Longitude 77° 32' 53" & 77° 32' 58" and Latitude 12° 55' 28" & 12° 55' 32". The area is spread approximately less than square kilometer which houses residential flats. The people in the layout depend mainly on bore well for their day to day water need. It is a Rocky upland Plateau and predominant geology is Granitic Gneisses. The Bangalore south taluk is categorized as Over Exploited with stage of development 175 % as on March 2011.

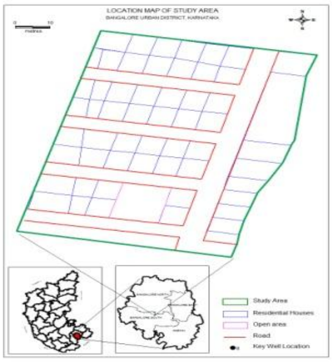


Fig: 1 Location of the study area

III. Methodology

Fieldwork was carried out in the study area and collected the GPS locations from various points within the layout for geo referencing the layout map. 15 numbers of Borewells were inventoried and water samples are collected for basic parameter analysis. A total of 20 GPS readings were recorded at different points Based on the inventoried data, thematic maps are prepared using GIS software. Check for the completeness has been done. The borewell details from which the water samples are collected are tabulated (Table 1).

TABLE 1 : DETAILS OF BORE WELLS INVENTORIED

Sl. No	Location	Latitude	Longitude	Altitude	Depth of well (m bgl)	Depth of casing (mbgl)	Discharge (lps)	Fractured zone (mbgl)	Year of drilling	Status of well	Pump lowered (mbgl)
1	2	12.9413	77.5488	876	200	80	0.75		1996	WORKING	170
2	22	12.9252	77.5487	870	200	90	0.75		1997	WORKING	170
3	47	12.9249	77.5485	888	400	150	2.45		2009	WORKING	300
4		12.9248	77.5482	884	190	60	0.75	90	1995	WORKING	HAND PUMP
5	45	12.9253	77.5486	888	150	100	0.75	80	2001	WORKING	100
6	11	12.9253	77.5489	893	430	128	4.27	285	2011	WORKING	300
7	16	12.9245	77.5489	888	150	70	0.75		1990	WORKING	100
8	44	12.9255	77.5486	887	350	250	4.27	120	2013	WORKING	250
9	26	12.9255	77.5488	889	170	160	2.45	140	2008	WORKING	160
10	4	12.9247	77.5489	879	600	200	1.18	160	1999	WORKING	350
11	12	12.9255	77.5493	915	200	120	0.75		1995	WORKING	160
12		12.9247	77.5483	891	650	250	4.27		2012	WORKING	400
13	8	12.9258	77.5491	895	300	250	0.75		1993	WORKING	250
14		12.9250	77.5483	875	200	100	0.22	120	1994	WORKING	190
15	18	12.9246	77.5487	877	500	200	4.26		2012	WORKING	300

Depth of Well:

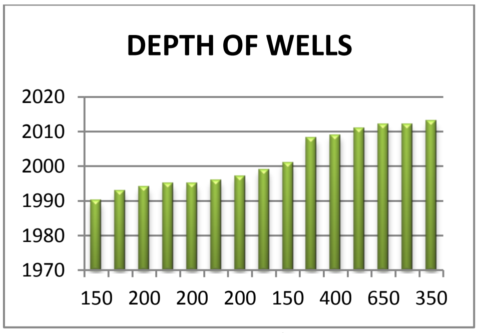


Fig 2: Depth of well

The above bar graph represents the depth of the wells drilled in the study area from 1990 – 2014 (Fig 2). The water availability in the ground has decreased which has resulted in increase in the depth of the wells. This indicates the decrease in the level of water table. In the recent past artificial recharge is introduced compulsory. It is expected artificial recharge scheme is enhances the level of water table in future scenario.

- **Elevation**: The elevation in the study area ranges from 875 – 915 m bgl where as 60% of the area ranges from 875 – 885 m bgl. There is increase in elevation towards north east. About 15% of area ranges with an elevation between 885 – 895 m bgl and maximum elevated area lies in the north eastern region with values ranging from 905 – 915 m bgl (Fig 3).
- **Fractures**: The fractures which are yielding water in the study area ranges from 20 – 100 m bgl. The western side of the study area the fractures are encountered within the range of 20 – 40 m bgl whereas the north eastern portion of the study area have deep seated aquifers with depth up to 100 mts (Fig 4).
- **Discharge:** The yield from the bore wells ranges from < 1 lps to > 4 lps. Around 20 % of the study areas have borewells having yield less than 1 lps, where has borewells having yield more than 4 lps is located in isolated pockets. The common discharge from the borewells in the study area is between 1 to 3 lps (Fig 5).
- **Overburden thickness:** In the Study area the likeliness of encountering the massive rock at greater depth is more on the south-western part and in northern part, whereas possibility of massive rock at the shallow depth is more in the central portion of the study area. The depth to massive rock increases gradually from central part towards North and south (Fig 6).

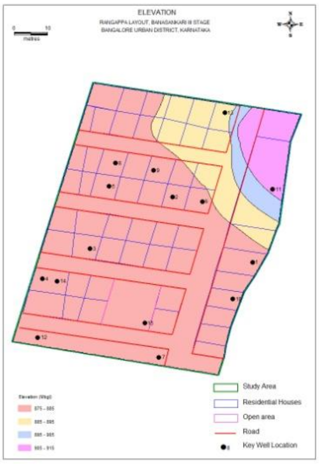


***Fig: 3** Elevation map*

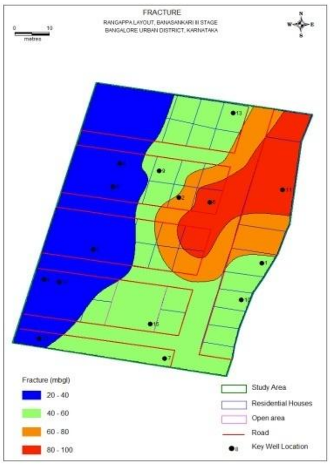


***Fig: 4** Distribution of Fracture zone*

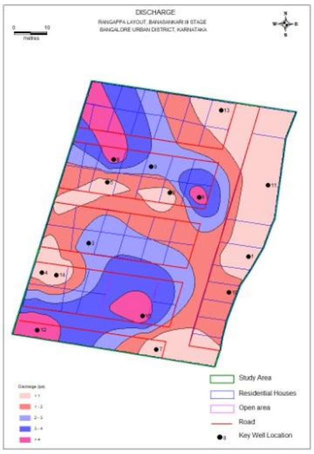


***Fig: 5** Discharge Map*

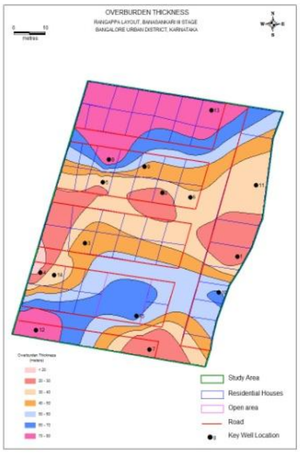


***Fig: 6** Overburden Thicknesses*

IV. Chemical Analysis

15 Ground water samples were collected from the Bore wells in the Study area. The water samples thus collected were analyzed for Total hardness, calcium, magnesium, nitrate, fluoride, Sulphate & TDS. Whereas Electrical conductivity and pH were measured insitu at the sampling collection site itself. Standard methods were used for the analysis. The sample locations are given in the (Fig. 7). The result of the chemical analysis is given in Table No: 2.

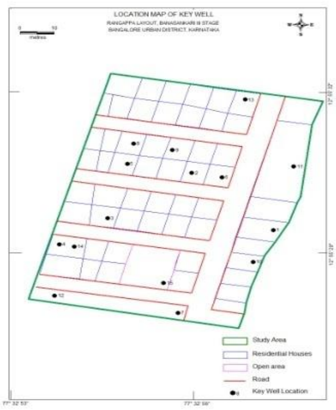


Fig: 7 Location map of key well

TABLE 2: CHEMICAL ANALYSIS DATA

Sl. No	Parameter/Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	pH	7.5	7.3	7.7	7.7	7.7	7.5	7.5	7.4	7.4	7.4	7.5	7.4	7.6	7.5	7.3
2	Temp	27	27	26	27	25	26	26	26	27	25	27	27	27	27	27
3	TSS	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
4	Turb	0.1	0.15	0.1	0.15	0.2	0.1	0.1	0.15	0.2	0.1	0.2	0.1	0.2	0.1	0.15
5	TDS	390	400	380	370	350	370	380	360	380	390	410	400	370	380	400
6	EC	630	645	630	610	580	610	630	590	620	630	650	640	620	620	635
7	Na	30	25	26	17	14	20	22	19	21	18	19	23	18	23	20
8	K	5	5	4	2	2	4	3	2	5	5	4	6	5	4	3
9	Ca	52	56	53	51.2	54	52.9	56	52	52.1	55	55.6	52.8	53.1	52	56
10	Mg	24	24.1	24	23	22.4	23.8	24.1	25.5	21.9	24.78	25.3	25.2	22.4	21.6	24.1
11	Th	230	240	232	225	230	230	240	235	220	240	243	237	225	220	240
12	Cl	95	90	90	90	85	95	93	90	90	90	95	94	85	90	95
13	CO3	3.4	3.1	4	2.8	2	3	3.5	3	3.5	4	4.1	3	2.5	2	3
14	HCO3	160	170	165	150	140	165	170	155	155	170	165	168	160	155	160
15	F	0.31	0.39	0.31	0.35	0.39	0.28	0.31	0.26	0.35	0.32	0.39	0.37	0.35	0.34	0.35
16	NO3	6.14	5.56	4.12	5.23	6.19	5.63	5.12	6.83	5.01	3.41	7.79	5.94	3.49	5.28	5.56
17	PO4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0.01
18	SO4	24	26	23.1	20	20	19	23	22	24	25	23	25	23	26	27
19	Cr+6	ND	ND	ND	ND	0	ND	ND	ND	0	ND	0	0	ND	ND	ND
20	Fe	0.02	0.02	0.03	0.01	0.03	0.01	0.02	0.03	0.03	0.019	0.03	0.02	0.02	0.02	0.03
21	Cu	0	0	ND	0	0	0	0	ND	0	0.001	0	ND	ND	0	ND
22	Zn	0.01	0.01	0.01	0	ND	0	0.01	0.01	0	0.002	0.01	0.01	0	0	0.01

pH: pH is the scale of intensity of acidity and alkalinity of water and measures the concentration of hydrogen ions. Normal range of pH in the irrigation water is 6.5 to 8.4 (Ayersand Westcot, 1985; KSPCBOA, 2000). The pH of the collected water samples were found by using pH meter (Electrometric method). It was found that pH in all the 15 samples are within the permissible limit of ISI i.e. 6.5-9.

TEMPERATURE: Water temperature directly as well as indirectly influences many abiotic and biotic components of aquatic ecosystem. It also reflects to the dynamics of the living organisms such as metabolic and physiological behaviour of aquatic ecosystem. The temperature is one of the important factors in aquatic environment since it regulates physicochemical as well as biological activities (Kumar et al., 1996). The water temperature was recorded 25°C to 27°C.

TOTAL SUSPENDED SOLIDS: The total suspended solids are composed of carbonates, bicarbonates, chlorides, phosphates and nitrates of Ca, Mg, Na, K, Mn organic matter, salt and other particles. The effect of presence of total suspended solids is the turbidity due to silt and organic matter. When the concentration of suspended solids is high it may be aesthetically unsatisfactory for bathing (APHA, 2002). In the present study TSS is not detected.

TURBIDITY: Turbidity is an expression of optical property; wherein light is scattered by suspended particles present in water (Tyndall effect) and is measured using a nephelometer. Turbidity of groundwater samples obtained from 2.1 to 6.2 which showed limits under the CPCB.

TOTAL DISSOLVED SOLIDS: The dissolved solids in water samples include all solid materials in solution. It does not include suspended sediments, colloids or dissolved gases. Different limits of TDS content are fixed for different purposes by various organizations and individuals. (Davis and Dewiest, 1967)

TABLE 3 : PERMISSIBLE LIMITS FOR TDS

TDS(ppm)	CLASS
< 500	Desirable for Drinking
500 - 1000	Permissible for Drinking
1000 - 3000	Slightly Saline
3000 – 10,000	Moderately Saline
10,000 – 35,000	Very Saline
>35,000	Brine

From this classification the water samples collected in the study area are found suitable for drinking water with its value within 500ppm (Table 3).

ELECTRICAL CONDUCTIVITY: Conductance is a function of water temperature; hence a standard temperature usually 25°C must be specified in reporting conductivity test. As the ion concentration increases conductance of solution also increases. Therefore conductance measurement indicates the ion concentration. The Electrical conductivity was measured using conductivity meter (Electrometric method) at the sampling site. EC ranged between 620 µs/cm to 670 µs/cm.

SODIUM: Sodium content of bore well ranged from a minimum of 17 mg/L to a maximum of 30 mg/L. Spatial variation (Fig.8) has been studied and concentration of Na is found high in sample no 1 and it is found less in concentration in sample no 5.

POTASSIUM: Although potassium is nearly as abundant as sodium in igneous rocks, its concentration in ground water is comparatively very less as compared to sodium (nearly one-tenth or one-hundred that of sodium). This is due to the fact that the potassium minerals are resistant to decomposition by weathering. Potassium content of bore well ranges from 2-6 mg/L. Spatial variation (Fig.9) has been studied and concentration of K is found high in sample no 12 and it is found less in concentration in sample nos 5, 8 and 4.

CALCIUM: Calcium found in water samples was estimated by EDTA titrimetric method. It was found that all the calcium concentration in water samples are within in the permissible limits of 200ppm prescribed by ISI. Spatial variation (Fig.10) has been studied and concentration of Ca is found high in sample no 12 and it is found less in concentration in sample nos 4, 5 and 8.

MAGNESIUM: Magnesium content in water samples was determined by using total hardness and calcium hardness value. It was found that the magnesium concentration in water samples is within the permissible limit of 30ppm as per WHO and ISI standards. Spatial variation (Fig.11) has been studied and concentration of Mg is found high in sample nos 8, 10, 11 and 12, it is found less in concentration in sample nos 5, 9, 13 and 14.

TOTAL HARDNESS: Total hardness is the measure of Ca and Mg content and it is customarily expressed as the equivalent of CaCO3. Hardness results from the presence of divalent metallic cations of which Ca and Mg are most abundant on ground water. The total hardness was estimated by EDTA titrimetric method. The total hardness of all the 15 samples range from 150 – 300 which indicates that the given water samples are hard.

CHLORIDE: The chloride concentration in water samples are within the permissible limit i.e, it ranges from 250-1000ppm, according to IS. Spatial variation (Fig.12) has been studied and concentration of Cl is found high in sample nos 1, 6, 7, 11, 12, and 15, it is found less in concentration in sample no 5 and 13.

CARBONATE: Carbonate content of bore well ranges from 2-4.1 mg/L. Spatial variation (Fig.13) has been studied and concentration of CO_3 is found high in sample nos 11 and 3, it is found less in concentration in sample nos 5 and 14.

BI-CARBONATE: Bi-carbonate content of bore well ranges from 140-170 mg/L. Spatial variation (Fig.14) has been studied and concentration of HCO_3 is found high in sample nos 2, 3, 6, 7, 10, 11 and 12, it is found less in concentration in sample no 5.

FLUORIDE: The maximum permissible limit of fluoride in drinking water is recommended to be 1.5mg/l by WHO. Fluoride concentration in water samples were found by using the Fluorimeter. All the 15 samples are showing fluoride value within the permissible limit of less than 1.5mg/L. Spatial variation (Fig.15) has been studied and concentration of F is found high in sample nos 2, 5, 11and 12, it is found less in concentration in sample nos 6and 8.

NITRATE: Nitrate concentrations in ground water ranges from 50 mg/L are influenced by excessive applications of nitrate fertilizer. Nitrate concentration in water samples were detected by phenol disulphonic acid method. It was found that the Nitrate concentration in water samples is within the permissible limit. Spatial variation (Fig.16) has been studied and concentration of NO_3 is found high in sample no 11 and it is found less in concentration in sample no 3, 10 and 13.

PHOSPHATE: Phosphate content of bore well ranges from 0.004-0.011mg/L. Spatial variation (Fig.17) has been studied and concentration of PO_4 is found high in sample nos 4, 7, 8 and 11, it is found less in concentration in sample no 14.

SULPHATES: The sulphates in water samples are estimated by Turbidimetric method. The sulphate concentration in water samples in the study area are within the permissible limit which ranges between 200-

400ppm. Spatial variation (Fig.18) has been studied and concentration of SO_4 is found high in sample nos 2, 4 and 15, it is found less in concentration in sample no 4, 5 and 6.

CHROMIUM: As per IS the chromium content in the water should not be greater than 0.05mg/L. From the analysis it is determined that the concentration of chromium in the water samples in the study area is well within the permissible limit. Spatial variation (Fig.19) has been studied and concentration of Cr^{+6} is found high in sample nos 5, 9, 11 and 12, it is found less in concentration in more than 12 samples.

IRON: The standard of the BIS suggests that the Iron content of drinking water should not be greater than 0.3mg/L. The iron concentration in water samples in the study area are within the permissible limit. Spatial variation (Fig.20) has been studied and concentration of Fe is found high in sample nos 5, 8, 9 and 15, it is found less in concentration in sample nos 6 and 4.

COPPER: The permissible limit of copper according to IS suggested that the concentration of copper should not exceed 0.05 mg/L. It is found that the concentration of copper in water samples is within the permissible limit. Spatial variation (Fig.21) has been studied and concentration of Cu is found high in sample nos 4, 6 and 11, it is found less in concentration in sample nos 3, 8, 13, 12 and 15.

ZINC: Zinc concentrations in ground water ranges from 5-15ppm. It was found that the Zinc concentration in water samples is within the permissible limit. Spatial variation (Fig.22) has been studied and concentration of Zn is found high in sample nos 3, 5 and 7, it is found less in concentration in sample no 5.

V. Hill Piper Diagram

Piper diagram (Piper, 1994), is most useful to understand chemical relationships of ground water. The pipers trilinear diagram is one way of comparing quality of water. The first step is for determining the water facies for the purpose of studying the evolution of ground waters. The lower left ternary or cat ion ternary, compress the cation composition as on equivalent fraction (% epm) of calcium (total dissolved Ca), magnesium (total dissolved Mg) and the sum of sodium and potassium (Na+K). Similarly, the lower right ternary, or anion ternary contrasts the anion composition in terms of fraction of equivalents of sulphate ion SO_4^{-2}, chloride (Cl-), and the sum of bicarbonate and carbonate ions (HCO_3^- + CO_3^{-2}). The central diamond is a combination of the cation and anion fractions.

The groundwater nature is explained by the Piper trilinear diagram which is divided into 4 groups which in turn are further subdivided into 9 groups. Most of the groundwater samples of the study area fall in group 9 which indicates that none of the cation or anion pair exceeds 50% and Ca, Mg-Cl, SO_4 are the dominating facies (Fig 23).

VI. Wilcox' Diagram

Quality of water used for irrigation can also be assessed based on salinity as determined by electrical conductivity and soluble sodium percentage according to the method proposed by Wilcox (1948). Percent of sodium content in natural water is an imperative parameter to assess its suitability for agricultural use. A maximum of 60% sodium in ground water is allotted for agricultural purposes (Wilcox, 1948, 1967; USSL,1954). Sodium percentage can be defined in terms of epm of the common cations (Wilcox, 1948).

$$\%Na = \frac{(Na^+ + K^+)\ 100}{Ca^{++} + Mg^{++} + Na^+ + K^+}$$

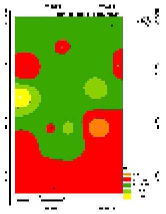
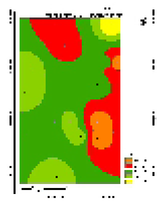
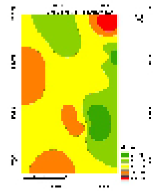
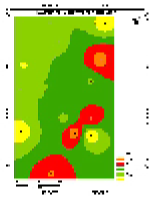
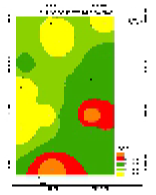
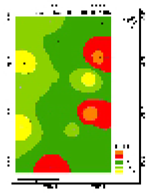
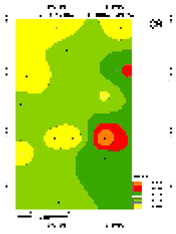
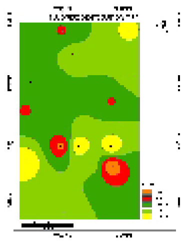
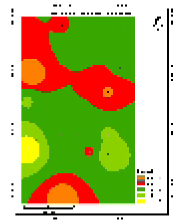
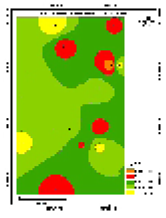
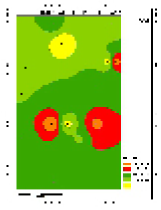
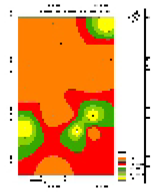
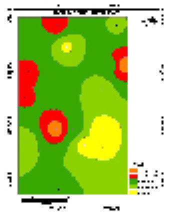
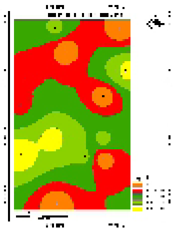
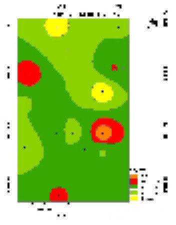
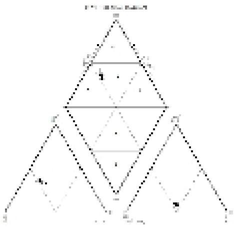
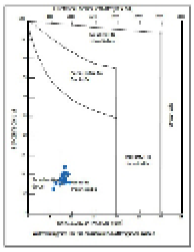
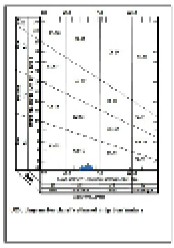
The concentration of cations is in epm. The chemical quality of water samples are studied from %Na versus EC on the Wilcox diagram (Fig.24). Out of 15 samples, 4 samples fall under excellent to good category and the remaining 11 samples fall under good to permissiblecategory (Table 4).

TABLE 4: WATER CLASSES FOR IRRIGATION ON THE BASIS OF %NA

Water Class for Irrigation	% of Na	No of Samples
Excellent to Good	< 20	4
Good to Permissible	20-40	11
Permissible to Doubtful	40-60	0
Doubtful to Unsuitable	60-80	0
Unsuitable	>80	0

VI. USSL Classification

Water used for irrigation can be related to salinity and sodium hazards. This sentence is given by "USSR" in 1954. This classification can be plotted by taking SAR values and EC to consideration (Fig.25).

SODIUM ADSORPTION RATIO: Sodium concentration in ground water is important since increase of sodium concentrations in water effect detritions of soil quality reducing permeability (Kelly, 1951 and Tijani, 1994). SAR is expressed as:

$$SAR= \frac{Na}{Sqrt\ (Ca+Mg)/2}$$

All the 15 water samples collected from the study area falls under C_2S_1 category which has medium salinity, low sodium water and are good for medium permeable soil (Table 5).

TABLE 5: USSL CLASSIFICATION FOR GROUND WATER

Category	No. of Samples	Water Quality
C1S1	0	Low salinity and lower alkali water
C2S1	15	Medium salinity and lower sodium water. Good for medium permeable soil
C3S1	0	Moderate to high salinity and less alkaline water
C2S2	0	Moderately alkaline and medium salinity. Good for medium permeable and coarse grained permeable soil.
C3S2	0	Moderate to high salinity and moderate alkaline.
C3S3	0	Highly alkaline and have moderate to high salinity.
C3S4	0	Highly alkaline and saline.

VII. Conclusion

The water samples collected from the area are subjected to chemical analysis. Check for the completeness of the analysis is carried out. All the components were converted into epm. Sum of the cation and anion were obtained and percentage of error has been calculated, it ranges between 1.9-3.9. It is compared with the TDS. All the samples show completeness of analysis. Spatial variation maps have been done using GIS. Hill Piper Trilinear Diagram represents that most of the groundwater samples of the study area fall in group 9 which indicates that none of the cation or anion pair exceeds 50%. Wilcox Diagram is plotted which shows that, Out of 15 samples, 4 samples fall under excellent to good category and the remaining 11 samples fall under good to permissible category. USSL Classification graph shows that, all the 15 water samples collected from the study area falls under C_2S_1 category which has medium salinity, low sodium water and are good for medium permeable soil. when compared with ISI and WHO, for all the 15 samples standards are recorded the range within the permissible limit.

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