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RESEARCH ARTICLE

WATER QUALITY ASSESSMENT OF GROUNDWATER SAMPLES IN BOBBILI REGION, ANDHRAPADESH, INDIA

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ABSTRACT

Water being an excellent solvent tends to dissolve the minerals in the geological system.The importance of the hydrochemical analysis underlies the fact that the chemistry of the ground water can directly be rated with the source of water, climate, and geology of the region. In this paper chemical analysis of the ground water has been carried out for Bobbili region in Andhra pradesh. There are eleven water quality variables (SO_4^{2-},Cl, Na^+, K^+, HCO_3^-, Mg^{2+}, Ca^{2+}, NO_3^-, TH, and pH),electrical Conductance and Total Dissolved Solids were selected for this analysis. In this paper water quality parameters were analyzed using statistical methodsand Water quality modeling software surfer, Aquachem and ArcGIS9.1 was used to analyze data set. The hydrochemical analysis of the water samples has shown that it is free from certain anomalies and the water is suitable for human and cattle consumption. However, the presence of certain degree of anions indicates that the ground water in the study area is facing stress which could change the quality of the water in the near future.

INTRODUCTION

Water quality analysis is one of the most important aspects in groundwater studies. Determination of physico chemical characteristics of water is essential for assessing the suitability of water for various purposes like drinking, domestic, industrial and irrigation. The groundwater quality may also vary with seasonal changes and is primarily governed by the extent and composition of dissolved solids. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices. A number of techniques and methods have been developed to interpret the chemical data. The physico-chemical contaminants that adversely affected the quality of ground water is likely to arise from a variety of sources, including land application of agricultural chemicals, infiltration of effluent from sewage treatment plants, municipal waste, ponds, etc. Groundwater is an important water resource in both urban and rural areas of vizianagaram but in the cities, pipe borne water is also available. Rural dwellers rely basically on hand-dug wells for potable water supply as the streams usually dry up in dry season. These resources are under threat from pollution either from human life style manifested by the low level of hygiene practiced in the developing nations.

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The neglect of rural areas in most developing countries in terms of basic infrastructures such as pipe-borne water and sanitation facilities, expose the villagers to a variety of health related problems such as water borne diseases. A number of techniques and methods have been developed to interpret the chemical data. For any area, a ground water quality map is important to evaluate the water safeness for drinking and irrigation purposes and also as a precautionary indication of potential environmental health problems. The main objective of the research work is to make a groundwater quality assessment using GIS, based on the available physico chemical data from 19 locations in the study area. The purposes of this assessment are to provide an overview of present groundwater quality to determine spatial distribution of groundwater quality parameters such as total dissolved solids, total hardness, calcium hardness, magnesium hardness, bicarbonates, sodium, potassium, nitrates, chlorides and sulphates to generate groundwater quality zone map for the study area. Though some discrete, hydro chemical data are available for the region, comprehensive seasonal variation of groundwater quality has never been studied so far. In this paper an attempt has been made to study the groundwater quality for irrigation and drinking.

MATERIALS AND METHODS

Study Area

The study area, between 18°37′ N and 18°55′ N latitudes and 83°29′E and 83°40′E longitudes (Figure 1) wide range of 80 kms around Bobbilimandal, vizianagaram district, Andhrapradesh. Irrigation in the district is done by surface water as well as ground water.

Methods of collection and analysis of water samples followed are essentially the same as given by Brown et al. (1983) and APHA (1985). Samples were collected in 0.5L capacity polythene bottles. Prior to the collection, bottles were thoroughly washed with diluted HNO_3 acid, and then with distilled water in the laboratory before filling bottles with samples. Each bottle was rinsed to avoid any possible contamination in bottling and every other precautionary measure was taken.

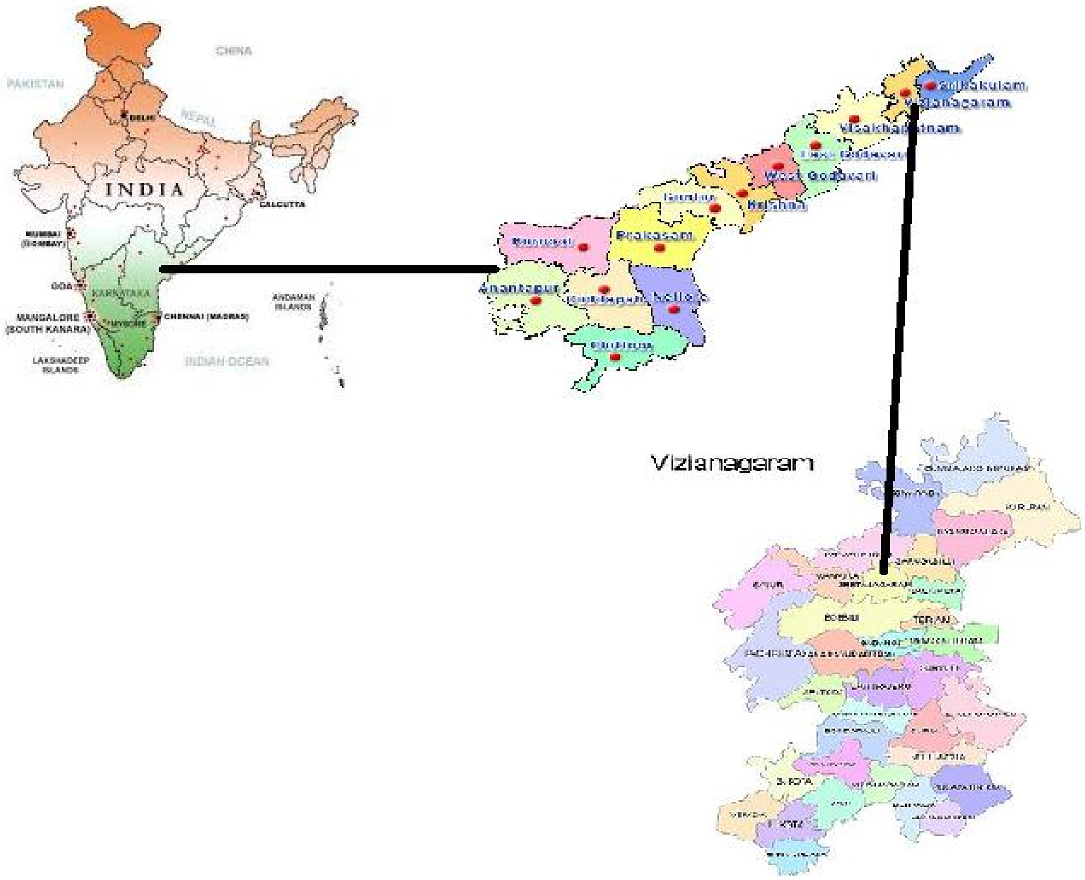

Figure 1. Shows the Study area map of selected samples

Materials and methodology

Groundwater samples were collected after well inventory survey from 19 representative wells during June 2014 (Figure 1). The samples were collected after 10 min of pumping and stored in Polyethylene bottles at 25°C. Immediately after sampling, pH and electrical conductivity were measured in the field. Total dissolved solids (TDS) were calculated from EC multiplied by 0.64. Nitrate (NO_3^-) by spectrophotometer, sulphate (SO_4^{2-}) analysed using Nephelometer, sodium (Na^+) and potassium (K^+) studied by flame photometer, bicarbonate (HCO_3^-), calcium (Ca^{2+}), and Total hardness (TH) were determined by volumetric methods. High purity analytical reagents were used throughout the study, and chemical standards (Merck, Germany) for each element were prepared separately.

Groundwater sampling

For evaluation of groundwater quality, 19 groundwater samples were collected whose depths varied from 4 to 12 m, located in the vicinities of Bobbili during June 2014 from bore wells (depths: 18–21 m) distributed throughout the area at 0.5 m below the water table, and were pumped for more than 5 minute.

WTW portable EC and pH meters measured hydro physical parameters, such as pH, DO, temp and EC on site. Sodium (Na^+) and potassium (K^+) were determined by flame photometer. Total hardness (TH), calcium (Ca^{2+}), bicarbonate HCO^{3-}, and chloride (Cl^-) were analyzed by volumetric methods. Magnesium (Mg^{2+}) was calculated from TH and Ca^{2+} contents. Sulphate $SO_4^{2-}$was estimated by Nephelometre, whereas nitrate NO_3^- was determined by Spectrophotometer. All concentrations are expressed in milligrams per litre (mg/L), except pH and EC. Analytical precision for measurements of cations and anions, indicated by the ionic balance error (IBE), was computed on the basis of ions expressed in me/l. The value of IBE was observed to be within a limit of ±5% (Mandel and Shiftan, 1980; Domenico and Schwartz, 1990).

RESULTS AND DISCUSSION

Electrical Conductance

Electrical conductance (EC) is the conductance of one centimeter cube of the substances and is represented in micromhos/cm at 25ºc.

Table 1. Analytical data of collected samples

S.No.	sample id	village	Long	Lat	EC	TDS	Salinity	pH	Temp	HCO_3^-	TH	Cl^-	Mg^{2+}	Ca^{2+}	Na^+	K^+	SO_4^{2-}	NO_3^-
1	ILA	Indt area	83.34048	18.50794	3240	2073.6	2.42	7.6	26.7	215.98	902.1	752.61	108.45	186.09	165.00	59.36	43.20	34.9
2	IMD	Itlamamidipalle	83.32773	18.50229	2230	1427.2	1.67	8.3	27.90	179.98	475.3	310.10	55.91	100.20	91.53	41.12	4.00	2.21
3	BVD	Bankuruvalasa	83.32835	18.51565	2060	1318.4	1.46	8.16	29.60	143.98	281.3	27.87	33.09	59.30	21.08	12.31	20.10	3.42
4	PVD	Panukuvalasa	83.35121	18.52079	819	524.16	0.50	8.5	29.70	30.00	38.8	34.84	3.40	10.22	42.14	23.87	40.20	1.51
5	PTD	Penta	83.36766	18.52055	208	133.12	0.14	7.5	29.40	59.99	92.15	31.36	13.76	14.31	15.06	9.02	29.40	0.47
6	BMH	Bheemavaram	83.37138	18.37138	320	204.8	0.20	6.5	32.80	107.99	77.6	23.48	5.62	22.49	20.16	14.19	6.90	5.18
7	RRB	Rangarayapuram	83.37376	18.53203	260	166.4	0.18	6.6	32.20	71.99	72.75	31.36	6.80	18.40	22.94	17.08	14.50	1.08
8	GVH	Gunnathotavalasa	83.35371	18.53491	256	163.84	0.04	7.7	28.10	53.99	101.85	10.45	7.89	28.63	20.96	16.7	23.00	12.4
9	VRH	Vijayarampuram	83.33504	18.53264	1020	652.8	0.14	7.8	28.10	107.99	145.5	101.05	8.94	44.99	33.49	18.24	29.80	6.38
10	PLD	Paltheru	83.39965	18.52118	1450	928	0.20	7.2	28.40	125.99	315.25	219.51	27.15	83.84	87.89	23.20	30.10	8.2
11	ALH	Alajangi	83.40584	18.5421	837	535.68	0.53	8.1	35.60	233.97	363.75	24.39	38.70	83.84	22.75	11.83	36.80	6.16
12	YVH	Yemlavalasa	83.39898	18.54616	614	392.96	0.09	6.7	41.20	197.98	155.2	31.36	14.75	38.85	58.77	22.49	32.40	11.67
13	NVH	Narayanappavalasa	83.31996	18.53758	360	230.4	0.27	8.4	27.00	161.98	140.65	13.94	11.29	38.85	76.06	12.00	77.70	4.31
14	KSH	Kasidoravalasa	83.30766	18.54208	1780	1139.2	1.21	7.3	31.00	221.98	184.3	248.00	11.16	57.26	50.38	23.41	30.80	17.1
15	GPH	Gollapeta	83.29667	18.54333	1800	1152	1.25	6.8	30.90	251.97	329.8	174.22	55.15	40.90	70.95	45.74	14.20	15
16	MPD	Mettavalasa	83.32693	18.55476	884	565.76	0.04	7.3	28.40	341.96	276.45	73.17	30.77	61.35	65.35	21.66	22.70	1.99
17	BBD	Bhubandavalasa	83.30895	18.55094	829	530.56	0.12	7.9	28.30	137.99	169.75	205.58	15.88	42.94	98.78	38.25	4.50	15.26
18	GSH	G seetharampuram	83.32834	18.53252	589	376.96	0.08	7.42	28.30	299.97	232.8	62.72	14.53	71.57	59.45	20.12	18.00	0.79
19	PRH	Paradi	83.30738	18.52372	412	263.68	0.27	8.3	30.80	119.99	169.75	52.26	22.89	30.67	11.46	4.06	7.20	2.19

Table 2:- Water Quality Classification Based on TDS Content byCarroll (1962)

TDS in ppm	Water Quality
0 -1000	Fresh water
1000 – 10, 000	Brackish water
10, 000- 100, 000	Salty water
> 100, 000	Brine

Table 3. Sodium percent water class

Sodium (%)	Water class	Samples
<20	Excellent	19
20-40	Good	-
40-60	Permissible	-
60-80	Doubtful	-
>80	Unsuitable	-

Table 4. Drinking Water Standards Recommended by World Health Organization (WHO, 1971), Public Health Examination (PHE) Committee of Govt. of India (1963) and Indian Council of Medical Research (ICMR, 1975) along with the maximum Concentration of Substances from the Water Samples of Study Area

Chemical Constituents (mg/L)	WHO Std.		PHE Std.		ICMR Std.		Maximum Concentration in the Study Area (mg/L)
	A	B	A	B	A	B	
Calcium	75	200	75	200	75	200	186
Magnesium	30	150	50	150	50	100	108
Chloride	200	600	250	1000	200	1000	752
Sulphate	200	400	250	400	200	400	77
TH	100	500	300	600	300	600	902
TDS	500	1500	500	1500	500	1500	2073

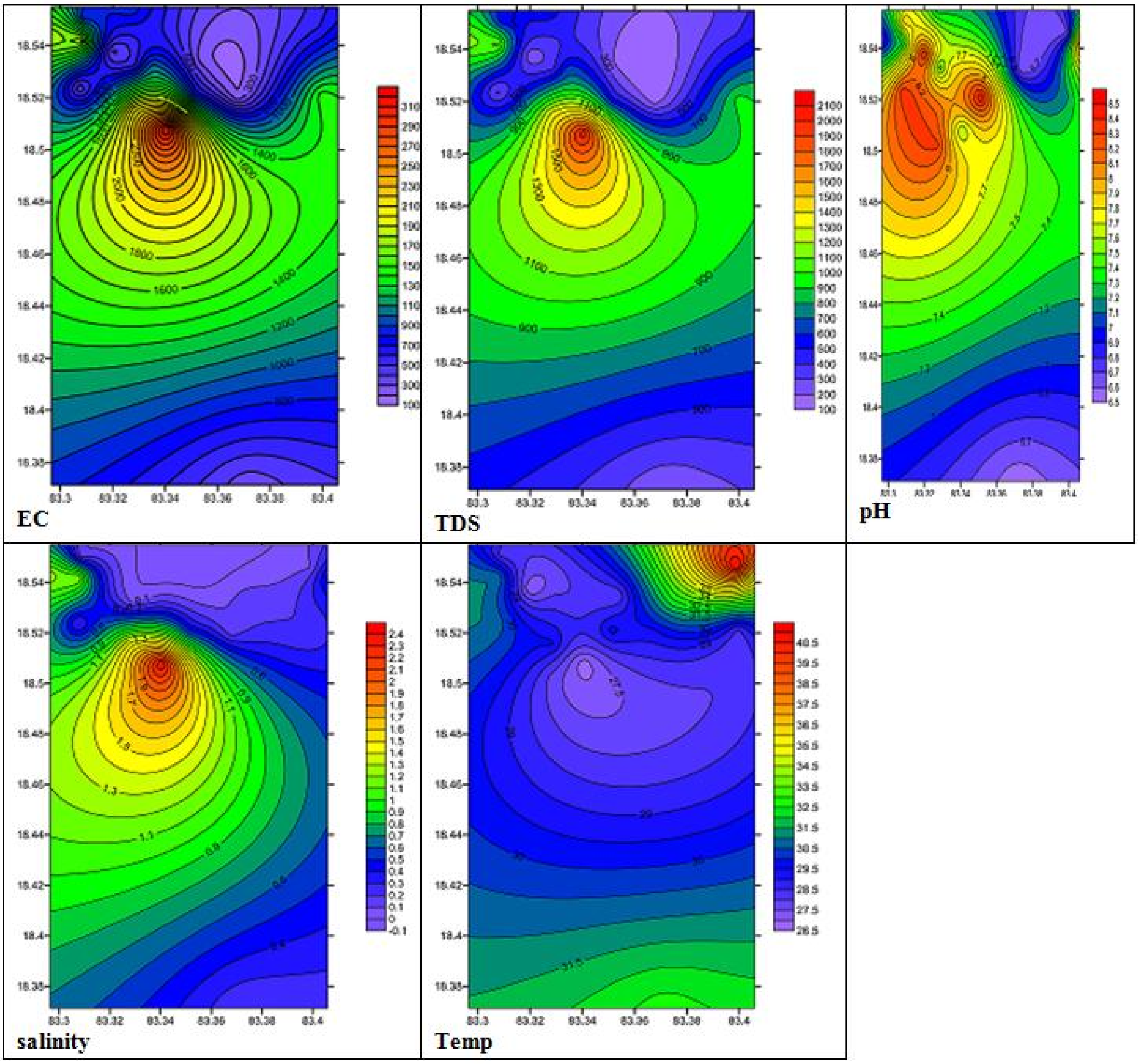

Figure 2. Shows distribution concentration of various physical parameters

The presence of ions in solution increases conductivity of water. The EC of water samples from the study area varies between 208 to 3240micromhos/cm.

Total Dissolved Solids (TDS)

TDS is defined as the residue of filtered water sample after evaporation. The bulk TDS include bicarbonates, sulphates and chloride of calcium, magnesium, sodium, potassium, silica, potassium chloride, nitrate and boron. According to Hem (1959) TDS was calculated using the relationship given below TDS (in ppm) = 0.64 * EC (in micromhos/cm).Analysis of water samples of the study area revealed that the presence of TDS varies between 133 to 2073 ppm. Among all, only industrial are as ample exceeds the limit due to polluted vicinity. Subsequently, four classes of water were proposed based on the procedures adopted from Carroll (1962) [7] and is given in Table 2 which confirms majority of samples belongs to fresh water category.

Hydrogen Ion Concentration (pH)

The pH of a solution is defined as the negative logarithmic of the ion concentration and is normally expressed in moles per liter at a given temperature.

pH of a solution can affect the toxicity of other elements and has very pronounced effect on many chemical reactions which are important to industry, irrigation and domestic water treatment. The pH value was determined in the field using a pH meter and the values vary between 6.5 to 8.5.

Chloride

Chlorides are important in detecting the contamination of ground water by waste water. The permissible limit of chloride in drinking water is 250 mg/L. The values of chloride observed in all samples were very low *i.e.* within the permissible limit except in ILA was well above the standard desirable limits prescribed by WHO (1984) due to natural processes such as the passage of water through natural salt formations in the earth orit may be an indication of pollution from industrial or domestic use. The range of Cl concentration is 10-752 mg/L.

Nitrate

Nitrate is a major problem in some shallow aquifers and is increasingly becoming a threat to groundwater supplies. There are numerous sources of nitrogen in groundwater systems.

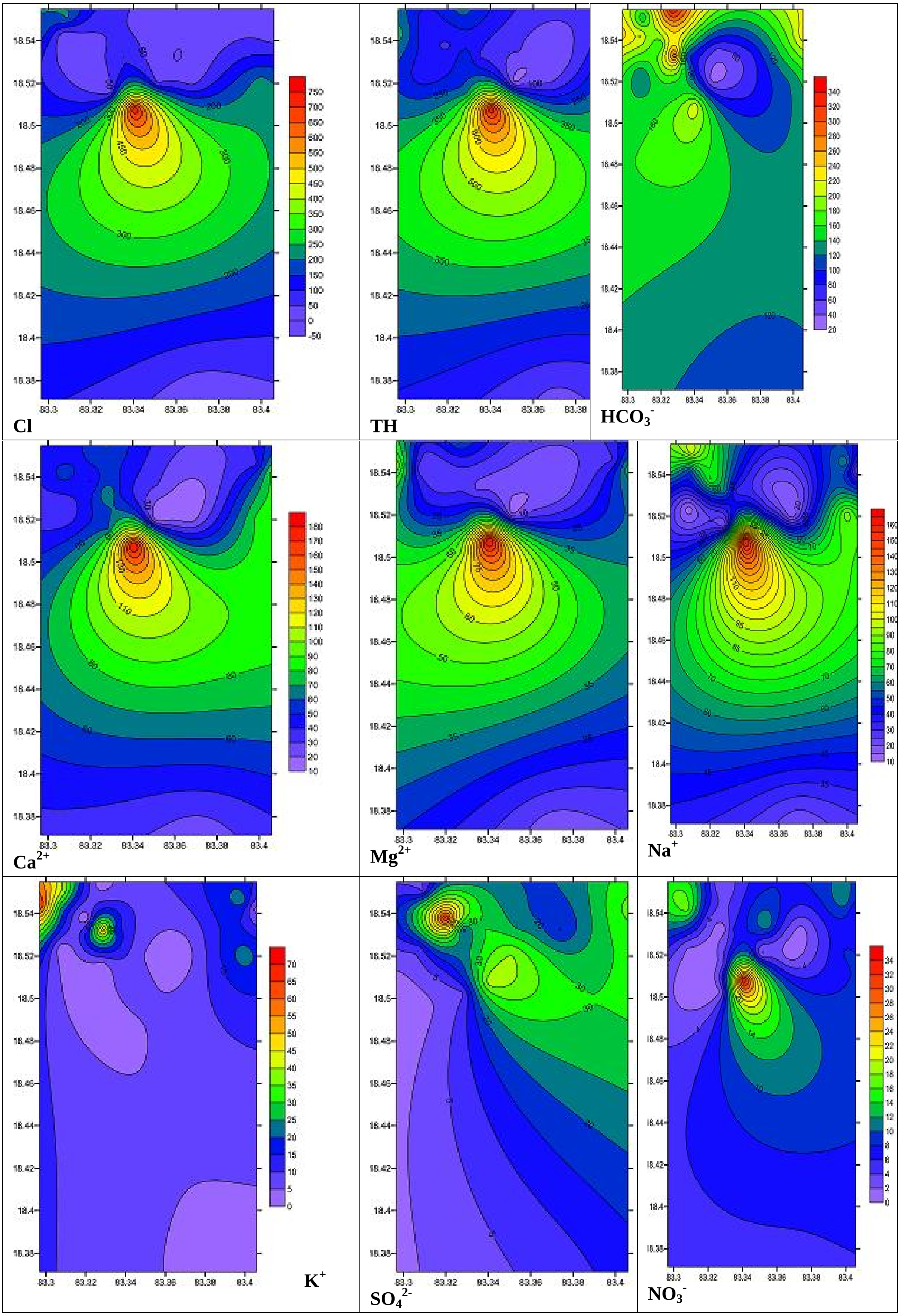

Figure 3. Shows distribution concentration of various chemical parameters

Most of them are strongly influenced by human activities. Nitrogen fertilizers are widely used in agricultural practice, organic nitrogen is present in number of waste products, notably sewage effluents, animal excrement and manure and municipal wastes. The nitrate concentration in groundwater samples is higher than 10 mg/l in 4 samples. The maximum value is 34.9 mg/l which is recorded in ILA due to the presence of industry.

Bicarbonate

Most bicarbonate ions in groundwater are derived from carbon dioxide in the atmosphere, carbon dioxide in the soil and dissolution of carbonate rocks. Bicarbonate is an ion that is common to all natural waters because all bicarbonates are water soluble. The array of bicarbonate from 30 to 342 mg/L with average of 161 mg/L.

Total hardness (TH)

ISI has specified the total hardness to be within 300 mg/L of $CaCO_3$. Regarding total hardness values were well within the limits. ILA has comparatively high TH value(902 mg/L) than PVD(39 mg/L).

Total dissolved solids (TDS)

The average value of TDS in the ground waters of selected area was 672 mg/L. ISI prescribed the desirable limit of TDS is 500 mg/L. The maximum permissible level is 2000mg/L observed in ILA. High TDS in ground water may be due to ground water pollution when waste waters from both residential and dyeing units are discharged into pits, ponds and lagoons enabling the waste migrate down to the water table 2**.**

Calcium

Calcium concentrations were found to vary from 10 to 186 mg/L. The upper limit of calcium concentration for drinking water is specified as 75 mg/L (ISI, 1983). The calcium hardness observed in all the 5 stations are well within the desirable limits with a minimum of 10mg/L in panukuvalasa to a maximum of 186 mg/L in ILA and IMD, PLD and ALH have exceeded the range.

Magnesium

Magnesium is an important constituent of basalt. It's solubility in water is around five times that of calcium. Calcium and Magnesium together cause the hardness of water. EDTA titration was used to determine the magnesium concentration in the samples. The range of magnesium varies from 3 to 108mg/L. All samples are within range of Mg limit except ILA.

Sulphate

The sulphate content in the atmosphere precipitation is only about 2 mg/L, but a wide range in sulphate content in ground water is made possible through reduction, precipitation, solution and concentration. The primary minerals ources of sulphate ions include evaporate minerals such as calcium, gypsum and sulphates of magnesium and Sodium. The sulphate concentrations in the water samples were determined by Nephelometer and results revealed that all analysed samples in permissible limit. The sulphate content in the samples varies between 4 ppm in IMD to 77 ppm for NVH with an average of 25 mg/L.

Sodium

Sodium is an important constituent for determining the quality of irrigation water. Sodium bearing minerals likealbite and other members of plagioclase feldspars, naphthalene and sodalite weather to release the primary soluble sodium products. Most sodium salts are readily soluble in water, but take no active part in chemical reactions. Sodium has wide variations in its concentration in ground water. The sodium content of the samples was determined by a flame photometer. Sodium content in the water samples varies between 11 to 165mg/L with an average of 54 mg/L except ILA.

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. The potassium concentration in the water was determined with the help of Flame photometer. Analysis of water samples in the study area indicates that potassium value varies between 4 to 59mg/L whereas ILA crossed the potassium acceptable limit.

Correlation analysis and cross-plots

To understand the relation between different ionic species, inter-elemental correlation was made. TDS was related to sodium (Na^+), magnesium (Mg^{2+}), chloride (Cl^-) and sulfate $SO_4{}^{2-}$ with a correlation coefficient of 0.929, 0.921, 0.966, and 0.936, respectively; and EC was related to these with r = 0.99, 0.976, 0.890, and 0.973, respectively. The high correlation implies that groundwater chemistry was mainly controlled by these ions. Sodium and magnesium were also strongly correlated with chloride and sulfate with r = 0.989 and 0.945; and 0.936 and 0.97, respectively.

Piper Trilinear Diagram

The Piper-Hill diagram (1953) is used to infer hydro-geochemical facies. These plots include two triangles, one for plotting cations and the other for plotting anions (figure 4). The cations and anion fields are combined to show a single point in a diamond-shaped field, from which inference is drawn on the basis of hydro-geochemical facies concept. These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than with other possible plotting methods. Chemical data of representative samples from the study area is presented by plotting them on a Piper-tri-linear diagram This diagram reveal the analogies, dissimilarities and different types of waters in the study area. The concept of hydrochemicalfacies was developed to understand and identify the water composition in different classes. Facies are recognizable parts of different characters belonging to any genetically related system. Hydrochemicalfacies are distinct zones that possess action and anion concentration categories. Because of each analysis is represented by a single point, water with very different total concentrations can have identical representations on this diagram. After plotting cations and anions of 19analyzed samples in the piper diagram, it can be observed that the plots mostly fall in sodium, potassium, bicarbonate, Magnesium and Chloride field.

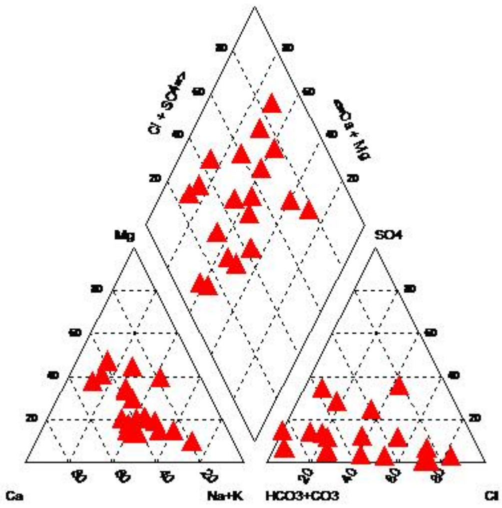

Figure 4. Shows the piper diagram for the various cations and anions composition of the water samples

Wilcox (1995) classified groundwater for irrigation purposes based on per cent sodium and Electrical conductivity. Eaton (1950) recommended the concentration of residual sodium carbonate to determine the suitability of water for irrigation purposes. The US Salinity Laboratory of the Department of Agriculture adopted certain techniques based on which the suitability of water for agriculture is explained. The sodium in irrigation waters is usually denoted as per cent sodium and can be determined using the following formula. Where the quantities of Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+} are expressed in mill equivalents per litre (meq/l). In waters having high concentration of bicarbonate, there is tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. As a result, the relative proportion of sodium in the water is increased in the form of sodium carbonate. RSC is calculated using the following equation. The classification of groundwater samples with respect to per cent sodium is shown in table 3 interprets that all samples are excellent class. The total dissolved solids content gives the salinity hazard of irrigation water. Presence of excessive sodium content in water makes it unsuitable for irrigation purposes. The figure 5 states that sodium hazard in irrigated water is expressed by determining the sodium adsorption ratio (SAR) as stated below

$$SAR = Na/ \mathrm{sqrt}((Ca + Mg)/2)$$

In which, the concentrations are expressed in mill equivalents per liter and function ‘sqrt’ is used for determination of square root. The sodium concentration in water was calculated and is expressed in terms of percentage of sodium and is given by

$$\%Na= ((Na + K)*100 / (Na + Ca + Mg + K))$$

Where, all ionic concentrations are expressed in milli equivalents per liter. Increase in percentage of sodium makes water unsuitable for irrigation purposes. The US Ionic Regional Salinity Laboratory has constructed a diagram for classifying irrigation water with reference to Sodium Adsorption ratio as an index for sodium hazards and EC as an index for salinity hazard.

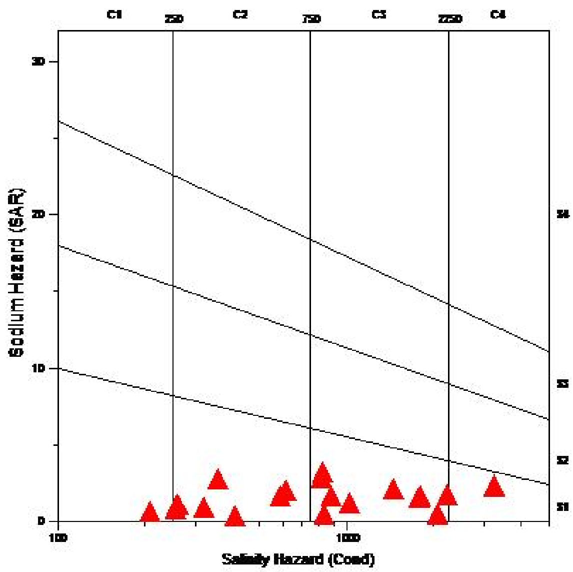

Figure 5. Shows the sodium hazard of the water samples

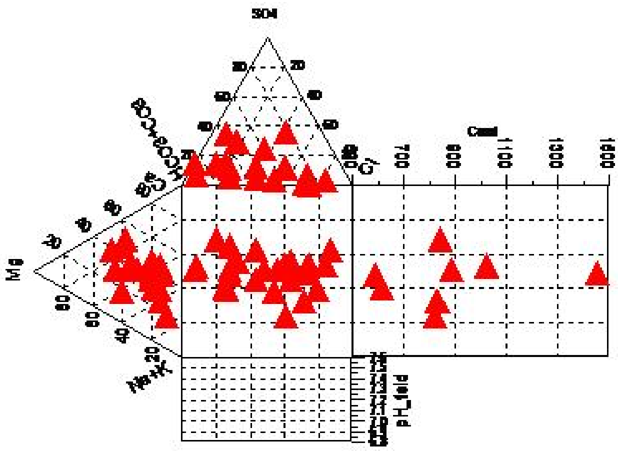

Figure 6. Shows the Durov diagram of the water samples.

Durov Diagram

Durov, (1948) introduced another diagram which provides more information on the hydrochemicalfacies by helping to identify the water types and it can display some possible geochemical processes that could help in understanding quality of groundwater and its evaluation. The diagram is a composite plot consisting of 2 ternary diagrams where the cations of interest are plotted against the anions of interest sides form a binary plot of total cationvs. total anion concentrations expanded version includes electrical conductivity (µS/cm) and pH data added to the sides of the binary plot to allow further comparisons. The Durov Diagram for the major cations and anions was plotted using Aquachem software as given in Figure 6. The Duorv plot for groundwater samples indicates that the pH part of the plot reveals that groundwater in study area is alkaline which is preferred for drinking and irrigation. The electrical conductivity of most of groundwater samples lies in the range of drinking water standards adapted in Bobbili area, Andhra pradesh.

Conclusion

The analysis of the water quality parameters of groundwater from 19 different stations inbobbili in the vizianagaram city shows that the pH, chloride, total hardness, calcium and values are well within the permissible limits. The TDS of industrial area was well above the desirable limit and the average of alkalinity has exceeded the desirable limits which are due to improper drainage system of the dyeing units. Surfer and aquachem results revealed that all samples are within the permissible limits except ILA. In conclusion from the results of the present study it may be said that the groundwater of bobbili is though fit for domestic and drinking purpose need treatments to minimize the contamination especially the alkalinity. The values of correlation coefficients and their significance levels will help in selecting the proper treatments to minimize the contaminations of groundwater of bobbili. There is an increasing awareness among the people to maintain the groundwater at their highest quality and purity levels and the present study may prove to be useful in achieving the same.

REFERENCES

APHA. Standard methods for the examination of water and wastewater, 19th ed. American Public Health Association 1995

APHA. Standard methods for the examination of water and wastewater, 17th Edition; Prepared and published jointly by USA: American Public Health Association 1989.

Piper AM. A graphic procedure in the geochemical interpretation of water analyses. Trans Amer Geophysics 1944; 25: 914- 23.

ICMR. Manual of standards of quality for drinking water supplies.Indian Council Med Res 1979(44): 21-27.

Sathish Mohan Botsa, PunnanaRamu Naidu, Gadisatyanarayana, ManjeeraDevaraju and Pondala Seetharamhydrochemical analysis of ground water samples of coastal region of srikakulam district, andhrapradesh, india Int. J. Adv. Res. 4(12), 1166-1173.

VikasTomar, Kamra. S.K, Kumar. S, Kumar Ajay, Khajuria Vishal, International Journal of Environmental SciencesVolume *3 No.2, 2012*

Zhang B, Song X F, Zhang Y H, Han D M, Tang C Y, Yu Y L and Ma Y 2012 Hydrochemical characteristics and water quality assessment of surface water and groundwater in Songnen plain, Northeast China; *Water Res.* 462737–2748.

Leung C M and Jiao J J 2006 Heavy metal and trace element distributions in groundwater in natural slopes and highly urbanized spaces in mid-levels area, Hong Kong; *WaterRes.* 40 753–767.

(Brown, Skougstand, & Fishman, 1970)

Manjare, S.A., Vhanalakar, S.A. and Muley, D.A. (2010) Analysis of water quality using physico-chemical parameters Tamdalge tank in Kolhapur district, Maharashtra. International journal of advanced biotechnology and research. 1, 115-119

Bheshdadia, B.M., Chauhan, M. B. and Patel, P.K. (2012) Physicochemical analysis of underground drinking water in Morbi-MaliaTerritor. Current world env. 7, 169-173.

Shimaa M. Ghoraba1 & A.D. Khan2,(2013)hydrochemistry and groundwater quality assessment in balochistan province, pakistan, IJRAS 2 185-199.

Wilcox, L.V.: “Classification and Use of irrigation Waters”. washinngton, United States Department of Agriculture, Circ.969 (1955).

WHO : “Gide Lines for Drinking Water Quality ”, WHO Labrary Cataloguing-in-Publication Data, fourth Edition, Vol.1, Geneve (2011).

Rajappa, K., Gallagher, M., & Miranda, R. (2011). Emotion dysregulation and vulnerability to suicidal ideation and attempts. Cognitive Therapy and Research, 36, 833–839.

Sarma, V.V.J., Prasad, N.V.B.S.S., Prasad, R., 1982. The geochemistry of groundwater along Visakhatnam–Bhimilipatnam coast with regard to their utility in drinking, domestic and irrigation purposes. J. Explor. Geophys. 2 (4), 37–52.

Sukhija, B.S., Varma, V.N., Nagabhushanam, P., Reddy, D.V., 1996. Differentiation of paleomarine and modern seawater intruded salinities in coastal groundwaters(of Karaikal and Tanjavur, India) based on inorganic chemistry, organicbiomarker fingerprints and radiocarbon dating. J. Hydrol. 174, 173–201.

Mondal, N.C., Singh, V.P., Singh, V.S., Saxena, V.K. 2010. Determining the interaction between groundwater and saline water throughgroundwater major ions chemistry, Journal of Hydrology 388 100–111

Guanxing Huang, Zongyu Chenand Jichao Sun (2014) Water quality assessment and hydrochemicalcharacteristics of groundwater on the aspect of metals in an old town, Foshan, south China, *J. Earth Syst. Sci.* 123, No. 1, 91–100

Leung C M and Jiao J J 2006 Heavy metal and trace element distributions in groundwater in natural slopes and highly urbanized spaces in mid-levels area, Hong Kong; *WaterRes.* 40 753–767.

G¨uler C, Thyne G D, McCray J E and Turner A K 2002 Evaluation of graphical and multivariate statistical methods for classification of water chemistry data; *Hydrogeol. J.* 10 455–474.

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