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Assessment of Ground Water Quality of Bidar City and its Industrial Area for Drinking and Irrigation Purpose: A Geo-chemical Analysis

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ABSTRACT
The quality of groundwater of any area is of great importance for human beings and irrigation. In order to evaluate the problems of pollution hazards of groundwater and to ascertain its suitability for drinking and agricultural purpose in Bidar City & its industrial area, Karnataka State, the data relating to groundwater chemical quality are analyzed from 35 wards covering the whole city and its industrial area. The available data was analyzed and compared with standards laid down by BIS 10500:1991. The analysis showed that in general, the quality of the groundwater is suitable for drinking purposes and also suitable for irrigation purposes. Geo–chemical analysis through Piper diagram and US Salinity Graphs showed that water samples are primary saline secondary alkaline groundwater
Keywords: Groundwater, Water quality standards, Water quality characteristics, Piper Diagram, U S Salinity gaph.

INTRODUCTION

Rapid urbanization, especially in developing countries like India, has affected the availability and quality of groundwater due to its overexploitation and improper waste disposal, especially in urban areas. According to WHO organization, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored back easily and to device ways and means to protect it [1, 3].

The quality of groundwater of any area is of great importance for human beings and irrigation. All the ground waters irrespective of their source of origin contain mineral salts and their chemical properties. The kind and concentration of these constituents depend upon various geological and physical factors. Since most of these factors are varying from place to place, the groundwater of any region are characterized by marked difference in their chemical properties. Since the quality of groundwater is directly or indirectly depends on its related use, there is always a need to classify the ground waters of an area on a regional basis. In recent times the environment activists of this area, especially ground water of Bidar city have often demonstrated against the excessive pollution. The Karnataka Pollution Control Board has taken some measures to contain pollution of the city water and nearby river water [11]. The objective of the present work is to discuss the suitability of groundwater for human consumption and for irrigation purpose based on computed groundwater characteristics, quality assessment through geo–chemical analysis by Piper Diagram and by US Salinity Graphs.

MATERIALS AND METHODS

The study area Bidar City, the head quarters of the Bidar district of Karnataka State, India, is located in the northern most part of the state of Karnataka on Deccan plateau (Figure No. 1). The city including its industrial area is divided into 35 wards. Bidar is situated at a distance of 669 Kms. from the state capital Bangalore and at a distance of 141 Kms from Hyderabad. Bidar City and the ancient monuments that exist today belong to the period of Bahumani Kings in the fifteenth century. The important monumental works in Bidar are, the Kings Fort with the old palace and other ancient monuments inside it, Madarasa Mohammad Gawan (Oldest International University), Tombs of Barid Shahi Kings, Dargah of Hazarath Khaja –Abdul Fiaz, Tomb of Ali Barid and Tomb of Hazarath Ziauddin Sahib.

Bidar can be located at 17°35’ north latitude and 77°32’ east longitude and its elevation is about 664 m above the mean sea level. The climate of Bidar and its environs is reported to be pleasant and is relatively cooler when compared to the temperatures in the neighboring districts of Karnataka. The average annual rainfall as recorded in the previous years is 916.508 mm and 919.630 mm, the monsoon period is over four months i.e. between June to September. The highest recorded during the above period is 925.05 mm during July month. The

average maximum temperature of 43° C is recorded during the period 1963-1979 is in the month of May. The maximum temperature however varies from 39° C to 43° C during the month of February to June and falls to 18° C during November month. The mean annual maximum humidity observed in the morning was 62.72 per cent and the minimum was observed in the evening was 43.7 per cent. Humidity will be least during the month of May. During summer the predominant wind direction is westerly and during the monsoon seasons wind blows in Southwesterly directions. During the winter seasons, the predominant wind direction is Southeasterly.

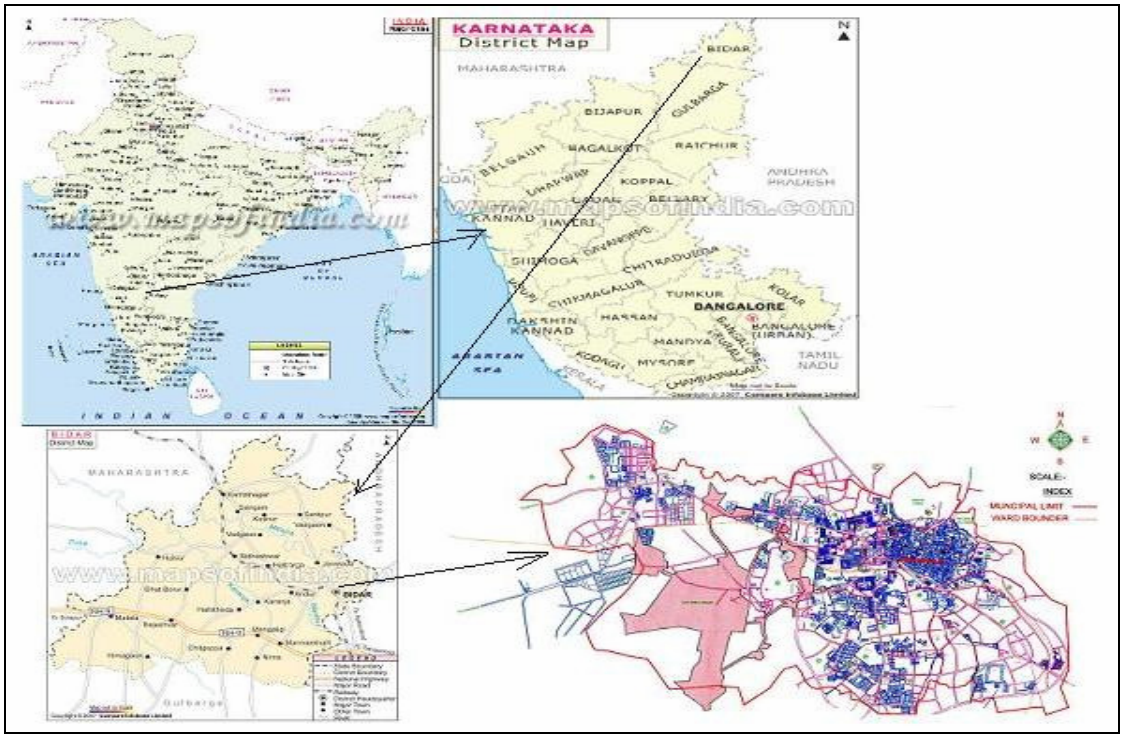

Fig.-1a: Location of Bidar City

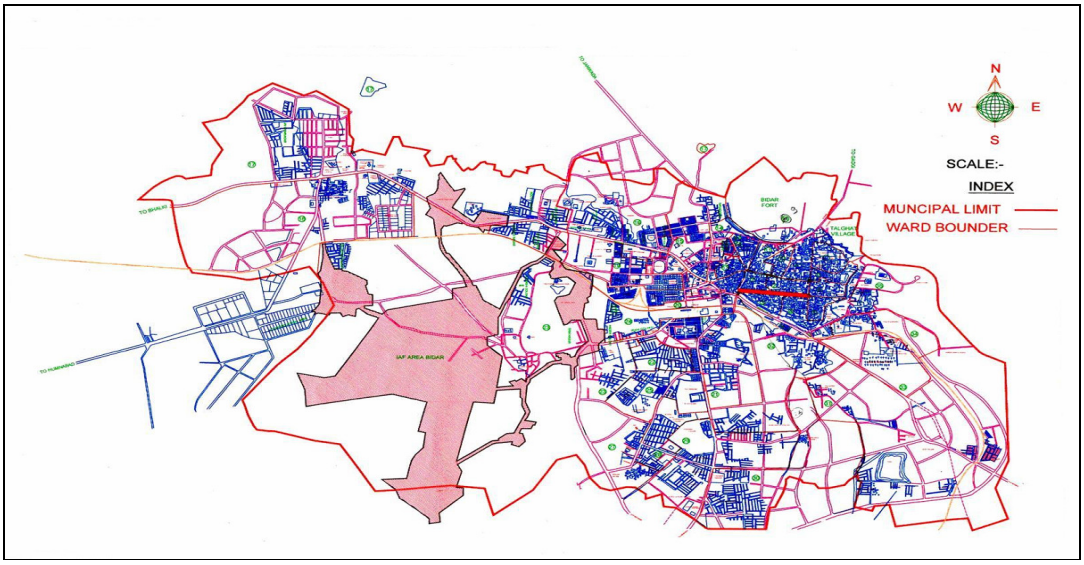

Fig.-1b: Bidar City Map

Bidar city is on the plateau being almost on its northern edge, which gives a picturesque view of the low-lying lands on the North and East. The plateau is of irregular shape, land stretching about 35.4 Km in length and 19.3 Km in width. The plateau consists of red laterite rocky crust, of a depth varying from 30.5 m to 152.4 m supported on impervious trap base. This has resulted in springs at the cleavages between trap and laterite rocks. Such water springs can be observed in Bidar at Gurunanak Zheera, Narasimha Zheera, Papanasha Shiva Temple and a few other places. The lands in Bidar and its environs drains into Manjira River (which flows in the region) is a tributary of Godavari River. The major soil types are, Red laterite soil, Black cotton soil and a combination of the above two types. The commonly used building materials (laterite stones) can be easily cut from laterite soil. Once they are cut and exposed to the atmosphere, it gets harder. Some parts of the district have black cotton soil, which is good for agricultural purposes. All reagents were analytical grade and solutions were made of distilled water. Various water quality parameters such as alkalinity, hardness, BOD, COD etc., were determined using standard analytical methods. The instruments used were calibrated before use for observing readings. The repeated measurements were made to ensure precision and accuracy of results [11].

Samples were collected from all the 35 wards as per standard procedural method for the physicochemical analysis of 17 parameters [4], it is revealed that all the parameters studied under the area are within the prescribed limits [5, 6]

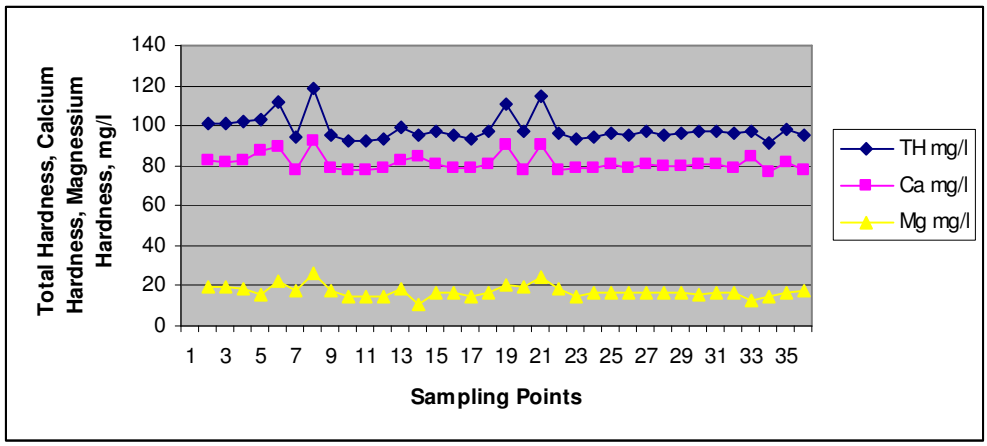

Fig.- 2: TH - Total Hardness, Ca - Calcium Hardness and Mg - Magnesium Hardness variations during the study period

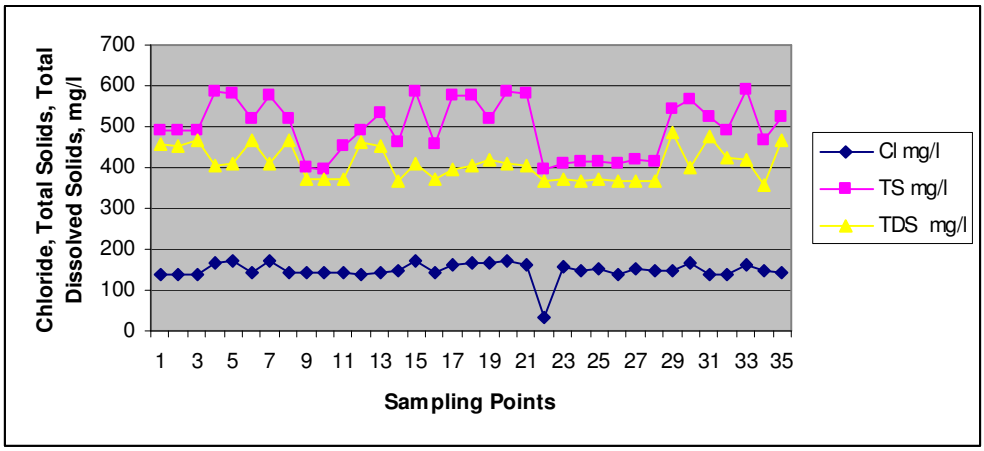

Fig.-3: Cl - Chloride, TS - Total Solids, and TDS - Total Dissolved Solids variations during the study period

RESULTS AND DISCUSSIONS

In this chapter for the purpose of revealing the water quality of 35 bore wells of 35 wards covering the study area have been established by determining the physical and chemical characteristics as per standard methods [4]. These parameters have been listed systematically and represented in table-2. The physical characteristics of the ground

water under the study area are known by the parameters viz., pH, total dissolved solids and total solids [10]. The chemical characteristics of the ground water under the study area are known by the parameters viz., total hardness, calcium hardness, magnesium hardness, iron, fluoride, nitrate, chloride, sulfate, sodium, potassium, alkalinity, manganese, zinc, and dissolved oxygen [10]. Total Hardness, Calcium Hardness & Magnesium Hardness variations during the study period is presented in Figure No. 2. Chloride, TS & TDS variations during the study period are presented in Figure No. 3. Iron, Fluoride & Manganese variations during the study period are presented in Figure No. 4. Sulfate, Sodium & Potassium variations during the study period are presented in Figure No. 5. Zinc, pH & DO variations during the study period are presented in Figure No. 6. Alkalinity & Nitrate variations during the study period are presented in Figure No. 7.The physicochemical analysis of the ground water and the percent compliance with the Indian Standards and WHO are summarized in table 1 [7].

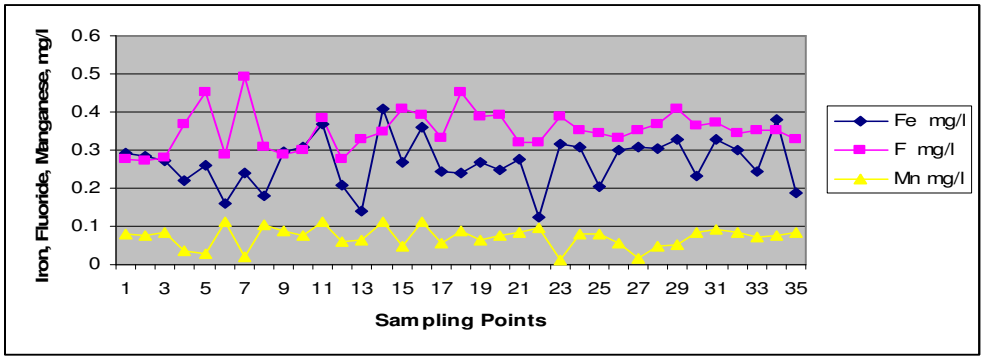

Fig.- 4: Fe - Iron, F - Fluoride, and Mn - Manganese variations during the study period

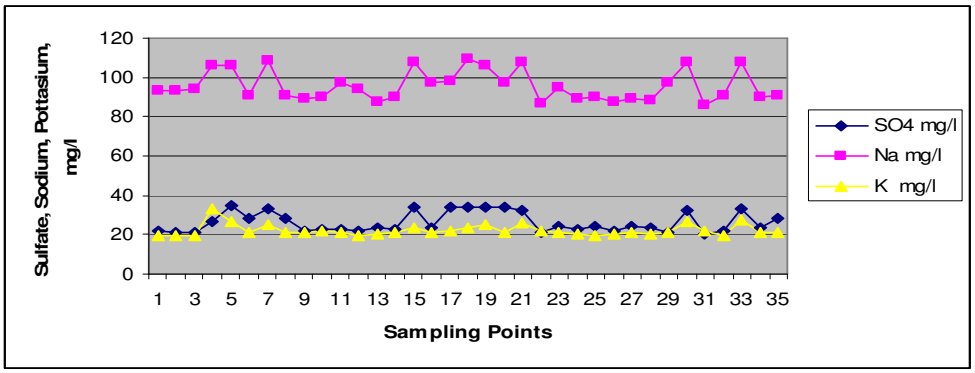

Fig.-5: SO_4 - Sulfate, Na - Sodium, and K - Potassium variations during the study period

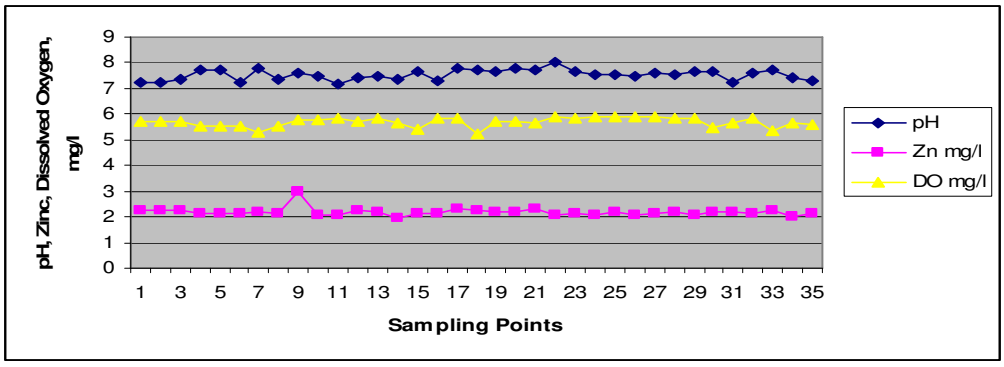

Fig.- 6: pH – Hydrogen Ion Concentration, Zn - Zinc, and DO – Dissolved Oxygen variations during the study period

Analysis of data for drinking purpose [7]

The water should be free from any risk and is suitable for drinking purposes. The water from all the wards after the analysis revealed that there is less pollution, except the iron parameter, which is little higher at few places. This might be due to the laterite soil prevailing in the region. Since laterite is rich in iron content, groundwater might have acquired little iron. This is evident from the table 1 comparing ground water quality with Indian Standards as well as with the WHO Standards.

Analysis of data for irrigation purpose [8, 9]

Generally the total dissolved solids, sodium content and sodium absorption ratio (SAR) values indicate the suitability of water for drinking and irrigation purpose. The criteria for classification of irrigation water as recommended by the United States Salinity Laboratory, Department of Agriculture (figures 8A & 8B) based on the TDS and SAR values. The limits of which have been indicated in table 3 & 4 given below.

SAR Value reported in the Table-4 is expressed as follows:

$$SAR = \frac{\text{Sodium}}{\left\{\left(\text{Calcium}^{++} + \text{Magnesium}^{++}\right)/2\right\}^{1/2}}$$

Where the concentrations (mg/l) of the constituents are expressed in milliequivalent per litre (epm).

The calculated values are given in table 6. In order to check the suitability of the groundwater for irrigation purpose the chemical data is presented on the sodium (alkali) hazard versus salinity hazard diagram (Fig. 8a & 8b) by the U.S. Salinity Laboratory Staff. On the basis of rating or irrigation water falling in various groups is given in table 5.

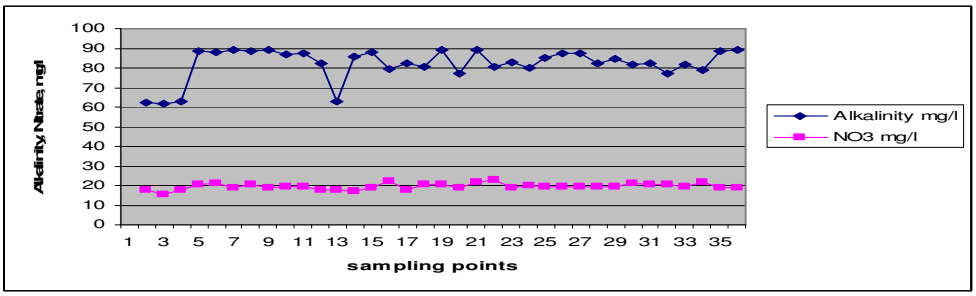

Fig.-7: Alkalinity and NO_3 - Nitrate, variations during the study period

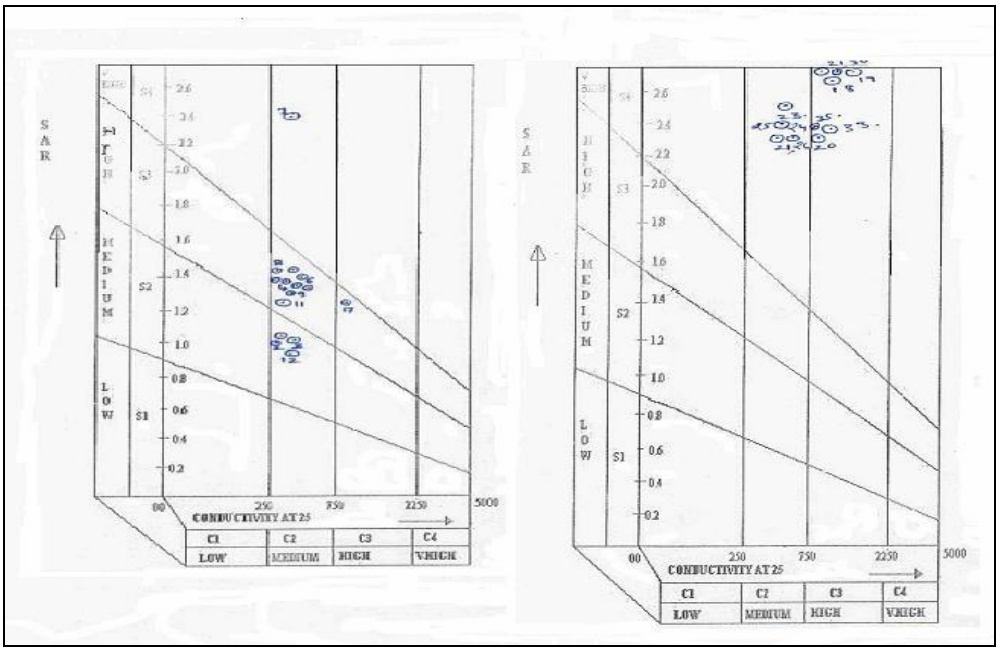

Fig.-8a: US Salinity diagram for Ward Nos. 1 – 18.

Fig.- 8b: US Salinity diagram for Ward Nos. 19 – 35.

Geo-chemical Analysis [8, 9]

Further results of chemical quality analysis of these waters have been plotted in a trilinear diagram, as recommended by Piper (1944). In this diagram only the relative proportions of principal cations and anions in terms of percentage EPM (equivalent per millions) have been plotted, as shown in figure 9a & 9b. The diamond shaped field in this diagram has been divided horizontally into two equal triangles. In this figure the water samples plots which fall in the lower half are termed as primary saline secondary alkaline and secondary saline water. Numerous graphical methods have been devised to facilitate the interpretation and presentation of chemical analysis. Since water is an excellent solvent, ground water will contain substances in solution in many areas that make the water unusable for one purpose or another. The chemical quality of water is also a valuable tool in water investigations, apart from its importance in the exploration of water. For example, differences in the chemical quality of water from one place to another in an area may reflect differences in the mineral composition of the aquifer, or the existence of geologic structures such as faults, which affect the movement of the water.

Example: For Sampling Point No. 1(Ward No. 1)

The above sample of water contains 83.1 mg/*l* of Calcium (Ca).
Atomic weight of Ca: 40.08
Ionic charge (volume): 2
Combining weight: 40.08/2 = 20.04
Eq/L of Ca = 83.1/20.04 = 4.15
Thus Eq/L of Na = 4.07 and Eq/L of Mg = 1.6

S.A.R Calculation:

$$\textbf{S.A.R.} = \frac{\text{Sodium}}{\left\{\left(\text{Calcium}^{++} + \text{Magnesium}^{++}\right)/2\right\}^{1/2}} = 4.07/\left[(4.15 + 1.6)/2\right]^{1/2} = 2.4$$

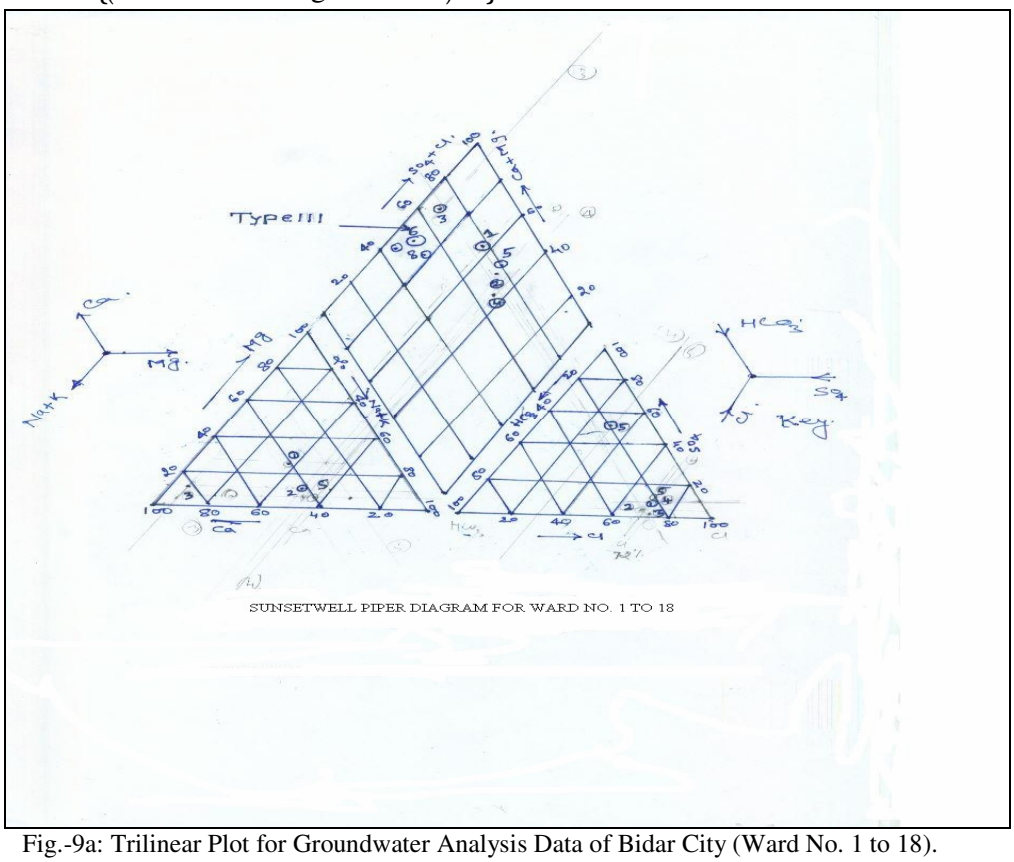

Fig.-9a: Trilinear Plot for Groundwater Analysis Data of Bidar City (Ward No. 1 to 18).

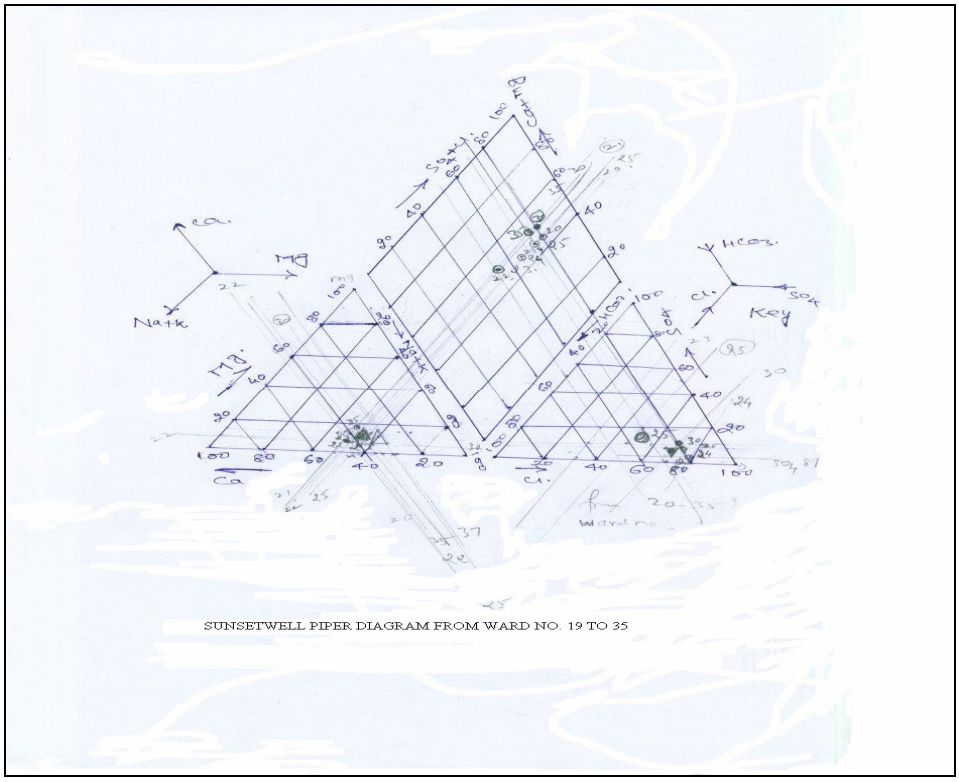

Fig.- 9b: Trilinear Plot for Groundwater Analysis Data of Bidar City (Ward No. 19 to 35).

Table 1: Comparison of groundwater quality with drinking water standards, Indian and WHO.

Parameters	Indian Standard	Percent Compliance	WHO Standard	Percent Compliance
pH	6.5 – 8.5	100	7.0 – 8.0	99
Total hardness, mg/l	300	100	100	98
Calcium, mg/l	75	0	75	0
Magnesium, mg/l	30	100	30	100
Chloride, mg/l	250	100	250	100
Total dissolved solids, mg/l	500	100	1000	100
Iron, mg/l	0.3	83	0.1	11.5
Fluoride, mg/l	1.0	100	1.0	100
Nitrate, mg/l	45	100	50	100
Sulfate, mg/l	200	100	250	100
Sodium, mg/l	--	--	200	100
Potassium, mg/l	--	--	--	--
Alkalinity, mg/l	200	100	--	100
Manganese, mg/l	30	100	0.05	100
Zinc, mg/l	5	100	5	100

Table- 3

S.No.	Water Class	TDS (mg/*l*)
1.	Excellent	Less than 160
2.	Good	160 – 480
3.	Permissible	480 – 1280
4.	Doubtful	1280 – 1600
5.	Unsuitable	More than 1600

Table-4

S. o.	Water Class	S.A.R. Value
1.	Excellent	Less than 10
2.	Good	10 – 18
3.	Fair	18 – 26
4.	Poor	More than 26

Table-5

Salinity groups	Quality for irrigation purposes
$C_1 S_1$, $C_2 S_1$	Good
C_1S_2, C_2S_2, C_3S_1, C_3S_2	Moderate
All other groups	Bad

Table-6: Conversion of milligrams/litre to milliequivalent/litre*

Ward Nos.	Ca as in epm	Mg as in epm	Na as in epm	SAR	Cl as in epm	K as in epm	SO4 as in epm	Alkalinity as in epm (HCO3)
1	4.15	1.60	4.07	2.403	3.8925	0.5013	0.4476	1.0227
2	4.10	1.59	4.06	2.407	3.8897	0.4911	0.4435	1.0145
3	4.12	1.56	4.09	2.429	3.8840	0.4987	0.4414	1.0309
4	4.36	1.30	4.64	2.756	4.7048	0.8440	0.5621	1.4521
5	4.45	1.83	4.64	2.617	4.8176	0.6906	0.7245	1.4422
6	3.89	1.46	3.94	2.407	4.0081	0.5371	0.5851	1.4570
7	4.62	2.12	4.73	2.577	4.7951	0.6343	0.6933	1.4537
8	3.91	1.47	3.95	2.411	4.0166	0.5448	0.5934	1.4603
9	3.88	1.17	3.89	2.447	4.0222	0.5422	0.4560	1.4226
10	3.89	1.19	3.93	2.467	4.0138	0.5678	0.4643	1.4373
11	3.94	1.19	4.22	2.634	4.0476	0.5422	0.4789	1.3472
12	4.15	1.55	4.08	2.418	3.8868	0.4987	0.4518	1.0292
13	4.23	0.89	3.80	2.376	4.0645	0.5269	0.4893	1.4013
14	4.04	1.35	3.91	2.384	4.1068	0.5371	0.4809	1.4455
15	3.92	1.37	4.69	2.884	4.7725	0.6113	0.7016	1.3046
16	3.93	1.22	4.23	2.639	4.0504	0.5473	0.4893	1.3521
17	4.04	1.37	4.26	2.592	4.5243	0.5627	0.7037	1.3177
18	4.52	1.70	4.76	2.699	4.7500	0.5934	0.7016	1.4586
19	3.86	1.56	4.61	2.799	4.7274	0.6445	0.7016	1.2652
20	4.52	1.99	4.22	2.338	4.7725	0.5320	0.7037	1.4619
21	3.88	1.53	4.70	2.856	4.5243	0.6548	0.6787	1.3210
22	3.95	1.16	3.79	2.370	0.9731	0.5499	0.4395	1.3537
23	3.94	1.38	4.13	2.534	4.4256	0.5422	0.5122	1.3144
24	4.02	1.35	3.88	2.368	4.1181	0.5192	0.4789	1.3996
25	3.93	1.34	3.91	2.406	4.2592	0.5039	0.5101	1.4291
26	4.03	1.33	3.79	2.316	3.9207	0.5090	0.4580	1.4324
27	4.00	1.32	3.88	2.379	4.3438	0.5346	0.5059	1.3505
28	3.98	1.34	3.83	2.349	4.2027	0.5269	0.4893	1.3882
29	4.03	1.32	4.22	2.580	4.2056	0.5422	0.4372	1.3439
30	4.03	1.35	4.69	2.859	4.7274	0.6906	0.6767	1.3505
31	3.94	1.39	3.74	2.292	3.9517	0.5499	0.4247	1.2685
32	4.23	1.05	3.97	2.440	3.9094	0.4962	0.4476	1.3439
33	3.83	1.18	4.71	2.971	4.5017	0.7008	0.6975	1.2882
34	4.07	1.37	3.93	2.381	4.1125	0.5422	0.4893	1.4504
35	3.90	1.45	3.95	2.412	4.0194	0.5473	0.5892	1.4603

*mg/l values may be converted to milliequivalents/l, by multiplying the mg/l by the reciprocal of the combining weight of the appropriate ions.

Table-2: Characteristics of ground water

Sampling points No. (Ward no.)	pH	TH *mg/l*	Ca *mg/l*	Mg *mg/l*	Cl *mg/l*	TDS *mg/l*	Fe *mg/l*	F *mg/l*	NO_3 *mg/l*	SO_4 *mg/l*	Na *mg/l*	K *mg/l*	Alkalinity *mg/l*	Mn *mg/l*	Zn *mg/l*	DO *mg/l*	TS *mg/l*
1	7.23	101.4	83.1	19.4	138.0	458.3	0.293	0.278	17.7	21.5	93.6	19.6	62.4	0.08	2.25	5.73	492.3
2	7.24	101.4	82.1	19.3	137.9	453.1	0.283	0.274	15.4	21.3	93.3	19.2	61.9	0.078	2.24	5.72	492.2
3	7.34	101.9	82.6	18.9	137.7	466.2	0.273	0.280	17.9	21.2	94.1	19.5	62.9	0.085	2.22	5.71	492.4
4	7.72	103.2	87.4	15.8	166.8	405.0	0.220	0.368	20.8	27.0	106.6	33.0	88.6	0.035	2.1	5.52	587.3
5	7.74	111.4	89.2	22.2	170.8	410.8	0.260	0.454	21.4	34.8	106.6	27.0	88.0	0.028	2.15	5.55	581.2
6	7.24	94.7	78.0	17.7	142.1	465.8	0.160	0.290	18.6	28.1	90.5	21.0	88.9	0.112	2.11	5.56	519
7	7.78	118.4	92.6	25.8	170.0	411.6	0.240	0.492	20.8	33.3	108.8	24.8	88.7	0.022	2.2	5.32	578.4
8	7.36	94.9	78.3	17.9	142.4	464.9	0.180	0.310	18.9	28.5	90.9	21.3	89.1	0.103	2.15	5.54	521
9	7.60	92.2	77.8	14.2	142.6	373.0	0.298	0.290	19.4	21.9	89.4	21.2	86.8	0.089	2.95	5.78	399
10	7.50	92.6	77.9	14.5	142.3	373.5	0.308	0.300	19.6	22.3	90.4	22.2	87.7	0.077	2.05	5.76	394
11	7.20	93.6	78.9	14.5	143.5	373.0	0.370	0.386	17.6	23.0	97.0	21.2	82.2	0.114	2.04	5.85	452
12	7.42	99.4	83.1	18.8	137.8	463.3	0.210	0.276	17.6	21.7	93.8	19.5	62.8	0.062	2.23	5.73	492.4
13	7.45	95.6	84.8	10.8	144.1	454.6	0.139	0.330	17.0	23.5	87.4	20.6	85.5	0.065	2.17	5.83	531
14	7.38	97.4	81.0	16.4	145.6	366.0	0.410	0.348	19.0	23.1	90.0	21.0	88.2	0.111	1.95	5.66	464
15	7.66	95.2	78.6	16.6	169.2	411.2	0.269	0.410	22.4	33.7	107.8	23.9	79.6	0.049	2.14	5.42	587.6
16	7.31	93.8	78.7	14.8	143.6	373.4	0.360	0.394	17.7	23.5	97.3	21.4	82.5	0.112	2.14	5.83	457
17	7.76	97.6	81.0	16.6	160.4	397.0	0.245	0.334	20.4	33.8	98.0	22.0	80.4	0.058	2.32	5.84	577.2
18	7.72	111.2	90.6	20.6	168.4	405.0	0.240	0.452	20.4	33.7	109.4	23.2	89.0	0.089	2.28	5.23	577
19	7.66	97.0	77.4	19.0	167.6	417.0	0.270	0.388	18.6	33.7	106.0	25.2	77.2	0.066	2.21	5.74	519.6
20	7.76	114.8	90.6	24.2	169.2	410.4	0.250	0.392	21.8	33.8	97.0	20.8	89.2	0.075	2.18	5.72	587.6
21	7.74	96.4	77.8	18.6	160.4	405.0	0.278	0.320	22.8	32.6	108.0	25.6	80.6	0.086	2.34	5.64	579.2
22	8.05	93.3	79.2	14.1	34.5	366.4	0.124	0.320	18.6	21.1	87.1	21.5	82.6	0.096	2.07	5.87	393
23	7.64	94.7	78.9	16.8	156.9	370.0	0.315	0.390	19.8	24.6	95.0	21.2	80.2	0.011	2.12	5.84	408
24	7.57	96.0	80.6	16.4	146.0	368.5	0.310	0.354	19.4	23.0	89.2	20.3	85.4	0.08	2.09	5.92	413
25	7.53	95.1	78.8	16.3	151.0	369.1	0.205	0.344	19.3	24.5	89.8	19.7	87.2	0.082	2.18	5.9	412
26	7.50	97.0	80.8	16.2	139.0	368.0	0.300	0.334	19.2	22.0	87.2	19.9	87.4	0.057	2.08	5.89	411
27	7.59	94.9	80.1	16.1	154.0	368.3	0.310	0.351	19.5	24.3	89.2	20.9	82.4	0.015	2.13	5.87	419
28	7.54	95.8	79.8	16.3	149.0	368.7	0.305	0.368	19.7	23.5	88.1	20.6	84.7	0.048	2.17	5.86	415
29	7.64	96.8	80.8	16.0	149.1	488.0	0.330	0.408	21.0	21.0	97.0	21.2	82.0	0.053	2.06	5.82	544
30	7.68	97.2	80.8	16.4	167.6	402.0	0.231	0.366	20.6	32.5	107.8	27.0	82.4	0.083	2.2	5.49	569
31	7.21	95.8	78.9	16.9	140.1	478.0	0.330	0.372	20.4	20.4	86.0	21.5	77.4	0.092	2.16	5.68	524
32	7.58	97.6	84.8	12.8	138.6	424.0	0.300	0.345	19.6	21.5	91.2	19.4	82.0	0.084	2.13	5.86	489
33	7.74	91.2	76.8	14.4	159.6	416.8	0.244	0.352	22.0	33.5	108.2	27.4	78.6	0.072	2.24	5.38	591.6
34	7.39	97.8	81.5	16.7	145.8	356.8	0.380	0.353	18.8	23.5	90.3	21.2	88.5	0.077	1.99	5.64	468
35	7.27	94.8	78.2	17.6	142.5	466.8	0.190	0.330	18.8	28.3	90.7	21.4	89.1	0.083	2.12	5.57	522
Sum	263.7	3442.1	2851.5	599.6	5174	14369.5	9.430	12.35	682.5	919.7	3352.7	776.4	2872.1	2.529	76.16	199.2	17460
Mean	7.535	98.346	81.471	17.131	147.8	410.557	0.269	0.353	19.500	26.277	95.791	22.18	82.060	0.072	2.176	5.693	498.8
S.D	0.206	6.366	4.133	2.959	22.85	40.262	0.066	0.052	1.603	5.076	7.753	2.941	8.024	0.027	0.159	0.178	68.02
C.V%	0.027	0.065	0.051	0.173	0.155	0.098	0.246	0.148	0.082	0.193	0.081	0.133	0.098	0.375	0.073	0.031	0.136
Min	7.20	91.2	76.8	10.8	34.5	356.8	0.124	0.274	15.4	20.4	86.0	19.2	61.9	0.011	1.95	5.23	394
Max	8.05	118.4	92.6	25.8	170.8	488.0	0.410	0.492	22.8	34.8	109.4	33.0	89.2	0.114	2.95	5.92	591.6

Hardness in *mg / l*, Mg – Magnesium Hardness in *mg / l*, Fe – Iron in *mg / l*, F – Fluoride in *mg / l*, No3 – Nitrate in *mg / l*, Cl – Chloride in *mg / l*, So4 – Sulphate in *mg / l*, K–Potassium in *mg / l*, Mn –Manganese in *mg / l*, Zn –Zinc in *mg / l*, DO – Dissolved Solids in *mg / l*, TS – Total solids in *mg / l*, S.D – Standard deviation, C.V – Co-efficient of variation per cent, Min – Minimum, Max - Maximum.

CONCLUSIONS

After the careful study of analysis, interpretation and discussions of the numerical data following conclusions have been drawn for the Bidar City & its Industrial area. Water is soft in almost all the sampling points. The concentration of fluoride and nitrate in the entire Bidar City is well within the permissible limit except iron content, which is slightly high when compared with the Indian Standards and with the WHO Standards. From the U.S. salinity diagram it can be concluded that water from many wards are unfit for irrigation purpose only. From the Geo chemical analysis and Tri linear piper diagram it is concluded that thirteen wards of Bidar groundwater belongs to upper triangle of Piper diagram and are unfit for agricultural purpose. From TDS values it is observed that the ground water belongs to good class (16 – 480), whereas from the SAR value the groundwater belongs to excellent class (S A R <10).

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