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STUDY ON THE PHYSICO-CHEMICAL CHARACTERISTICS OF GROUND WATER OF BIDAR CITY AND ITS INDUSTRIAL AREA

Shivasharanappa[1*], Dr. Padaki. Srinivas[2], Mallikarjun. S. Huggi[3]

[1] P. D. A. College of Engineering, Gulbarga - 585102, Karnataka State, India.*

[2] P. D. A. College of Engineering, Gulbarga - 585102, Karnataka State, India.

[3] G. N. D. College of Engineering, Bidar, Karnataka State, India.

*shivasharanappa.g@gmail.com

ABSTRACT : The present work is aimed at assessing the ground water quality characteristics of Bidar city and its industrial area. The groundwater samples of all the 35 wards were collected and subjected for a comprehensive physicochemical analysis. The following 17 parameters have been considered viz., pH, total hardness, calcium, magnesium, chloride, nitrate, sulfate, total dissolved solids, iron, fluoride, sodium, potassium, alkalinity, manganese, dissolved oxygen, total solids & zinc. The results analyzed by Correlation and Regressions, have been used to suggest models for predicting water quality. The analysis reveals that the groundwater quality status of the study area is good, but it also needs to be protected from the perils of contamination by giving certain degree of treatment

Keywords: Groundwater, Water quality standards, Water quality characteristics, Correlation co-efficient, Regression analysis.

INTRODUCTION

Groundwater is used for domestic, industrial, water supply and irrigation all over the world. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. Human health is threatened by unsanitary conditions through open drain carrying and disposing wastewater into natural water bodies. 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] To communicate information on the quality of water to the concerned citizens and policy makers, analysis of water is utmost important. It, thus, becomes an important factor for the assessment and management of groundwater. 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 river water.[8] The objective of the present work is to discuss the suitability of groundwater for human consumption based on computed groundwater characteristics, quality assessment through correlation and regression analysis of important water quality parameters.

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 1).The city including its industrial are is divided into 35 wards. It 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.

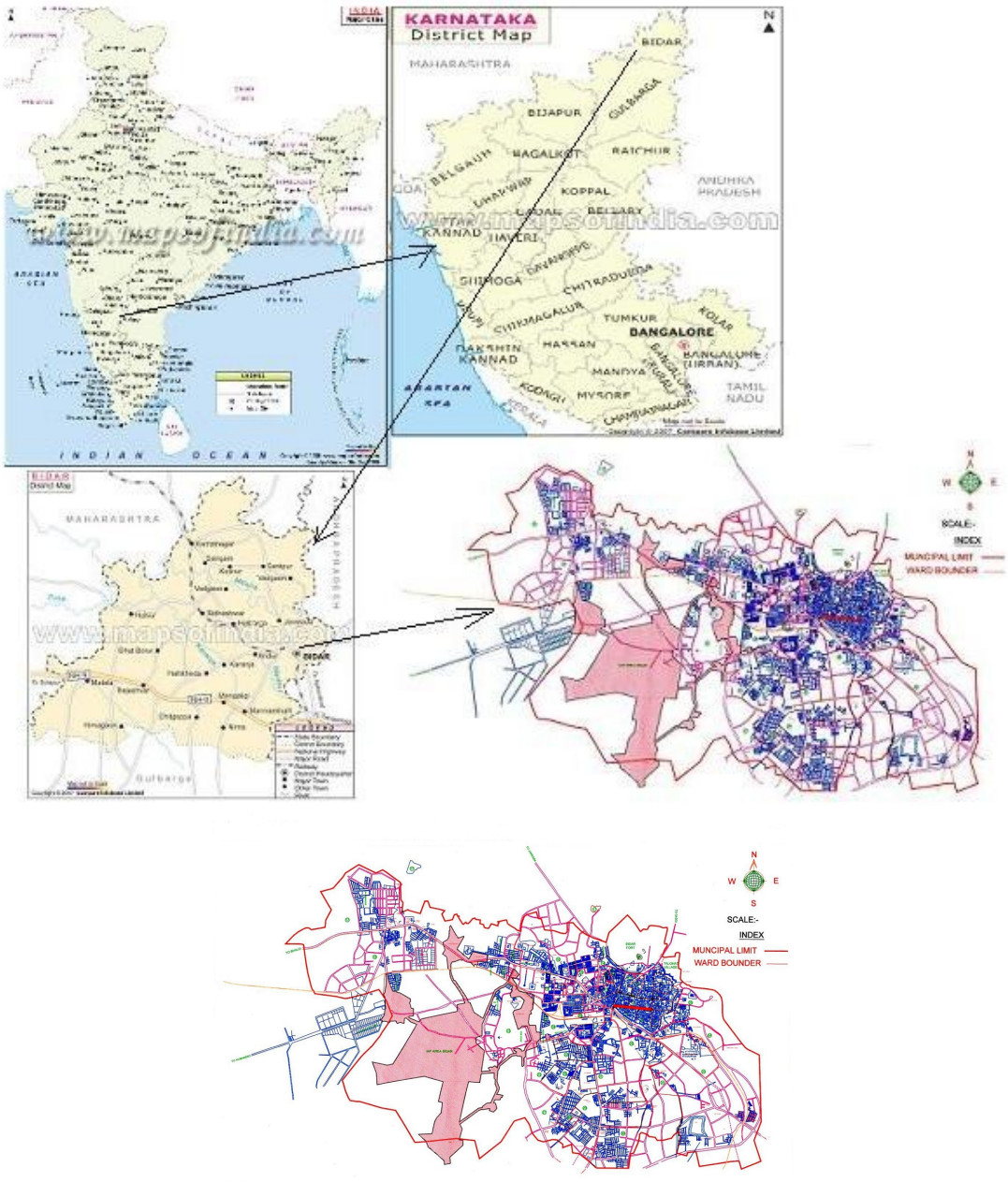

Figure 1.1: Bidar City Map

Figure No. 1: Showing the Location of Bidar City

The average annual rainfall as recorded in the previous years is 916.508 mm, 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.

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 the reagents used were of 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.[8] Samples were collected from all the 35 wards as per standard procedural method for the physicochemical analysis of 17 parameters. It was revealed that all the parameters studied under the area are within the prescribed limits[5-6]

RESULTS AND DISCUSSION

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]. They have been listed systematically and represented in table 2, after the keen examination of the, analysis and interpretation of the numerical data the following important aspects in them have been discussed in successive stages. The physical characteristics of the ground water under the study area are known by the parameters viz., pH, total dissolved solids and total solids. 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. Total Hardness, Calcium Hardness & Magnesium Hardness variations during the study period is presented in figure 2. Chloride, TS & TDS variations during the study period are presented in figure 3. Iron, Fluoride & Manganese variations during the study period are presented in figure 4. Sulfate, Sodium & Potassium variations during the study period are presented in figure 5. Zinc, pH & DO variations during the study period are presented in figure 6. Alkalinity & Nitrate variations during the study period are presented in figure 7. The physicochemical analysis of the ground water and the percent compliance with the Indian Standards and WHO are summarized in table 1.[9]

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 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

TDS – Total dissolved solids in *mg / l*, TH – Total Hardness in *mg / l*, Ca – Calcium Hardness in *mg / l*, Mg – Magnesium Hardness in *mg / l*, Fe – Iron in *mg / l*, F – Fluoride in *mg / l*, NO_3 – Nitrate in *mg / l*, Cl – Chloride in *mg / l*, SO_4 – Sulfate 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 %, Min – Minimum, Max - Maximum.

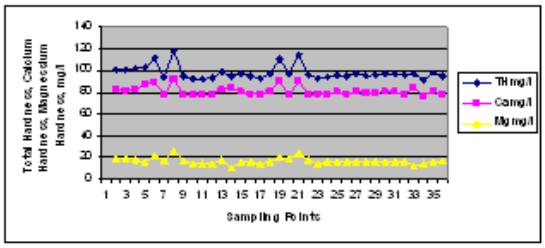

Figure No. 2: TH – Total Hardness, Ca – Calcium Hardness and Mg – Magnesium Hardness variations during the study period

Table- 3: Correlation co-efficient of different parameters [2, 3. 7]

	pH	TH	Ca	Mg	Cl	TDS	Fe	F	NO_3	SO_4	$CaCO_3$	Na	K	Mn	Zn	DO	TS
pH																	
TH	0.294																
Ca	0.324	**0.903**															
Mg	0.144	**0.813**	0.572														
Cl	0.013	0.331	0.25	0.347													
TDS	0.353	0.137	0.102	0.204	0.081												
Fe	-0.509	0.06	0.052	0.009	0.276	-0.263											
F	0.014	0.495	0.469	0.343	0.426	-0.218	0.304										
NO_3	0.628	0.331	0.28	0.282	0.428	-0.13	0.37	0.582									
SO_4	0.5	0.419	0.274	0.485	0.564	-0.001	-0.255	0.508	0.617								
$CaCO_3$	0.313	0.057	0.112	-0.072	0.142	0.408	0.011	0.438	0.442	0.293							
Na	0.405	0.437	0.332	0.418	0.575	0.037	-0.015	0.535	0.523	**0.767**	0.002						
K	0.497	0.288	0.263	0.197	0.387	-0.072	-0.115	0.388	0.516	0.6	0.283	0.669					
Mn	-0.093	-0.168	-0.152	-0.181	-0.298	0.197	0.355	-0.296	-0.208	-0.167	0.091	-0.157	-0.229				
Zn	0.178	0.044	-0.006	0.085	0.12	0.038	-0.033	-0.257	0.075	0.119	-0.134	0.073	0.025	0.076			
DO	-0.021	-0.259	-0.094	-0.406	-0.381	-0.249	0.475	-0.176	-0.377	-0.604	-0.053	-0.606	-0.546	0.438	-0.034		
TS	0.241	0.49	0.434	0.419	0.519	0.497	-0.228	0.371	0.488	**0.716**	0.002	**0.724**	0.565	-0.053	0.038	**-0.672**	

Table - 4: Computation of regression line for various samples [3]

SAMPLE	X-axis	Y-axis	N	$\overline{X}$	δX	$\overline{Y}$	δY	$r = \frac{(\Sigma XY / N - \overline{X}\,\overline{Y})}{\delta X\, \delta Y}$	$Y = r\frac{\delta Y}{\delta X}(X - \overline{X}) +$
Ca & TH	Ca	TH	35	81.471	4.133	98.346	6.366	0.903	Y = 1.391 X - 14.97
Mg & TH	Mg	TH	35	17.131	2.959	98.346	6.366	0.813	Y = 1.749 X + 68.38
Na & So4	Na	So4	35	95.791	7.753	26.277	5.076	0.767	Y = 0.502X - 21.83
TS & So4	TS	So4	35	498.857	68.022	26.277	5.076	0.716	Y = 0.053 X - 0.377
TS & Na	TS	Na	35	498.857	68.022	95.791	7.753	0.724	Y = 0.083 X + 54.63
TS & DO	TS	DO	35	498.857	68.022	5.693	0.178	-0.672	Y = - 1.758*10^{-3} X + 6.57

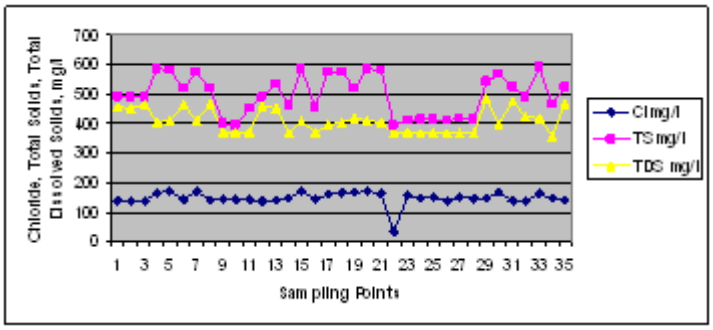

Figure No. 3: Cl – Chloride, TS – Total Solids, and TDS – Total Dissolved Solids variations during the study period

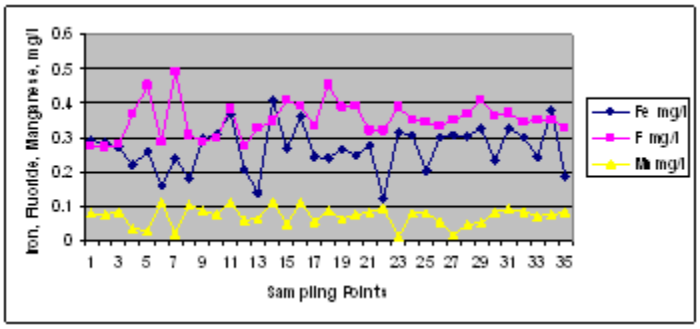

Figure No. 4: Fe – Iron, F – Fluoride, and Mn– Manganese variations during the study period

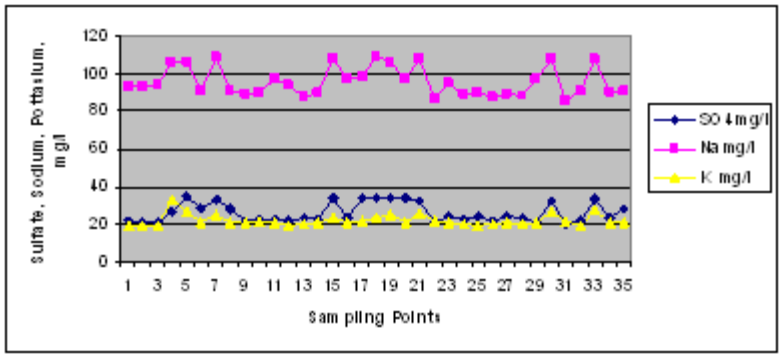

Figure No. 5: SO_4 – Sulfate, Na – Sodium, and K – Potassium variations during the study period

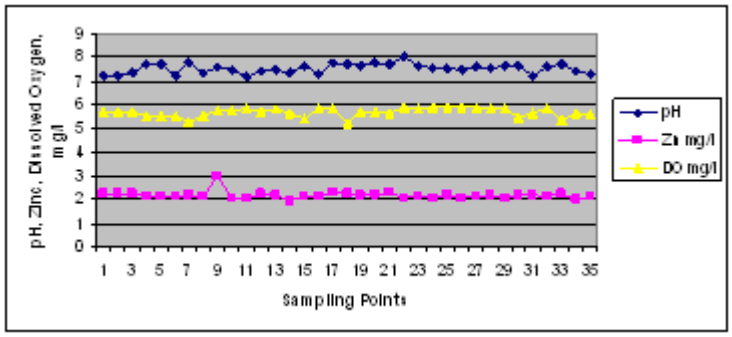

Figure No. 6: pH – Hydrogen Ion Concentration, Zn – Zinc, and DO – Dissolved Oxygen variations during the study period

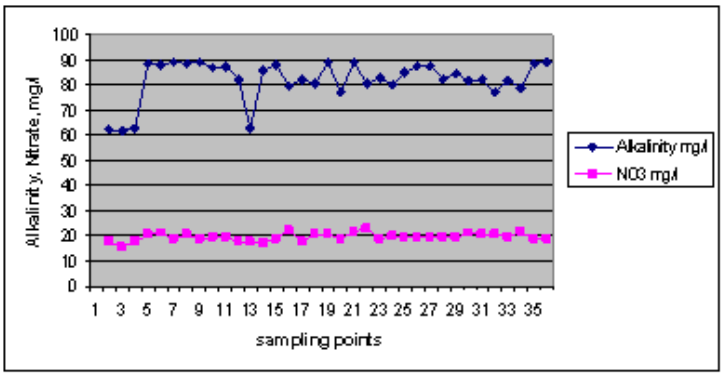

Figure No. 7: Alkalinity and NO_3 – Nitrate, variations during the study period

Correlation and Regression Analysis: [2, 3, 7]

In the present study area, the correlation coefficient (r) between every parameter pairs is computed by taking the average values as shown in table 3. Correlation coefficient (r) between any two parameters, x & y is calculated for parameter such as pH, TH, Ca, Mg, Cl, TDS, Fe, F, NO_3, SO_4, Na, K, Mn, Zn, DO, TS & Alkalinity of the ground water. The degree of line association between any two of the water quality parameters as measured by the simple correlation coefficient (r) is presented in table 3, as 17 x 17 correlation matrix. The highest positive correlation (r = 0.903) is found between calcium and total hardness and the highest negative correlation (r = -0.672) is found between total solids and dissolved oxygen. High values of the correlation coefficient (r = 0.67) between Ca & TH (0.903), Mg & TH (0.813), Na & SO_4 (0.767), TS & SO_4 (0.716), TS & Na (0.724), TS & DO (-0.672) as shown in table 4, were observed for the regression analysis, regression equations were formed and regression lines are drawn as shown in figures 8, 9, 10, 11, 12, and 13.

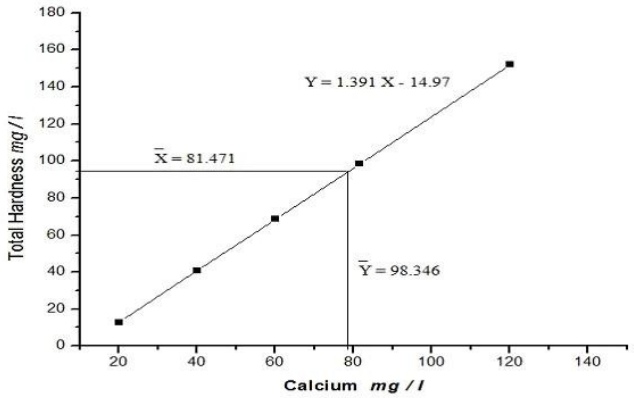

Figure No. 8: Regression Line for Total Hardness v/s Calcium in *mg/l*

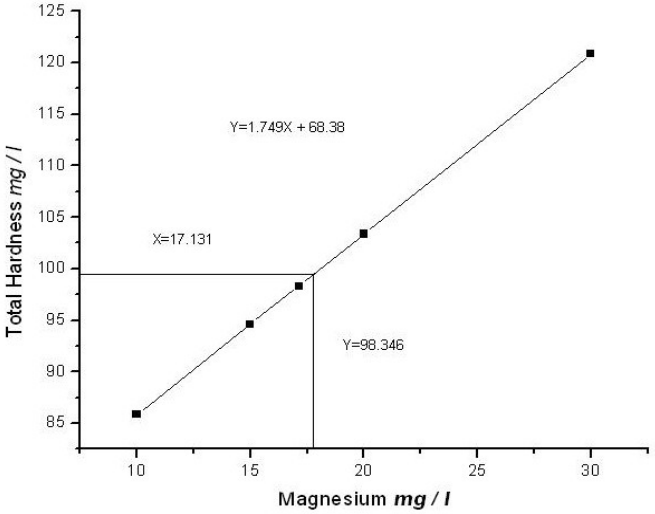

Figure No. 9: Regression Line for Total Hardness v/s Magnesium in *mg/l*

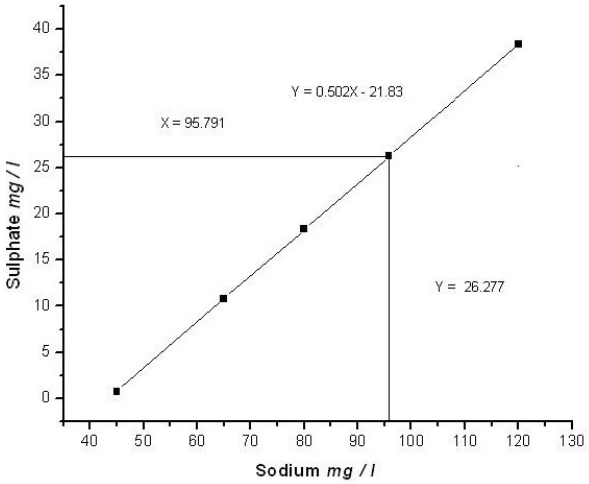

Figure No. 10: Regression Line for Sulfate v/s Sodium in *mg/l*

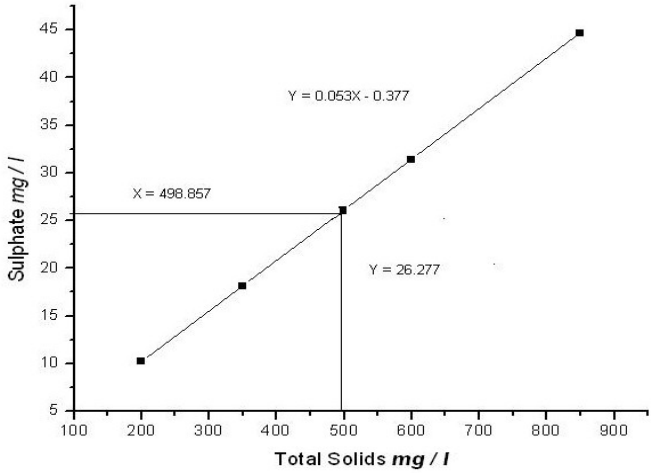

Figure No. 11: Regression Line for Sulfate v/s Total Solids mg / *l*

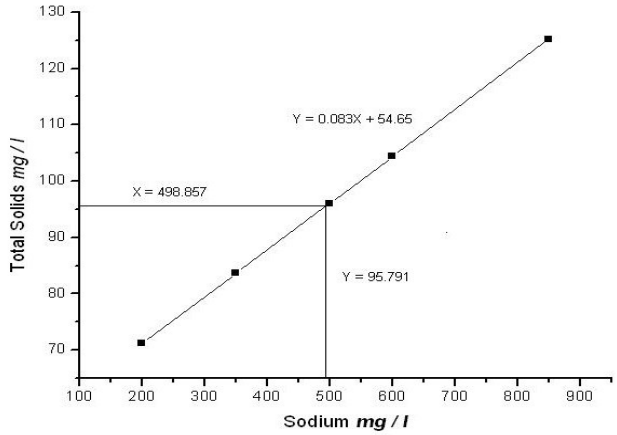

Figure No. 12: Regression Line for Total Solids v/s Sodium mg / *l*

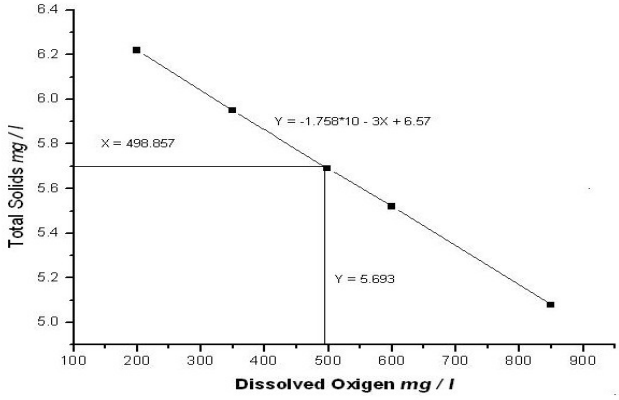

Figure No. 13: Regression Line for Total Solids v/s Dissolved Oxygen mg / *l*

CONCLUSION

After the careful study of analysis, interpretation and discussions of the numerical data following conclusions have been drawn for the Bidar city. 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. Otherwise the groundwater is crystal clear, odorless, and palatable. This is evident from the table 1 comparing ground water quality with Indian Standards as well as with the WHO Standards. Most of the bore wells yield potable water with moderate mineral or dissolved salts. Water is soft in almost all the sampling points. As there is no considerable increase in chloride and sulfate, it shows that there is no possible contamination of groundwater due to percolation of polluted surface water. The concentration of fluoride in the entire Bidar City is well within the permissible limit. The concentration of nitrate was also well below the permissible limit. The analysis reveals that the groundwater of the area, needs certain degree of treatment before consumption (at least disinfection), and it also needs to be protected from the perils of contamination. Good correlation evolved ($r \geq 0.67$) between Ca & TH (0.903), Mg & TH (0.813), Na & SO_4 (0.767), TS & SO_4 (0.716), TS & Na (0.724), where as negative correlation evolved between TS & DO (-0.672) as shown in table no.2. It shows that total hardness, sodium, sulfate and calcium hardness relate each other and are permanent in nature. Since there is no relation between TS & DO, hence negative correlation has arrived. Regression lines were drawn for the above said parameters and the equations obtained can be utilized to get one parameter value from the other parameter, but the analysis has to be performed on the seasonal basis so as to arrive at correct values.

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