WWJMRD 2017; 3(9): 272-277
www.wwjmrd.com
International Journal
Peer Reviewed Journal
Refereed Journal
Indexed Journal
UGC Approved Journal
Impact Factor MJIF: 4.25
e-ISSN: 2454-6615

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Appraisal of Underground Water Quality and Water Quality Index in Sandur Taluk of former capital of Vijayanagara Empire, Karnataka, India

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Abstract
Appraisal of ground water quality and its management has the paramount in the field of environmental quality management. Underground water quality of former capital of Vijayanagar Empire has a special significance and in this area under ground is the main source for the drinking and domestic activity of the human beings. In the present appraisal greater attention made towards the declining in the ground water level and quality due to increase in the community and rapid urbanization. The present study was made attempt to access the underground water quality using water quality index in the former capital of Vijayanagar Empire of Karnataka state. The underground water samples were collected manually from bore well and hand pump, which are identified based on the activity, equally distributed in the all over the selected area in the present study. Total twenty five ground water samples were collected and transferred to the laboratory for analysis using standard procedure. The water quality index were calculated using some of the ground water quality variables. The ground water quality index was used to express the water quality for different purposes in daily human needs. WQI has been computed based on ten different quality parameters to assess the suitability of groundwater for drinking purposes in Sandur taluk of former capital of Vijayanagara Empire, Karnataka. The computed WQI shows that 28.0% of water sample falls in the 'Fair' it Needs Treatment (Filtration & Disinfection) water category. 32.0% of water sample falls in the 'Good' it is acceptable category On the other hand 40.0% of water samples fall in the 'excellent' category which indicates that the about 29.0 % of the ground water is not suitable for direct consumption and requires treatment.

Keywords: underground water quality, WQI, Vijayanagar Empire, human consumption

Introduction
Groundwater is most important and it is used especially for domestic and industrial activity and also agricultural practices 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 (Mishra, P.C. and R.K. Patel, (2001). Human health is threatened by most of the agricultural development activities particularly in relation to excessive application of fertilizers and unsanitary conditions. According to WHO organization, about 82% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source (Ramakrishnaiah, *et al.*, 2009). Hence, regularly monitor is required to know the quality of groundwater and to device ways and means to protect it.

Underground Water Quality Index (UWQI) determine the water quality of water resources is considered as one of the most operative tool for comparing water resources. The WQI was developed in the 1970s by the Oregon Department of Environmental Quality for the purpose of summarizing and evaluating water quality trends and status (ODEQ, 2004). Thus, ground water quality becomes an important adaptable variable to appraisal and management of underground water. WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption (Rizwan R and Gurdeep S, 2010). As per the literature survey, (WHO/UNICEF, 2012) in developing world due to microbiological

and chemical contaminations about 780 million people are not accessing potable water for drinking purposes.

Groundwater is rarely treated and presumed to be naturally protected, it is considered to be free from impurities, which are associated with surface water, because it comes from deeper parts of the earth. In India, almost 80% of the rural population depends on untreated groundwater for potable water supplies (Tiwari *et al.*, 2013). Due to rapid growth of population, urbanisation, industrialization, water resources of our country are now getting stressed with declining per capita availability and deteriorating quality. Assessment of groundwater quality requires determination of ion concentrations which decide the suitability for drinking, agricultural and industrial uses (Tiwari, 2011). In the present appraisal, distribution of physicochemical variables in underground water samples in the selected villages of the Sandur Taluka are presented. The data collected from the underground water could be regarded as the background physiochemical variables in the natural environment of this region. These data are employed to evaluate the extent of ground water quality index in the Sandur taluk of former capital of Vijayanagara Empire. As per the literature survey, this is the first comprehensive study using Ground water quality index (GWQI) in Sandur Taluk. The results may be instructional for other mining locations with similar levels of urban development to understand the potential threats to their groundwater resources.

Study Area

Former capital of Vijayanagar Empire is also called as Karnata Empire. It was established by Harihara and his brother Bukkaraya. The empire is named after its capital city of Vijayanagara, whose ruins surround present day Hampi, now a World Heritage Site in Karnataka, India. Vijaynagar kingdom was one of the important kingdoms in the medieval Indian history. For 200 years the vijayanagar Empire emerged as one of the most powerful kingdoms in the peninsular India. Now, the ruins of this great kingdom have been declared a protected location by the United Nations Educational, Scientific and Cultural Organization (UNESCO). Overall WQI (OWQI) has been developed for surface water by Singh et al. (2006) which can also be used for groundwater also Singh, et al., 2015. As reported by Singh et al. (2006) and Krishan et al. (2016) to gauge the influence of each individual parameter on a common single scale, the score generated by each parameter was averaged out.

Experimental Work

25 underground water samples were taken from different wells and hand pump in the selected village of Sandur taluk (Fig. 1), for twelve months (June 2016 to May 2017). Underground water samples were collected in the early morning from 9.00AM to 12.00 PM for three days. The collected samples were preserved and analysed for 10 parameters in laboratory. The parameters are pH (pH meter), total dissolved solids (TDS) using conductivity meter, alkalinity, total hardness, calcium, magnesium and chloride by titration method, sulfate and nitrate using Spectrophotometer and sodium and potassium using flame photometer (APHA, 1994 and Nertan C and Rosu C., 2008).

Calculation of WQI: The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method. The quality rating scale for each parameter qi was calculated by using this expression (Sinha, D. K., *et al.*, 2004). Quality rating, Qi = 100 [(Vn -Vi) / (Vs -Vi)] Where, Vn: actual amount of nth parameter Vi: the ideal value of this parameter Vi = 0, except for pH. Vi = 7.0 for pH. Vs: recommended WHO standard of corresponding parameter Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter. Wi = 1/ Si, WQI are discussed for a specific and intended use of water. In this study the WQI for human consumption is considered and permissible WQI for the drinking water is taken as 100. The overall WQI was calculated by using Equation: Water Quality Index (WQI) =Σ (Qi) WI /ΣWi (WQI)

Results and Discussion

The average value of physico-chemical parameters and WQI along with water type of 25 samples are given in Tables 1. Parameter-wise WHO standards and their assigned unit weights is given in Table 2. The spatial distribution of water quality index is shown in Table 4.

The pH values ranged between 6.75 at Jaisingpura and 7.43 at Mallapura village indicating samples was neutral to slightly alkaline. The TDS varied from 611.00 mg/l at Bujanganagara to 1942.72 mg/l at S Basapura. Very high TDS were observed during the study compared to standard limit of 500 mg/l may be due to high concentrations of chloride and nitrates. Chloride concentration ranged from 49.46 mg/l at Mallapura village to 434.09 mg/l at V Nagalapura village and the maximum concentration is very high as compared to standard limit 250 mg/l. Sulphate concentration ranged between 46.05 mg/l at Narsingapura village and 115.54 mg/l at Nandihalli village which were below the permissible limit of 200 mg/l. Nitrate concentration in groundwater samples ranged between 4.63 mg/l Venkatagiri village and 20.88 mg/l at Ranajithpura village. High concentration of nitrate may be due to leaching from nitrogenous fertilizers, manures and may also be due to other anthropogenic origin. Total hardness ranged from 284.31 at Mallapura village to 2060.12 mg/l at S Basapura village and most of the ground water samples have crossed the standard limit of 300 mg/l.

It is observed from the work the maximum and minimum value of WQI has been found to be 99 and 57 delineated as per the Table 5 which fall under the 'Excellent' and 'Fair' category, Needs Treatment (Filtration & Disinfection) respectively. In the present study it is observed that 10 of the groundwater samples (40.0%) qualify in the 'Excellent' category and are acceptable for domestic use and 8 samples qualify in the 'Good' category which are of acceptable quality; 7 ground water samples qualify in the 'Fair' category which needs 'Filtration and disinfection' treatment and no one samples qualify in the 'Poor' category which needs 'Special treatment'. It may also be reflected that parameters particularly chloride, sulphate, nitrate and hardness are found to be higher compared to the permissible level resulting TDS value at higher order owing to anthropogenic contribution viz. agricultural and industrial activities in the Sandur Taluk. It is evident from the Table 4 It is evident from the present work, that the ground water quality is fairly good in Sandur taluk of the study area, while the water quality needs treatment in the some of the parts of the Sandur Taluk (Table 5).

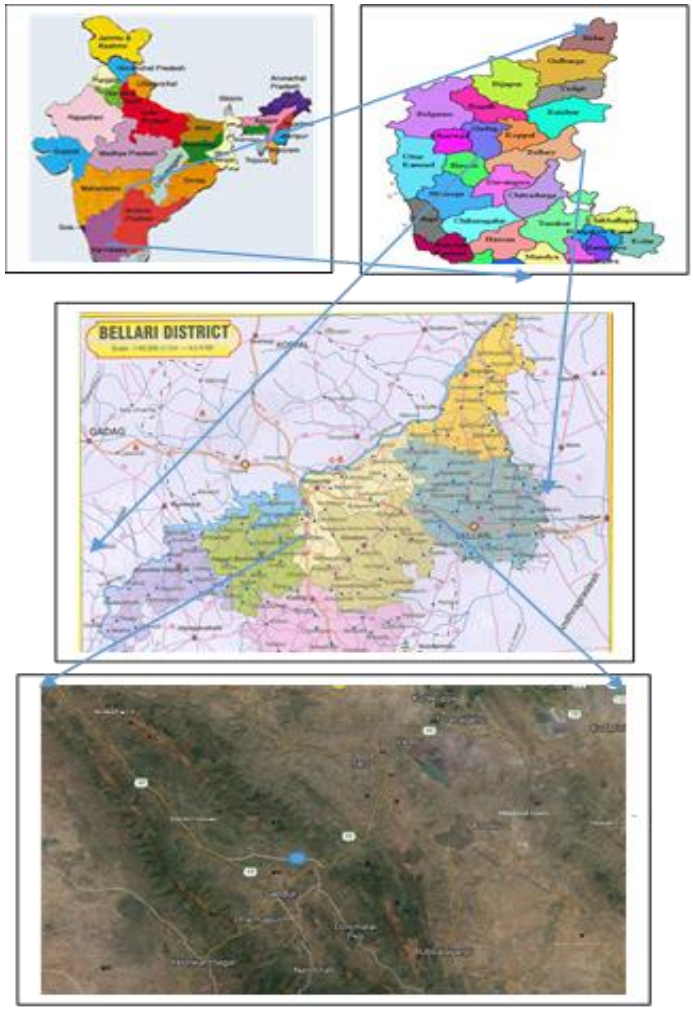

Fig. 1: Location Map of the Study Area Showing Underground Water Sampling locations

Conclusion

WQI has been computed based on ten different quality parameters to assess the suitability of groundwater for drinking purposes in Sandur taluk of former capital of Vijayanagara Empire, Karnataka. The computed WQI shows that 28.0% of water sample falls in the 'Fair' it Needs Treatment (Filtration & Disinfection) water category. 32.0% of water sample falls in the 'Good' it is acceptable category On the other hand 40.0% of water samples fall in the 'excellent' category which indicates that the about 29.0 % of the ground water is not suitable for direct consumption and requires treatment. After treatment, this water can be used for drinking purpose. Chloride, sulphate, nitrate and hardness are found to be higher compared to the permissible level resulting TDS value at higher order owing to anthropogenic contribution which might occur due to the agricultural and industrial activities in the selected water samples of Sandur taluk. The continuous monitoring of groundwater is required in the district to protect water in future from any possible contamination due to growing industrialization and agricultural practices.

Table 1: Average actual values (Vn) of physicochemical parameters of selected water samples in the study area

Code	Village	Latitude and Longitude	pH	EC	TDS	TH	Ca	Mg	Alk	Cl	SO_4	NO_3
1	Laxmipura	15.10 Lati, 76.48 Longi	7.17	2794.44	1369.28	1091.48	633.06	69.40	344.58	368.24	56.31	9.56
2	Nandihalli	15.11 Lati, 76.48 Longi	7.03	1068.96	523.79	410.70	238.21	26.11	178.58	78.93	115.54	11.95
3	Tumati	15.10 Lati, 76.48 Longi	7.07	1088.52	533.38	366.12	212.35	23.28	202.58	82.64	61.26	8.51
4	Bujanganagara	15.11 Lati, 76.48 Longi	7.33	1247.51	611.28	473.89	274.86	30.13	212.58	118.39	51.97	11.41
5	Narasingapura	15.10 Lati, 76.48 Longi	7.13	2156.99	1056.93	821.46	476.45	52.23	216.58	355.16	46.05	11.99
6	Ranajithpura	15.12 Lati, 76.48 Longi	7.03	1252.63	613.79	473.89	274.86	30.13	192.58	118.39	50.45	20.88
7	Susheelanagara	15.10 Lati, 76.47 Longi	7.05	1583.80	776.06	600.28	348.16	38.17	188.58	197.31	49.16	15.57
8	Siddapura	15.12 Lati, 76.48 Longi	6.88	1507.30	738.58	402.08	233.21	25.56	198.58	98.93	65.51	16.45

9	Jaisingpura	15.12 Lati, 76.48 Longi	6.75	2231.94	1093.65	976.58	566.42	62.09	188.58	315.70	52.75	5.81
10	Venkatagiri	15.12 Lati, 76.48 Longi	6.92	2064.54	1011.63	789.87	458.12	50.22	194.58	276.24	44.50	4.63
11	Dowlatpura	15.10 Lati, 76.50 Longi	7.13	1822.94	893.24	695.08	403.14	44.19	202.58	197.31	63.94	10.89
12	D.Thimmalapura	15.04 Lati, 76.49 Longi	6.98	1745.94	855.51	631.88	366.49	40.18	188.58	157.85	59.50	6.67
13	Taranagara	15.12 Lati, 76.50 Longi	7.07	1501.63	735.80	494.41	286.76	31.43	202.58	197.31	65.06	12.60
14	Muraripura	15.11 Lati, 76.50 Longi	6.97	2240.48	1097.84	853.06	494.78	54.24	212.58	276.24	58.80	15.64
15	V-Nagalpura	15.11 Lati, 76.50 Longi	7.08	2726.97	1336.22	1042.65	604.73	66.29	144.58	434.09	58.28	8.83
16	Taluru	15.11 Lati, 76.51 Longi	7.17	1420.52	696.05	537.09	311.51	34.15	186.58	157.85	63.57	11.87
17	Chikkantapura	15.12 Lati, 76.53 Longi	6.98	2314.31	1134.01	1206.38	699.70	76.70	172.58	236.78	62.64	18.92
18	S-Basapura	15.11 Lati, 76.52 Longi	6.81	3964.73	1942.72	2068.12	1199.51	131.49	182.58	907.64	102.97	16.27
19	Kurekuppa	15.11 Lati, 76.52 Longi	7.41	1337.68	655.46	505.49	293.19	32.14	144.58	157.85	54.29	10.30
20	Dharmapura	15.11 Lati, 76.52 Longi	6.81	2312.96	1133.35	884.66	513.10	56.25	196.58	355.16	51.43	9.24
21	Yashavantanagara	15.04 Lati, 76.49 Longi	6.92	2156.91	1056.89	769.76	446.46	48.94	198.58	315.70	49.56	18.01
22	Nidagurthi	15.03 Lati, 76.48 Longi	7.13	998.29	489.16	315.91	183.23	20.09	144.58	69.46	61.16	10.82
23	Mallapura	15.03 Lati, 76.48 Longi	7.43	759.81	372.31	284.31	164.90	18.08	102.58	49.46	67.04	8.90
24	Katinakamba	15.02 Lati, 76.47 Longi	6.90	1819.90	891.75	695.08	403.14	44.19	152.58	257.98	53.05	6.51
25	Bandri	15.02 Lati, 76.47 Longi	7.03	3626.07	1776.78	1685.47	977.57	107.16	266.58	591.94	58.45	7.37
	Maximum Contaminated Level		6.5-8.5	2500	500	300	200	50	250	250	250	50

Table 2: Parameter-wise WHO standards and their assigned unit weights

Sl No	Parameters	Units	WHO Standard	Assigned unit Wt. (Wn)
1	pH	-	8.5	0.1176
2	Conductivity	mS/cm	0.3	3.3333
3	TDS	mg/L	500	0.0020
4	Total hardness	mg/L	100	0.0100
5	Calcium	mg/L	100	0.0100
6	Magnesium	mg/L	30	0.0333
7	Total Alkalinity	mg/L	100	0.0100
8	Chloride	mg/L	200	0.0050
9	Sulphate	mg/L	250	0.0040
10	Nitrate	mg/L	50	0.0200

Table 3: Parameter-wise and location-wise estimated actual values (Qn) during the study period

Code	Village	pH	EC	TDS	TH	Ca	Mg	Alk	Cl	SO_4	NO_3
1	Laxmipura	26.67	48.00	204.00	185.00	60.00	40.00	86.59	58.33	100.00	170.00
2	Nandihalli	11.33	61.60	241.33	205.00	82.00	72.00	85.05	44.50	60.00	150.00
3	Tumati	4.67	102.00	186.67	240.00	90.00	64.00	89.01	42.00	72.60	280.00
4	Bujanganagara	74.67	104.00	106.67	184.00	44.60	118.40	99.78	36.83	140.00	244.00
5	Narasingapura	53.33	50.00	239.33	210.00	51.00	55.00	80.44	50.00	140.00	130.00
6	Ranajithpura	46.67	59.60	180.67	164.00	90.00	78.00	97.80	51.33	120.00	220.00
7	Susheelanagara	40.00	58.00	196.33	170.00	84.00	58.00	75.82	90.33	168.60	176.00
8	Siddapura	39.33	62.00	163.00	185.00	72.00	52.00	74.51	99.50	150.00	152.00
9	Jaisingpura	60.00	73.40	208.00	210.00	60.20	58.00	82.20	63.33	100.00	160.00
10	Venkatagiri	40.00	65.00	153.00	180.00	83.60	58.00	68.68	80.00	150.00	158.00
11	Dowlatpura	39.33	62.00	163.00	185.00	72.00	52.00	74.51	99.50	150.00	152.00
12	D.Thimmalapura	60.00	73.40	208.00	210.00	60.20	58.00	82.20	63.33	100.00	160.00
13	Taranagara	40.00	65.00	153.00	180.00	83.60	58.00	68.68	80.00	150.00	158.00
14	Muraripura	36.67	56.00	178.67	190.00	65.60	60.80	73.63	75.17	146.00	250.00
15	V-Nagalpura	53.33	50.00	236.33	210.00	51.00	55.00	80.44	50.00	140.00	130.00
16	Taluru	40.00	65.00	153.00	180.00	83.60	58.00	68.68	80.00	150.00	158.00
17	Chikkantapura	54.67	62.40	151.00	200.00	57.60	40.80	69.23	75.00	100.00	114.00
18	S-Basapura	11.33	61.60	258.33	205.00	82.00	72.00	85.05	44.50	60.00	150.00
19	Kurekuppa	40.00	65.00	153.00	180.00	83.60	58.00	68.68	80.00	150.00	158.00

20	Dharmapura	39.33	62.00	163.00	185.00	72.00	52.00	74.51	99.50	150.00	152.00
21	Yashavantanagara	26.67	48.00	204.00	185.00	60.00	40.00	86.59	58.33	100.00	170.00
22	Nidagurthi	54.67	62.40	151.00	200.00	57.60	40.80	69.23	75.00	100.00	114.00
23	Mallapura	54.67	62.40	151.00	200.00	57.60	40.80	69.23	75.00	100.00	114.00
24	Katinakamba	60.00	73.40	208.00	210.00	60.20	58.00	82.20	63.33	100.00	160.00
25	Bandri	54.67	62.40	151.00	200.00	57.60	40.80	69.23	75.00	100.00	114.00

Table 4: Water Quality Index value of groundwater samples during the study period

Code	Village	WQI (Qi)	Hydro-chemical Composition
1	Laxmipura	82	Ca-Na-HCO_3-Cl
2	Nandihalli	70	Na-SO_4 –HCO_3
3	Tumati	87	Na-Ca-Mg- HCO_3 -Cl-SO_4
4	Bujanganagara	99	Ca-Na- HCO_3 -Cl
5	Narasingapura	71	Ca-Na-Mg-Cl- HCO_3
6	Ranajithpura	87	Mg-Ca-Na-Cl- HCO_3-SO_4
7	Susheelanagara	57	Mg-Na-Ca-Cl
8	Siddapura	86	Mg-Ca-Na- HCO -Cl
9	Jaisingpura	81	Na-Mg-Ca- HCO_3 -Cl
10	Venkatagiri	75	Na-Mg- HCO_3 -Cl
11	Dowlatpura	95	Na-Mg- HCO_3 -Cl
12	D.Thimmalapura	94	Na- HCO_3 -Cl
13	Taranagara	70	Na-Ca-Cl
14	Muraripura	98	Na-Ca-Mg- HCO_3
15	V-Nagalpura	83	Ca-Na-Mg- HCO_3 -Cl-SO_4
16	Taluru	94	Ca-Na-Cl- HCO_3 –SO_4
17	Chikkantapura	91	Ca-Mg-Na-HCO -Cl
18	S-Basapura	58	Na-Ca-Mg-Cl
19	Kurekuppa	95	Na-Ca-Mg- HCO -Cl
20	Dharmapura	67	Ca-Mg-Na-Cl
21	Yashavantanagara	73	Mg-Na-Ca-Cl- HCO_3
22	Nidagurthi	93	Na- HCO_3-Cl-SO_4
23	Mallapura	60	Na-Mg-Cl-HCO_3
24	Katinakamba	91	Na-Mg-Cl- HCO_3
25	Bandri	83	Na-Cl- HCO_3 –SO_4

Table 5: WQI and corresponding class and status of water quality

Class	WQI Value	Status of Water	Ground Water Samples
Heavily Polluted	0 - 24	Unsuitable for All Purposes	-Nil-
Poor	25 - 49	Special Treatment (Special Treatment)	-Nil-
Fair	50 - 74	Needs Treatment (Filtration & Disinfection)	07
Good	75 - 94	Acceptable	08
Excellent	95 - 100	Pristine Quality	10

Acknowledgement
The author is very thankful to Vijayanagara Sri Krishnadevaraya University, Bellary and Department of Chemistry for providing necessary research facilities.

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