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Assessment of Groundwater Quality of Ranchi Township Area, Jharkhand, India by Using Water Quality Index Method

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Abstract: Water quality index (WQI) a well known method as well as one of the most effective tools to express water quality that offers a simple, stable, reproducible unit of measure and communicate information of water quality to the policy makers and concerned citizens. Twenty Seven water samples were collected from well and tube well of the Ranchi township area. The quality of water were evaluated by testing various physico-chemical parameters such as pH, Total Dissolved Solid, Total Hardness, Bicarbonate, Fluoride, Chloride, Nitrate, Sulphate, Calcium and Magnesium. The WQI value 139 is maximum and the value 29 is minimum in the study area. The computed WQI shows that 18% of water sample falls in the Very Good water category and 67% water samples fall in Good category. On the other hand 15% of water samples falls in the poor category. Ground Water Quality Index (GWQI) of 85% of groundwater samples were found as Very Good to Good category and can be use for direct consumption while 15% of water samples are the Poor category shows that the water is not suitable for direct consumption and requires treatment before its utilization. The high value of WQI at these stations has been found to be mainly from the higher values of total dissolved solids, hardness, fluorides, bicarbonate, chloride, nitrate and calcium in the groundwater.
Key words: Groundwater Quality, WOI, Ranchi Township.

Introduction

Water is addressed as a necessary resource and life preservative. It is required for most human activities like drinking, cooking bathing, washing, agriculture, industry, recreation, navigation and fisheries etc. About 75% of the world's surface area is covered with water. Out of which 97% of the earth's water is in the ocean, not fit for human use due to its high salt content. Remaining 2% is locked in polar ice caps and only 1% is available as fresh water in rivers, lakes, streams reservoirs and ground water, suitable for human consumption. Though the world has achieved tremendous progress in all fields of science and technology but adequate and safe drinking water is a still a distance dream for many people. This is due to the uneven distribution of water. Hence, there is a need to develop and manage the water resource of country with natural perspective. The demand of water is increases due to the increase in population and other developmental activities. In many parts of the world - especially in developing countries there is a water crisis, and it is estimated that by 2025 more than half of the world population will be facing water-based vulnerability. Access to safe drinking water remains an urgent necessity, as 30 % of urban and 90 % of the rural Indian population still depends completely on untreated surface or groundwater resources[1]. Though recent years shift in usage from surface water to groundwater has controlled microbiological problems in rural India to a certain extent[2]. While scarcity of clean and potable drinking water has emerged in recent years as one of the most serious developmental issues in many parts of West Bengal, Jharkhand, Orissa, Western Uttar Pradesh, Andhra Pradesh, Rajasthan and Punjab[3].

Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water[4]. The WQI is a single number that expresses water quality by aggregating the measurements of water quality parameters (such as, pH, nitrate, sulphate, chloride, hardness, calcium, magnesium etc.). Usually the lower score alludes to better water quality (excellent, good) and higher score to degraded quality (bad, poor). The index provides a simple and concise method for expressing the quality of water bodies for varied uses such as recreation, swimming, drinking, irrigation, or fish spawning, etc. Horton (1965) first introduced and defined it as mathematical form of WQI by selecting, rating and integrating the significant physical, chemical and biological parameters of water in a simple, yet scientifically defensible manner[5]. Then it was developed and improved by Brown et al., 1970 and Deininger (Scottish Development Department, 1975) respectively[6,7]. Also the development of WQI for water resources is described by several studies[8,9,10,11]. Temporal changes in the source and nature of the recharged water, hydrologic and human factors may cause periodic changes in groundwater quality[12]. Due to the unavailability of surface water at many places, groundwater is the only alternate source of good quality water in rural areas. While access to drinking water in India has increased over the past decade, the tremendous adverse impact of unsafe water on health continues[13,2]. According to (Foster, 1995) the intensive use of natural resources and increased human activities are posing great threat to groundwater quality[13]. Groundwater quality assessment can be a complex process undertaking multiple parameters capable of causing various stresses on overall groundwater quality[15]. The aim of this study is to assess the quality of groundwater for the suitability of drinking and domestic purpose.

Study area

Ranchi is the capital city of the Indian state of Jharkhand. The total area covered by Ranchi - Municipal Area is about 110 sq km and the average elevation of the city is 2,140 feet above sea level. Geographically, Ranchi is located on southern part of the Chota Nagpur plateau which forms the eastern edge of the Deccan plateau system. Ranchi was the centre of the Jharkhand movement, which called for a separate state for the tribal regions of South Bihar, northern Orissa, western West Bengal & the eastern area of what is present-day Chhattisgarh. It is connected through NH-33 from prominent district headquarters of the state. It is also connected through Gumla and Rourkela by NH-23. As per latest 2011 India census, Ranchi city has a population of 1,073,440, making it the 37th largest urban city in India and third largest city in Jharkhand after Jamshedpur and Dhanbad. Males constitute 51.3% of the population and females 48.7%. Ranchi is the second most populous district of Jharkhand after Dhanbad. The area surrounding Ranchi has been endowed with natural attractions and it is referred to as the “City of Waterfalls”. The Subarnarekha river and its tributaries constitute the local river system. The channels Kanke, Rukka and Hatia have been dammed to create reservoirs that supply water to the majority of the population.

Ranchi district experiences subtropical climate, which is characterized by hottest part of the year, extends from mid April to the middle of June, but even during this period the nights remain cool and pleasant. Occasional rains help to keep down the temperature in summer. The monsoon commences from middle of June and continues upto the end of September. The winter is rather severe extending from middle of November to middle of February. Minimum temperature of about 10°C is recorded for the period during late December and early January. The normal annual rainfall data indicate that average rainfall is 1394mm. Maximum rainfall has been observed from June to October months. About 90% of the total annual rainfall is received to the monsoon period.

The oldest geological formation of this district is represented by Dharwar sediments with the basic intrusive. These, being later intruded by the batholithic mass of Chota Nagpur granite, were metamorphosed into various types of schistose and gneissic rocks. The remnants of the earlier sedimentary and igneous rocks are known from the inclusions of phyllites and schists of varying dimensions in the granite mass and the extensive areas of Khondalites. Phyllites are by far the predominant rock type in the south-east portion of this district. Chota Nagpur granite gneiss forms the country rocks of the district and is a part of the enormous intrusive mass. Within the main body, the granite gneiss varies from a normal medium- grained rock to a porphyritic material with large crystals of potash feldspar. Quartz, biotite or hornblendes are the other essential minerals. Apatite, zircon, sphene are rutile are the accessories. The amphibolites occur as minor intrusive in the Khondalite series. Amphibolite also occurs as minor enclaves in the granite gneisses in and around Ranchi city.

Materials and Methods

Table 1. Detail of Sampling Locations of Ranchi Township Area

S. No.	Sample Code	Sampling Location	Latitude	Longitude	Elevation (meter)
1	GW1	Ratu Road	23^{0}22’24.1”	85^{0}16’53.4”	689
2	GW2	Ratu Road	23^{0}22’42.5”	85^{0}17’48.0”	686
3	GW3	Ratu Road	23^{0}22’44.2’’	85^{0}18’42.2”	645
4	GW4	Hinoo	23^{0}19’20.2”	85^{0}19’5.50”	646
5	GW5	Hinoo	23^{0}19 ’37.6”	85^{0}19’10.0”	642
6	GW6	Doranda	23^{0}20’13.2”	85^{0}19’28.3’’	633
7	GW7	Doranda	23^{0}20’10.9”	85^{0}19’13.5”	632
8	GW8	Harmu	23^{0}21’43.4”	85^{0}18’23.17”	640
9	GW9	Harmu	23^{0}21’43.4”	85^{0}18’13.2”	667
10	GW10	Morabadi	23023’31.3”	85^{0}20’16.9”	651
11	GW11	Morabadi	23^{0}23’39.5”	85^{0}20’44”	624
12	GW12	Morabadi	23^{0}23’34.8”	85^{0}20’27.2”	638
13	GW13	Bariyatu	23^{0}23’42.8”	85^{0}21’15.6”	649
14	GW14	Bargai Basti	23^{0}24’12.1”	85^{0}22’13.3”	674
15	GW15	Rani Bagan	23^{0}23’25.1”	85^{0}22’5.6”	643
16	GW16	Band Gari	23^{0}23’29.9”	85^{0}22.7.6”	644
17	GW17	Kanke	23^{o}24'27.6"	85^{o}19'00.7"	679
18	GW18	Near Mecon	23^{o}20'33.6"	85^{o}18'14.1"	656
19	GW19	Hatia	23^{o}17'54.9"	85^{o}16'29.2"	699
20	GW20	D.T.H.E.C	23^{o}18'1.6"	85^{o}15'52.7"	671
21	GW21	Hawai Market	23^{o}18'49.4"	85^{o}19'4.7"	641
22	GW22	Solanki Basti	23^{o}17'34.6"	85^{o}19'12.1"	650
23	GW23	Hisang Basti	23^{o}17'59.5"	85^{o}19'59.3"	647
24	GW24	Latma Road	23^{o}17'59.5"	85^{o}19'15.8"	644
25	GW25	Latma Basti	23^{o}17'55"	85^{o}19'59.7"	672
26	GW26	Harmu Market	23^{o}21'35.9"	85^{o}18'17.9"	715
27	GW27	Harmu	23^{o}21'19.4"	85^{o}18'45.1"	671

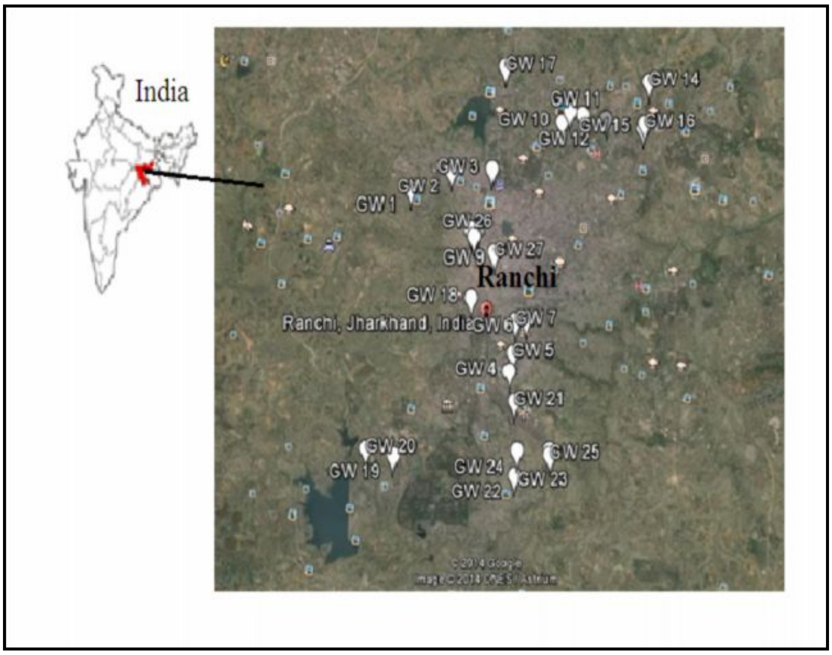

Figure 1. Location map of Ranchi Township showing the sampling site

For the assessment of groundwater quality of the Ranchi township area, systematic samplings were carried out during post- monsoon, 2013 (Fig. 1 & Table 1). Twenty Seven water samples were collected from well and tube well of the Ranchi township area. The groundwater samples were collected in one liter narrow mouth pre-washed polyethylene bottles. Temperature, electrical conductivity (EC) and pH values were measured in the field using a portable conductivity and pH meter. In the laboratory, the water samples were filtered through 0.45 µm Millipore membrane filters to separate suspended particles. Twelve parameters were analysed for WQI such as pH, Total Dissolved Solid (TDS), Total Hardness (TH), Bicarbonate (HCO_3^-),, Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Fluoride (F^-), Chloride (Cl^-), Nitrate (NO_3^-) and Sulphate (SO_4^{2-}).

Estimation of WQI

WQI a well known method as well as one of the most effective tools to express water quality that offers a simple, stable, reproducible unit of measure and communicate information of water quality to the policy makers and concerned citizens. It thus, becomes an important parameter for the assessment and management of groundwater[16]. WQI's aim at giving a single value to the Water quality of a source reducing great amount of parameters into a simpler expression and enabling easy interpretation of monitoring data[15]. Water Quality Index, a technique of rating water quality, is an effective tool to assess quality and ensure sustainable safe use of water for drinking[11]. For assessing the suitability of drinking water, the water quality data of the analyzed samples were compared with the prescribed drinking water standard of BIS 2003 (IS:10500) have been considered for the calculation of WQI[16]. The Indian Standards as per ISI for the drinking water together with its corresponding status categories of WQI[17]**.** For computing WQI three steps are followed. In the first step, each of the 10 parameters (pH, TDS, F^-,Cl^-, NO_3^-, SO_4^{2-} HCO_3^-, Ca^{2+}, Mg^{2+} ,TH) has been assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purposes (Table 2)

Table 2. Relative weight of chemical parameters

Chemical parameters	Standards (BIS)	Weight (w_i)	Relative weight (W_i)
pH	8.5	4	0.11
TDS	500	5	0.13
Fluoride	1	5	0.13
Chloride	250	5	0.13
Nitrate	45	5	0.13
Sulphate	200	5	0.13
Bicarbonate	200	1	0.03
Calcium	75	3	0.08
Magnesium	30	3	0.08
Total Hardness	300	2	0.05
		$\sum w_i$=38	$\sum W_i$ =1.00

All concentration in mg/l, accept pH

The maximum weight of 5 has been assigned to the parameters like TDS, F^-, Cl^- NO_3^-, and SO_4^{2-} due to their major importance in water quality assessment[18,11]. HCO_3^- is given the minimum weight of 1 as it plays an insignificant role in the water quality assessment. Other parameters like Ca^{2+}, Mg^{2+} Na^+, and TH were assigned weight (w_i) between 1 and 5 depending on their importance in water quality determination. In the second step, the relative weight (W_i) is computed from the following equation:

$$W_i = w_i / \sum_{i=1}^{n} w_i \quad (1)$$

Where, the W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters.

Calculated relative weight (W_i) values of each parameter are given in (Table 2).

In the third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS 10500 (2003) and the result is multiplied by 100:

$$q_i = (C_i/S_i) \times 100 \qquad (2)$$

Where, the q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample in mg/l and S_i is the BIS standard for each chemical parameter in mg/l according to the guidelines of the BIS 10500 (2003).

For computing the WQI, the *SI* is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation

$$SI_i = W_i \times q_i \qquad (3)$$

$$\text{WQI} = SI_i \qquad (4)$$

Where, the SI_i is the sub-index of i^{th} parameter, q_i is the rating based on concentration of i^{th} parameter and n is the number of parameters.

Water quality category, were determined on the basis of WQI. The computed WQI values range from 29 to 139 and average 70 respectively (Fig. 2). WQI range and category of water can be classified (Table 3). The highest WQI were calculated from the samples collected from the Harmu, Band Gari, and Latama Basti sampling locations (Table 4). Among all the of the groundwater samples, the percentage (%) of WQI categories Very Good (18%), Good (67%) and Poor (15 %) were observed. More than half the location falls in Very Good to Good category (Fig. 3).

Table 3. Classification of WOI range and category of water

WQI Range	Category of water
<50	Very Good water
50-100	Good water
100-200	Poor water
200-300	Very Poor water
>300	Unfit for drinking purpose

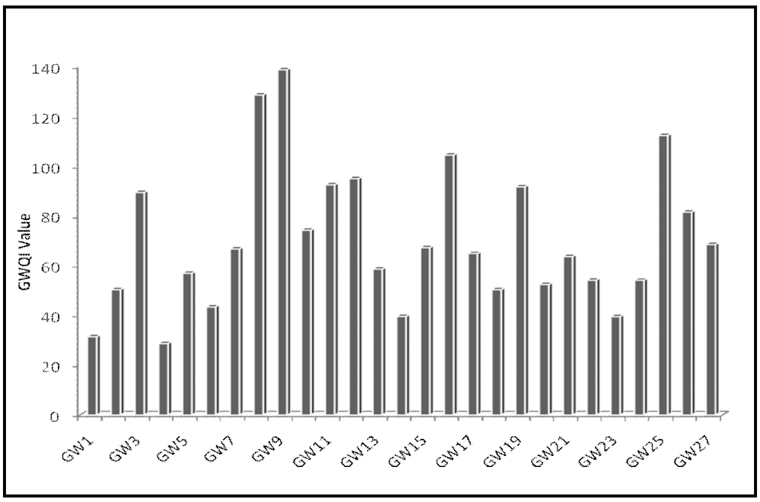

Figure 2. Graphs showing location wise GQWI in Ranchi Township

Table 4. Water Quality Index for Groundwater of Ranchi Township area

S. No.	**Sample Code**	**GWQI Value**	**Description**
1	GW1	31	Very Good
2	GW2	50	Good
3	GW3	89	Good
4	GW4	29	Very Good
5	GW5	57	Good
6	GW6	43	Very Good
7	GW7	67	Good
8	GW8	129	Poor
9	GW9	139	Poor
10	GW10	74	Good
11	GW11	92	Good
12	GW12	95	Good
13	GW13	59	Good
14	GW14	40	Very Good
15	GW15	67	Good
16	GW16	104	Poor
17	GW17	65	Good
18	GW18	50	Good
19	GW19	92	Good
20	GW20	52	Good
21	GW21	64	Good
22	GW22	54	Good
23	GW23	40	Very Good
24	GW24	54	Good
25	GW25	112	Poor
26	GW26	81	Good
27	GW27	69	Good

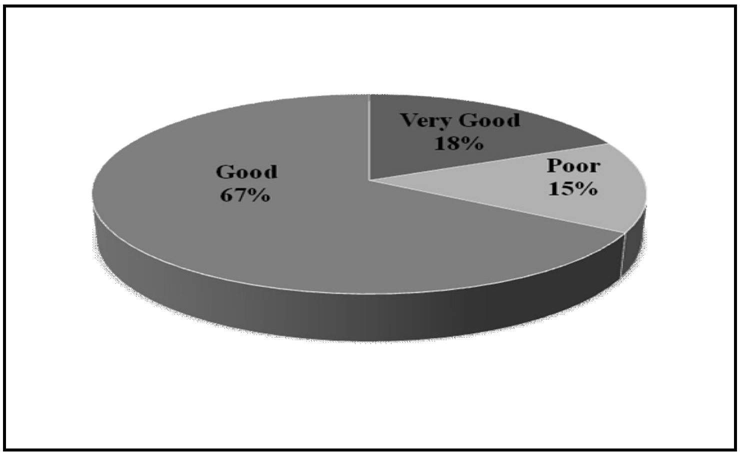

Figure 3. WQI Categories of Samples (%)

Conclusions

The WQI for 27 samples ranges from 29 to 139. The WQI shows that 85% of groundwater samples were found as Very Good to Good category and can be use for direct consumption while 15% of water samples are the Poor category shows that the water is not suitable for direct consumption and requires treatment before its utilization. The high value of WQI at these stations has been found to be mainly from the higher values of total dissolved solids, hardness, fluorides, bicarbonate, chloride, nitrate and calcium in the groundwater.

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