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GROUNDWATER QUALITY MAPPING BY USING GEOGRAPHIC INFORMATION SYSTEM (GIS): A CASE STUDY OF BARIPADA CITY, ODISHA, INDIA

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Abstract

Groundwater samples were collected from 12 locations in the Baripada urban area and its surrounding settlements to analyze their quality, so as to ascertain their suitability for drinking and agricultural use. In addition to TDS (total dissolved solids) and TH (total hardness), the concentration of several ions such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-} and SO_4^{2-} were measured. Analysis results showed that the concentration of $Ca2^{+}$ and HCO_3^{-} was higher in comparison to other ions. The value of TDS and TH and the concentration of major ions were well within their limiting values, as recommended by the World Health Organization (WHO). It was found that the water was completely fit for drinking. Taking into consideration the %Na and SAR (sodium absorption ratio), the groundwater was also found to be suitable for irrigation.

Keywords: *GIS; Ground Water Sample; Suitability analysis; Baripada*

Introduction

Groundwater is one of earth's most vital renewable and widely distributed resources as well as an important source of water supply throughout the world. The quality of water is a vital concern for mankind since it is directly linked with human welfare. In India, most of the population is dependent on groundwater as the only source of drinking water supply [1]. Water plays an important role in the development of human society. Fresh water that every living being necessitates constitutes only 2.8% of the total water available on earth. More than 98% of the available fresh water is groundwater. As the population is increasing at a fast pace, there is rise in demand for water. The amount of surface water available for human consumption is much less than what is required. As a result, more and more emphasis is exerted on exploration and exploitation of groundwater. This is more relevant when the terrain such as in our case is undulating and a greater part of water from the atmosphere is lost in run-off. As a result, groundwater becomes the ultimate source for human consumption. In this regard, it becomes imperative that the groundwater should be qualitatively good and potable. Geographic Information System (GIS) has emerged as a powerful tool for storing, analyzing, and displaying spatial data and using these data for decision making in several areas including engineering and environmental fields [2-6].

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Compared to other methods [7-11] applied for assessing the productive potential of agricultural lands, the GIS technique use enables computer-based easy data storage and processing of complex data, geo-referenced and descriptive data coming from various sources, providing the decision makers in the agricultural and territorial management with the information they need in a short time and at a much lower cost [3-6]. Their integration in multicriteria analysis coupled to use of Geographic Information System (GIS) has then used to delineate protection area with underground water [3, 4].

In general, the increasing tendency of nitrates and chlorides content in the underground waters is in direct correlation with the agricultural land for use methods and implicitly the leachate quantity, using modeling methods based on GIS technique. Both the physical pollution (due to processes such as: hydraulic or wind erosion, destructuring, compacting etc.) and chemical pollution (due to the alluvial transport with significant pesticide quantities) contributed to the degradation of the groundwater quality.

The main objective of the research work is to make a groundwater quality assessment using GIS, based on the available physical-chemical data from 12 locations in Baripada city. The purposes of this assessment are (1) to provide an overview of present groundwater quality, (2) to determine spatial distribution of groundwater quality parameters such as Hardness, TDS, NO_3^- and Cl^-, and (3) to generate groundwater quality zone map for the Baripada city.

Study area

The area under study has an aerial extent of $100km^2$ and is situated between latitudes 21.54-21.58N and longitudes 86.42-86.46E (Fig. 1). It is consisted of around 24 villages including Baripada town which is the district headquarter of Mayurbhanj district and they all have a combined population of around four lakh out of which a majority belongs to various tribes. Since agriculture and animal husbandry are the main occupations of the populace here, water has become an important commodity. Though river Budhabalanga flows nearby, no proper surface irrigation system has been developed. For drinking, piped water supply has been provided only to a few places of the urban area. In rest of the places, people depend on dug wells and tube wells. Monsoon is said to be the chief source of water for irrigation.

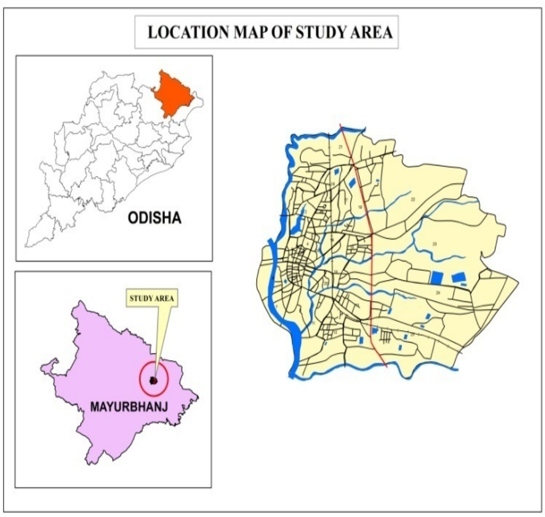

Fig. 1. Location of the Study area

Geology and hydrogeology of the study area

The study area has Archaeans of Singhbhum and Keonjhar on the north and west. The remnants of Archaeans and parts of the Similipal Lava are found as denudational hills exposed here and there with long stretching pediplains towards the east. Since these beds containing marine fossils are found on the eastern fringe of the Precambrians of Keonjhar. Here the groundwater occurs mainly in sandy and gravely horizons both in the zone of aeration and zone of saturation of Baripada Bed. All the dug wells occur in the zone of aeration at a depth of 55-65feet below ground level (BGL). In the summer, due to their phreatic nature, they either completely dry up or the water table goes much below the ground. While the water table in the pre-monsoon lies at a depth of as low as 18meter BGL, in the post monsoon that becomes 5 meter BGL. In the zone of saturation, the groundwater horizons those feeding the tube wells occur at depths of 95-105feet and 160-180feet. All the above aquifers are unconfined in nature. However, beyond 200feet, the groundwater mainly occurs in confined condition.

Methodology

Groundwater sample collection and analysis

As part of the study altogether twelve groundwater samples were collected from a dozen of population clusters of Baripada, representing one from each zone/ward of the city (Fig. 2). The samples taken during March 2012 were analyzed for various physico-chemical parameters. Bottles used for water sample collection are first thoroughly washed with the water being sampled and then were filled. After collection of the samples, the samples are preserved and shifted to the laboratory for analysis. Physico-chemical analysis was carried out to determine TDS (total dissolved solid), TH (hardness), EC (electrical conductivity), Cl^-, and NO_3^-, and compared with standard values recommended by World Health Organization [12] and Indian Standard Institution (Table 1).

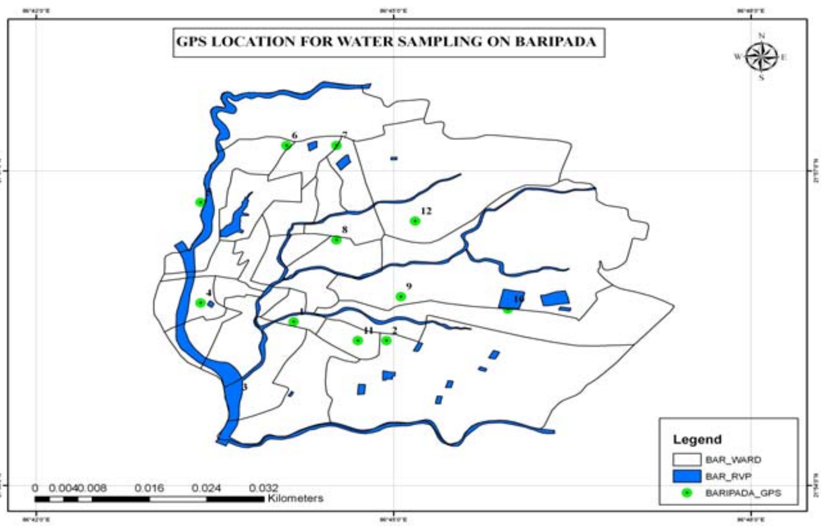

Fig. 2. GPS location of water sampling

Table 1. Standard value of World Health

Parameter	WHO (mg/L)	ISI (mg/L)
Total disolved solid (TDS)	500	500
Hardness (TH)	500	600
Chloride (Cl^-)	200	250
Nitrate (NO_3^-)	40	45

Preparation of well location point feature

We obtained the location of 12 wells all over the study area by using a handheld GPS instrument GARMIN GPS-60 receiver. GPS technology proved to be very useful for enhancing the spatial accuracy of the data integrated in the GIS. We utilized ArcGIS software in our study. Based on the location data we obtained, we prepared point feature showing the position of 12 wells From these wells, we collected and analyzed groundwater samples for the study area. The water quality data thus obtained forms the non-spatial database. It is stored in excel format and linked with the spatial data by join option in ArcMap. The spatial and the non-spatial database formed are integrated for the generation of spatial distribution maps of the water quality parameters.

Criteria for acceptability and rejection in water quality

In this stage, the criteria for suitability and non-suitability of the water samples were elucidated for analysis. This was performed based on the water quality standards stipulated by the WHO, and ISI. Ranks were assigned for each parameter depending on the respective tested values, as given in the Table 2.

Table 2. Criteria for acceptability and rejection in water quality

Samples No.	Parameter	Rank	Criteria	Remark
1	TDS (mg/L)	1	< 500	Desired
		2	500-1000	Acceptable
		3	>1000	Not acceptable
2	TH (mg/L)	1	<500	Desired
		2	500-1000	Acceptable
		3	>1000	Not acceptable
3	Cl^- (mg/L)	1	<250	Desired
		2	250-1000	Acceptable
		3	>1000	Not acceptable
4	NO_3^- (mg/L)	1	<45	Desired
		2	45-100	Acceptable
		3	>100	Not acceptable

The characteristics of the groundwater for this study area are represented in tables 3, 4 and 5.

Table 3. Groundwater hydrochemistry (expressed in mg/L) during the pre-monsoon season (2012)

Sl no.	Name of area	pH	EC*	TDS	SO_4^{2-}	CO_3^{2-}	Mg^{2+}	Na^+	K^+	Cl^-	HCO_3^-
1.	Station Bazar	8.32	845	580	95.0	34	40.32	35	2.4	41.52	185.2
2.	Sanamahi	8.34	903	695	96.0	42	23.25	74	8.5	80.53	190.5
3.	Jagarnath Temple	8.31	841	645	75.8	36	46.52	65	10.6	70.5	211.1
4.	Belgadia	8.40	893	615	95.0	12	41.61	50	7.5	55.72	132.5
5.	Jamunadipur	7.89	715	485	110.0	24	33.05	35	4.6	42.51	190.5
6.	Murgabadi	8.45	631	540	110.0	12	51.42	25	3.5	28.35	79.5
7.	Dargahi	8.35	665	451	132.0	0	36.70	25	4.5	31.92	79.5
8.	Takatpur(u)	7.68	472	300	76.5	30	7.36	24	3.8	28.25	175.8
9.	Takatpur	8.33	555	382	45.0	42	37.95	12	2.6	31.95	173.4
10.	Palbani	8.36	579	375	9.5	18	3.65	25	25.5	27.38	215.5
11.	Raghunathpur	8.35	623	395	4.6	24	0	19	19.3	14.16	105.8
12.	Chipatastia	8.31	585	391	9.5	24	4.65	25	6.5	15.11	110.3

* EC – Electrical conductivity, measured in milliomhs/cm

The physico-chemical characteristics were analyzed during the pre-monsoon season (2012). After analysis we see that the pH of Baripada is range from 6.5 to 8.5, the EC is range from 190-695 milliomhs/cm, the TDS is range from 122-395mg/L, the Ca^+ is range from 12.0

to 36.0mg/L, Mg^{2+} in range from 2.41 to 34.02mg/L, Na^{+} is range from 3.20 to 31.30mg/L, the K^{+} is range from 0.40 to 4.00mg/L, the SO_4^{2-} is range from 0 to 2.50mg/L, the CO_3^{2-} is range from 0 to 12.00mg/L and the HCO_3^{-} is range from 48.00 to 158.60mg/L. These characteristics confirm that the water is completely fit for use in drinking and irrigation purpose (Tables 3 and 4). Also, after chemical testing of water sample found that normal hardness of water (Table 5).

Table 4. The range of physical-chemical characteristics of groundwater in the area studied

Sl no.	Name of analyzed parameter	Range (From)	Range (To)
1.	pH	6.80	8.50
2.	EC (milliomhs/cm)	190.00	695.00
3.	TDS (mg/L)	122.00	395.00
4.	Ca^{2+}(mg/L)	12.00	36.00
5.	Mg^{2+}(mg/L)	2.41	34.02
6.	Na^{+}(mg/L)	3.20	31.30
7.	K^{+}(mg/L)	0.40	4.00
8.	SO_4^{2-}(mg/L)	0.00	2.50
9.	CO_3^{2-}(mg/L)	0.00	12.00
10.	HCO_3^{-}(mg/L)	48.00	158.60

Table 5. Groundwater hardness in study area

Sl. no	Name of observation wells	Hardness of water (°G)
1.	Station Bazar	330
2.	Sanamahi	265
3.	Jgaarnath temple	250
4.	Belgadia	250
5.	Jamunadipur	310
6.	Murgabadi	270
7.	Dargahi	310
8.	Takatpur(u)	270
9.	Takatpur	100
10.	Palbani	210
11.	Raghunathpur	185
12.	Chipatastia	205

Suitability for drinking and irrigation purpose

As the concentrations of TDS, sodium and chloride ions in groundwater have a bearing on human health, a detailed discussion is felt necessary. Drinking water standards are generally based on two main criteria (1) presence of objectionable taste, odor and color, and (2) presence of substances with adverse physiological characteristics. As far as the first criterion is concerned, none of the water samples has objectionable color and odor. For considering a groundwater as potable, WHO has recommended certain limiting concentration of various ions. The maximum permissible limit of TDS, Na^{+} , Cl^{-} and SO_4^{2-} which are strictly considered for portability are 1000 mg/L, 200 mg/L, 200 mg/L and 400 mg/L respectively. From Table 1, it is evident that the maximum concentration of various parameters at all the places is within the recommended limit. So the groundwater at these places is perfectly suitable for drinking and irrigation purpose in both the seasons.

Conclusions

Ground water samples were collected at random from several places, to analyze their hydrochemistry, so that their suitability for drinking and agricultural use could be determined. Concentration of several ions such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-} and SO_4^{2-} were determined. After chemically testing the water samples we found that water had a normal hardness. Hydrochemical analysis confirmed that the water was completely fit for drinking and irrigation purposes. The water level of the Baripada town depends on rainfall. From a chemical point of view the ground water is potable, as well as soft enough for domestic and industrial use

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