International Journal of Lakes and Rivers. ISSN 0973-4570 Volume 14, Number 2 (2021), pp. 211-222 © Research India Publications https://dx.doi.org/10.37622/IJLR/14.2.2021.211-222 □

# Hydrochemical Assessment of Groundwater in the Spit-Bar System of Chilika Lagoon in Krushnaprasad Block, Odisha, India

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#### **Abstract**

Groundwater hydrochemistry in some parts of Krushanprasad block was determined to assess its quality. Krushnaprasad block is not a single Unit. Some part of it is situated in the main land and some part in form of island within Chilika lagoon. Groundwater samples from 30 different island locations were collected in the post monsoon season. It was found that the groundwater is rich in sodium, magnesium and chloride ions as compared to calcium, potassium, bicarbonate and sulphate ions. The analysis was carried out as per international standards. The groundwater is high in TDS. The parameters chloride / bicarbonate, magnesium/calcium were used to identify the intrusion of salt water in the coastal aguifers. It was concluded that groundwater of Krushnaprasad block in the island regions is in danger under the saltwater intrusion condition. The main groundwater type is sodium chloride type followed by Magnesium chloride waters. The groundwater in most part of the study area is not fit for drinking and for agriculture. The anthropogenic factor may be taken as one of the factors for seawater intrusion. The results were observed and compared with standards of WHO, ICMR and ISI so as to determine its suitability for different use.

# INTRODUCTION

In Odisha, many rural settlement pockets are located along the coastal tracts. In these centers, apart from dwelling apartments, industrial organizations have also come up. Due to this demographic setting, overexploitation of groundwater resources are found to be taking place. Except in the Summer, the status of fresh water availability remains satisfactory. Fresh water becomes available from surface sources such as ponds and rivers. During this time, the groundwater is rarely utilized. However in the summer, surface water depletes and groundwater comes under mounting pressure both from human settlements and from industrial units. Due to continuous drawl of

groundwater, the water level goes down and invites the adjoining saline water to invade the fresh water areas giving rise to salt water intrusion. Such occurrences of saline water has been reported from different pockets of coastal Odisha, such as Balasore, Bhadrak, Jagatsinghpur, Puri and Ganjam. In such situations, the groundwater has to be assessed for its use for drinking, industry and agriculture. Saline water may pollute the fresh water wells. It may lead to rusting of industrial components and use of saline water may bring negative growth to standing crops. Though much work has been carried out in northern coasts, the central part of coastal Odisha lacks such research work. For this purpose, a part of Krushnaprasad block has been selected and was taken for carrying out the groundwater quality work.

## **STUDY AREA**

The study area (Fig. 1) is located between longitudes 85° 10' 28.38''E and 85° 37' 50.68''E and latitudes 19° 28' 00.58''N and 19° 53' 02.25''N falling in Survey of India toposheet no. E45B2, E45B6, and E45B10, in 1:50,000 scale and covers an area of about 151 km² in Krushnaprasad, in the coastal belt of Odisha. It is located approximately 75.6 km east of the district headquarter, Puri. Its elevation is 25 m above sea level and is about 174 km away from the state capital Bhubaneswar. A major part of Krushnaprasad Block in the Puri district is situated in the mainland. Only some portion of this block is situated within the Chilika lagoon as islands. Even some villages are found in the spits and barriers in the periphery of the lagoon system. National estimation of beach change has identified Krushnaprasad as one of the environmental hotspots and, in eastern coastal tract of Odisha, the salinity hazard is widespread.

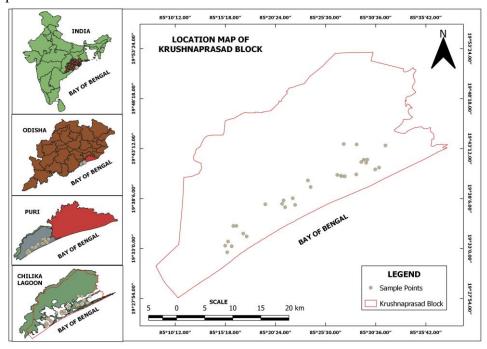


Fig. 1: Location map of Krushnaprasad block

# GEOLOGY AND GEOMORPHOLOGY OF THE STUDY AREA

The entire Puri district can be subdivided into two natural divisions - (I) the littoral tract and (II) the alluvial tract. The littoral tract which takes the form of a sandy ridge varies approximately 6.5 km to a few hundred metres in width and lies between the alluvial tract and the Bay of Bengal. There are ridges in this tract which have been formed due to accumulations of windblown sand. The alluvial tract has been formed mainly due to the deposition of the southern branches of the Mahanadi River. The broad soil group of the eastern and south eastern coastal plain of Odisha to which Krushnaprasad belongs is essentially deltaic alluvial and lateritic in nature.

The study area forms part of Mahanadi delta and it is underlain by unconsolidated alluvial sediments of Sub-Recent to Recent periods. According to Mahalik (2000)<sup>10</sup>, the sediments comprise mainly of sand, clay, gravel and silt of varying proportions. The sand and gravel layers generally form potential aquifers. The sediments deposited are in heterogeneous pattern due to several phases of marine transgression and regression and depositional environments.

The Quaternary period consists of laterites and alluvium. While the laterite occurs only in the western and north-western parts, major parts of the area are covered by alluvium of varying thickness. The older alluvium is generally exposed in the north-western parts including a sequence of sand, clay and kankars of grey to brown in colour. The younger alluvium, which covers nearly 90% of the area, occurs as floodplain deposits along the course of major rivers and streams. These sediments consist of an admixture of silt, sand, gravel and pebble in varying proportions. These layers increase in thickness towards the sea, showing a gentle dip. Discontinuous ridges of sand dunes occur along the coast and are formed due to wind action.

- (i) Areas underlain by alluvium.
- (ii) Areas underlain by fractured, fissured and consolidated basement rock formations.

A few ash beds of volcanic origin have been recorded in Mahanadi river valleys. It is believed that they are belonging to an age of 74,000 years. Besides the above, Quaternary sediments are met with in both coastal tracts and upland river valley.

Hydrogeologically, the Puri district can be sub-divided into 3 broad regions viz; unconsolidated formation, consolidated formation and the hilly areas. The unconsolidated formation comprises of sand, silt, clay and 30% of the district is underlain by this formation. The groundwater in near surface shallow aquifer occurs under pheratic conditions, even down to a depth of 135m below ground level.

# DATA AND METHODOLOGY

All the data used for preparing this paper are primary in nature and they are mostly belonging to the hydrochemical domain of groundwater in parts of Krushnaprasad Block. For that purpose, thirty groundwater samples were collected from different sites of Krushanprasad Block in clean, well dried plastic bottles during the pre-

monsoon period. Water samples were analysed for temperature, pH, Electrical conductivity (EC), Total Dissolved solids (TDS), bicarbonate, total hardness, calcium, magnesium, chloride, sulphate, sodium, and potassium. Electrical conductivity and pH of the water samples were measured in the field instantaneously with potable Systronics pH and EC meters. Ca<sup>++</sup> and Mg<sup>++</sup> were determined by titrating with standard EDTA. Cl<sup>-</sup> was estimated titrimetrically using standard AgNO<sub>3</sub> solution. Na<sup>+</sup> and K<sup>+</sup> were determined using a Systronics flame photometer of type 128. SO<sub>4</sub><sup>--</sup> was determined by turbidimetric method (Clesceri et.al.1998)<sup>4</sup>. The collection, preservation and the analysis of various physico-chemical parameters were analysed according to APHA (1985)<sup>3</sup> guidelines.

#### **RESULTS**

The results of chemical analysis of the groundwater samples are presented in Table-1 and, Table-2 shows the range in values along with World Health Organization (WHO, 1993)<sup>17</sup> standards. The data show that the samples are enriched in Na<sup>+</sup>, Ca<sup>++</sup>, Mg<sup>++</sup>, Cl<sup>-</sup> and HCO<sub>3</sub><sup>-</sup> ions as compared to K<sup>+</sup> and SO<sub>4</sub><sup>--</sup> ions.

**Table 1.** Water Quality Parameters and their concentrations (in mg/l), ratio parameters with no dimension

LOCATION	Ca <sup>++</sup>	$Mg^{++}$	Na <sup>+</sup>	$K^{+}$	HCO <sub>3</sub> -	Cl-	SO <sub>4</sub>	TDS	Na+/Cl-	Cl <sup>-</sup> /HCO <sub>3</sub> -	Mg++/Ca++	TH	%Na
Fatepur	34.92	30.49	854.20	374.60	754.73	1243.00	96.20	3398	1.06	2.83	1.44	300	91.66
Adalabad	65.00	35.00	873.98	29.09	743.75	1048.92	63.81	2875	1.28	2.43	0.89	320	86.36
Ora	10.00	26.49	469.80	27.41	1135.97	81.34	88.25	1852	8.91	0.12	4.37	290	88.75
Hunda	30.00	43.34	808.92	35.03	2332.61	72.74	24.40	3359	17.15	0.05	2.38	280	87.70
Balarampur	75.00	27.95	135.80	38.33	322.03	175.00	20.62	820	1.20	0.94	0.61	160	53.27
Gilinasi	45.00	40.30	1080.77	48.39	455.06	1581.73	75.00	3345	1.05	5.98	1.48	189	89.67
Kanheipur	57.00	35.55	742.83	52.47	209.67	1209.35	22.10	2341	0.95	9.93	1.03	360	85.37
Patapur	10.00	18.24	198.43	48.29	245.00	125.00	24.90	676	2.45	0.88	3.01	320	83.15
Harichandanpur	12.00	24.68	166.50	185.14	275.00	150.00	37.94	862	1.71	0.94	3.39	270	82.00
Biripadar	16.00	41.08	1380.72	32.52	379.01	2059.73	18.20	3938	1.03	9.35	4.23	400	93.58
Balijagannathpur	8.00	51.62	269.50	44.03	412.22	258.21	28.50	1082	1.61	1.08	10.64	650	73.45
Deulaparha	22.00	39.18	292.02	72.90	487.06	242.76	150.00	1315	1.85	0.86	2.94	280	77.12
Patharakata	28.00	12.40	1269.74	75.43	1066.28	1428.72	75.00	3965	1.37	2.31	0.73	190	95.94
Chadheya	32.00	43.17	184.04	112.05	241.23	204.10	55.00	885	1.39	1.46	2.22	483	67.86
Bhabanipur	100.00	78.00	588.30	37.16	830.23	735.52	25.00	2410	1.23	1.52	1.29	178	69.94
Parala	29.96	31.75	1072.45	107.56	322.00	1669.35	32.00	3277	0.99	8.92	1.75	179	92.33
Baghamunda	50.92	31.06	868.05	34.94	211.00	1398.52	38.00	2651	0.96	11.41	1.01	195	88.35
Banamalipurpatna	85.00	26.50	422.02	65.47	160.00	617.51	30.00	1416	1.05	6.64	0.51	200	75.73
Guptapur	45.21	24.82	161.10	50.85	150.00	329.10	40.00	820	0.75	3.78	0.91	320	65.91
Nathpur	31.00	47.43	292.01	51.85	358.04	243.65	42.20	1080	1.85	1.17	2.52	220	72.02
Bankijal	19.00	29.17	1269.50	40.30	156.00	1999.81	45.20	3567	0.98	22.06	2.53	240	94.38
Baulapatana	50.00	12.24	827.37	33.89	125.99	1298.52	67.10	2431	0.98	17.74	0.40	270	91.32
Alupatana	24.96	34.88	1042.41	28.75	158.99	1665.58	25.50	2994	0.97	18.03	2.30	220	91.80
Naubarhi	42.00	32.12	388.44	43.34	190.00	566.79	82.10	1358	1.06	5.13	1.26	280	79.17
Porhadhihi	32.00	29.18	1014.96	38.04	230.00	1528.00	110.00	2998	1.02	11.43	1.50	290	91.86
Sana Basantapur	34.00	12.87	157.43	63.04	279.97	185.95	22.00	769	1.31	1.14	0.62	320	75.43
Gangadharpur	36.00	40.87	332.81	35.09	403.10	450.00	12.00	1317	1.14	1.92	1.87	225	74.88
Mirzapur	11.00	30.35	834.24	21.29	119.18	1334.77	16.00	2378	0.96	19.28	4.55	410	92.36
Gobakund	26.00	20.68	1086.87	33.36	561.13	1442.02	20.00	3220	1.16	4.42	1.31	290	94.14
Bhagabanpur	24.00	18.17	1660.19	33.40	268.22	2493.39	24.10	4539	1.03	16.00	1.25	175	96.45

**Table 2:** Water Quality Standards of various agencies:

Sl. Parameters		Observed	ISI Maximum	ICMR Maximum	WHO	
No.		Range of values	Permissible limits	Permissible	Guidelines	
		in mg/l		limits		
1	Colour	-	10	25		
2	Test	-	Agreeable	Unobjectionable		
3	Odor	-	Unobjectionable	Unobjectionable		
4	Turbidity	-	10 NTU	25 JTU		
5	pН	7.01-7.72	6.5 - 8.5	6.5 - 9.2		
6	TDS (in mg/l)	676-4539	500	1500-3000		
7	TH (in mg/l)	160-650	300	600		
8	Ca (in mg/l)	8-100	75	200	200	
9	Mg (in mg/l)	12.24-78.0	30			
10	Fe (in mg/l)	-	0.3	1.0	10 (Total	
					Iron)	
11	Cu (in mg/l)	-	0.05	1.5	1.5	
12	Mn (in mg/l)	-	0.1	0.5	0.5	
13	SO <sub>4</sub> (in mg/l)	12.0-150.0	150	400	400	
14	Cl (in mg/l)	72.24-2493.39	250	1000	250	
15	NO <sub>3</sub> (in mg/l)	-	45	100	10	
16	F (in mg/l)	-	0.6 - 1.2	1.5	1.5	
17	Hg (in mg/l)	-	0.001	0.001		
18	Cd (in mg/l)	-	0.01	0.01		
19	As (in mg/l)	-	0.05	0.05		
20	Cn (in mg/l)	-	0.05	0.05		
21	Pb (in mg/l)	-	0.1	0.05		
22	Zn (in mg/l)	-	0.5	0.10		
23	Cr (in mg/l)	-	0.05			
24	Na (in mg/l)	135.8-1600.19	-		200	

The concentration of all the major ions ranged between wide limits. Chemical analysis results indicate that the concentration of Ca<sup>++</sup>, Mg<sup>++</sup>, Na<sup>+</sup> and K<sup>+</sup> ions varied from 8 mg/l to100 mg/l, 12.24 mg/l to 78.0 mg/l, 135.8mg/l to 1600.19mg/l and 21.29 mg/l to 374.60 mg/l respectively. On the other hand, the anions such as Cl<sup>-</sup>, HCO<sub>3</sub><sup>-</sup>, and SO<sub>4</sub><sup>--</sup> showed variation from 72.74 mg/l to 2493.39 mg/l, 119.1824 mg/l to 2332.61 mg/l, and 12.0 mg/l to 150.0 mg/l, respectively. The concentration of Na<sup>+</sup> at Fatepur, Adalabad, Ora, Hunda, Gilinasi, Kanheipur, Biripadar, Balijagannathpur, Deulaparha, Patharakata, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Nathpur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Gangadharpur, Mirzapur, Gabakund, Bhagabanpur locations Showed higher values than what is recommended by WHO as Maximum Permissible Limit for drinking water.

Total hardness (TH) indicates the trend in the concentration of Ca<sup>++</sup> and Mg<sup>++</sup> with a value ranging from 160 mg/l to 650 mg/l. The total dissolved solids (TDS) values, representing the total salt content in the water, ranged between 676 mg/l and 4539 mg/l, amongst which at locations Fatepur, Adalabad, Ora, Hunda, Gilinasi,

Kanheipur, Biripadar, Balijagannathpur, Deulaparha, Patharakata, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Nathpur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Gangadharpur, Mirzapur, Gabakund, Bhagabanpur, the values were higher than the recommended value of 1000 mg/l, the maximum permissible limit for water.

Drinking water standards are generally based on two main criteria (Davis and De Wiest, 1966)<sup>6</sup>: (1) presence of objectionable tastes, odor, and color and (2) presence of substances with adverse physiological (health effects) characteristics. The chemical analysis results showed that the groundwater in the landward locations of the study area is potable, but waters close to shrimp ponds are unfit for drinking as they contain objectionable levels of TDS, Na<sup>+</sup> and Cl<sup>-</sup>.

#### **DISCUSSION:**

Most of the study area are entirely situated in islands and is geomorphologically situated in the continental shelf of East Coast of India. The geology is dominated by Quaternary sediments which are reworked several times before they rest finally to form the island. These islands have assembled themselves into spits and bars in the eastern periphery of the lagoon. So, it can be deciphered that the sediments are ultimately deposited here which once upon a time were exposed in the mainland. It, therefore, can be concluded that the major ions have been derived from the rock forming minerals constituting the lithology of the terrestrial domain. In normal conditions also, the regional geology determines the hydrochemistry of groundwater (Amadi, 1987)<sup>2</sup>. However, the erratic concentrations of the major ions observed in the water samples can be attributed to cation exchange process involving the aquifer materials (Mercado, 1985)<sup>11</sup>. However, a major trend that has been observed in this work is the elevated level of TDS, chloride, magnesium and sodium ions which are much much higher in content in the central regions of the islands.

The occurrence of salt water mixing or salt water intrusion can well be verified by considering the total dissolved contents (TDS) of the groundwater. The level of TDS in normal groundwater is generally less than 500 mg/l. In inland areas, groundwater at greater depths records higher TDS due to dissolution of mineral matter in groundwater. It is very rare that the TDS crosses 1000 mg/l mark. However, in coastal locations, groundwater is easy to mix with adjoining sea water to assimilate more salt to it thus increasing the TDS level to a greater level. In the present study, the TDS varied between 676mg/l to 4539mg/l out of which Fatepur, Adalabad, Ora, Hunda, Kanheipur, Biripadar, Balijagannathpur, Gilinasi, Deulaparha, Patharakata, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Nathpur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Gangadharpur, Mirzapur, Gabakund, Bhagabanpur number of samples reported TDS greater than 1000 mg/l and Fatepur, Adalabad, Ora, Hunda, Gilinasi, Kanheipur, Biripadar, Patharakata, Bhabanipur, Parala, Baghamunda, Bankijal, Baulapatana, Alupatana, Porhadhihi, Mirzapur, Gabakund, Bhagabanpur number of samples reported their TDS even greater than 1500 mg/l. This TDS level is sufficient to prove that the groundwater is salt affected. Another important fact is that 18 samples have their TDS greater than 1500 mg/l and Fatepur, Adalabad, Hunda, Gilinasi, Kanheipur, Biripadar, Patharakata, Bhabanipur, Parala, Baghamunda, Bankijal, Baulapatana, Alupatana, Porhadhihi, Mirzapur, Gabakund, Bhagabanpur samples have their TDS more than even 2000 mg/l. This indicates that the water is not normal, rather they are affected by seawater intrusion.

The phenomenon of seawater intrusion has been elaborately observed by Lusezynski and Swarzenski (1966)<sup>9</sup> who opined that concentration of chloride greater than 50 mg/l indicates saltwater intrusion. Similarly, Trembley et al. (1973)<sup>15</sup>, during their research survey in the summer side area of Prince Edward Island opined that the concentration level of chloride higher than 40 mg/l indicates saltwater intrusion. Amadi (1989)<sup>1</sup> during his work in Niger delta found that the chloride concentration greater than 50 mg/l points towards seawater intrusion. In the present study, the groundwater samples collected from the coastal parts of the island and also in the inland areas have recorded greater level of Chloride. Almost all the samples have their Chloride concentration more than 50 mg/l. The Chloride varied between 72.74 mg/l to 2493 mg/l out of which Fatepur, Adalabad, Balarampur, Gilinasi, Kanheipur, Patapur, Harichandanpur, Biripadar, Balijagannathpur, Deulaparha, Patharakata, Chadhaeya, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Guptapur, Nathpur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Sana Basantpur, Gangadharpur, Mirzapur, Gabakund, and Bhagabanpur number of samples reported Chloride greater than 100 mg/l and Fatepur, Adalabad, Gilinasi, Kanheipur, Biripadar, Patharakata, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Mirzapur, Gabakund, and Bhagabanpur number of samples reported their Chloride greater than 500 mg/l. The Chloride recorded is even greater than 1000 mg/l at Fatepur, Adalabad, Gilinasi, Biripadar, Patharakata, Parala, Baghamunda, Bankijal, Baulapatana, Alupatana, Porhadhihi, Mirzapur, Gabakund, and Bhagabanpur number of places. Elevated levels of TDS is also an indication of salt water intrusion.

The occurrence of seawater intrusion is also confirmed by higher value Cl<sup>-</sup>/ HCO<sub>3</sub><sup>-</sup> and Mg<sup>++</sup>/Ca<sup>++</sup> (Todd, 1976)<sup>14</sup>. The results in Table-1 may be observed. It is seen that many places have recorded their Cl<sup>-</sup>/ HCO<sub>3</sub><sup>-</sup> greater than 2. Out of 30 locations, around 18 locations have recorded their Cl<sup>-</sup>/ HCO<sub>3</sub><sup>-</sup> greater than 2. Such places are Fatepur, Adalabad, Gilinasi, Kanheipur, Biripadar, Patharakata, Parala, Baghamunda, Banamalipurpatna, Guptapur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Mirzapur, Gabakund and Bhagabanpur. The ratio parameter Mg<sup>++</sup>/Ca<sup>++</sup> may also be considered. Out of 30 locations, around 12 locations have recorded their Mg<sup>++</sup>/Ca<sup>++</sup> greater than 2. These places are Ora, Hunda, Patapur, Harichandanpur, Biripadar, Balijagannathpur, Deulaparha, Chadheva, Natpur, Bankijal, Alupatana, and Mirzapur. The study of both the above two ratio parameters indicate that salt water intrusion has taken place due to which the groundwater shows higher levels of various ions. Similar works have been carried out by Dalai et al. (2019)<sup>5</sup> in Ersama coast and by Panda et al. (2020)<sup>12</sup> in Kendrapada coast wherein they adopted the TDS and ratio parameter methods to identify and delineate sea water intrusion into fresh water aquifers.

The wide range of variations of ionic contents have given rise to several groundwater types. To get the exact picture of the groundwater chemistry and major groundwater types, the results were plotted in Piper's Diagram and Extended Durov's Diagram. These diagrams are shown in Fig-2 and Fig-3. In both the diagram, the concentration of Na and Mg is visibly much higher as compared to Ca and K. On the other hand, from among the anions, the chloride dominated the fields as compared to Carbonate and Sulpahte. As the Na and Chloride ions dominate in the coastal locations, the groundwater types in the peripheral areas are of Na-Cl type. This water type is prevalent at Fatepur, Adalabad, Balarampur, Gilinasi, Kanheipur, Patapur, Chadhaeya, Harichandanpur, Biripadar, Patharakata, Bhabanipur, Baghamunda, Banamalipurpatna, Guptapur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Sana Basantpur, Gangadharpur, Mirzapur, Gabakund, and Bhagabanpur. The second water type is Mg-Cl type, as evident from Fig-2 and Fig-3. Since the second dominant cation is Mg, the Mg-Cl type occurs adjacent to the Na-Cl type. This type of water is seen at Ora, Hunda, Patapur, Harichandanpur, Balijagannathpur, Deulaparha, and Nathpur, The bicarbonates are very less. So no carbonate type of groundwater is prevalent. Since only two or three points are plotted in Ca-CO<sub>3</sub> area, this type of water type is very rare. It may be possible only at the middle of the study area where rain water is the only source of groundwater without being mixed with salt water.

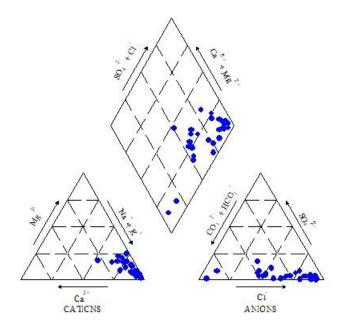


Fig. 2 Piper's Diagram

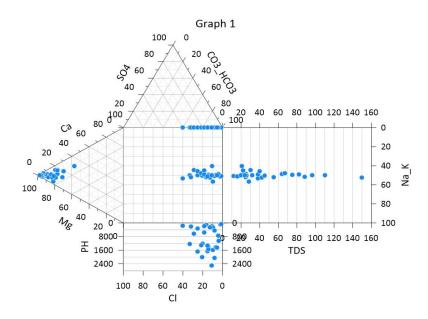


Fig. 3 Durov's diagram

The evolution of groundwater types can, to a satisfactory extent, be explained with the help of the "theory of encounter" proposed by Freeze and Cherry (1979)<sup>8</sup>. The theory states that the order in which groundwater encounters strata of different mineralogical composition can exert important control on the final water chemistry. As groundwater moves through varying mineralogical strata, the water composition undergoes adjustment of various ionic species, caused by imposition of new mineralogically controlled thermodynamic constraints.

Evolution of groundwater from alkaline earth carbonate type to sodium chloride type was discussed in detail by Tijani (1994)<sup>13</sup>. The author observed that in a basement complex terrain, alkaline earth carbonate type water occurs in the primary stage of evolution, whereas sodium chloride type occurs in the final stage. The geological literature shows that a major part of the study area covers sediments brought out from the Eastern Ghats, which form the basement complex of the study area, and the occurrence of calcium bicarbonate water type conforms with the observation made by Tijani (1994)<sup>13</sup>. Generally, within the evolutionary trend, groundwater tends to acquire a chemical composition similar to that of sea water (i.e. more dissolved solids and a relative increase in chloride ion) the longer it remains underground and the further it travels (Driscoll, 1986)<sup>7</sup>. Following the above logic, in this study, the alkaline earth carbonates, while flowing through the Quaternary sediments, finally emerge as NaCl type water, with magnesium chloride waters occurring as final water type. However, absence of Calcium carbonate type of water may be due to continuous interactions of primary water with sea water has converted the fresh waters into sodium chloride water types, with the cation exchange process playing the leading role. Though the evolution process appears to be complete, absence of intermediate type of water types, such as magnesium carbonate and sodium carbonate indicates

that the cation exchange process was vigorous so that the entire fresh water has been converted into the end water type-i.e. sodium chloride type.

## Suitability of groundwater for drinking purpose:

It has been observed that at most have location the TDS is greater than 1000 mg/l with which this maximum permissible limit of salinity set by WHO. Similarly, the concentration of Na<sup>+</sup> is also appreciable to the extent that they have crossed limit of 50 mg/l which is the limit set by WHO. The concentration of Cl<sup>-</sup> is also of importance since it, along with Na<sup>+</sup> and TDS, has greater health implications. Analysis results show that, the concentration of Cl<sup>-</sup> at many locations has recorded more than the maximum permissible limit of 50 mg/l. In combination, the locations which show higher concentration of TDS, Na<sup>+</sup> and Cl<sup>-</sup> are locations Fatepur, Adalabad, Gilinasi, Kanheipur, Biripadar, Balijagannathpur, Deulaparha, Patharakata, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Nathpur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Gangadharpur, Mirzapur, Gabakund, and Bhagabanpur. Groundwater of these places are not at all potable. Only very few places have recorded their TDS less than 1000 mg/l. They are Balarampur, patapur, Harichandanpur, Chadhiya, Guptapur, and Sanabasantapur. Groundwater at these locations is safe to drink.

# Suitability for agriculture use:

In addition to drinking water, the groundwater is also used for irrigation in the coastal areas. Since the study area is an island, the effect of seawater on groundwater in changing its hydrochemistry is important from the point of view of irrigation. For irrigation, it is very much important to observe the concentration of sodium (Na<sup>+</sup>) in the groundwater because it acts as a soil conditioner and determines the capacity of the plant roots to suck water from the ground for its ultimate use by the plant. Basing on Na%, Wilcox (1955)<sup>16</sup> classified the groundwater into five categories such as excellent, good, permissible, doubtful and unsuitable. The %Na is calculated by the formula

$$\%Na = \frac{Na + K}{Ca + Mg + Na + K} X100$$

Here the ions are expressed in meq/l. The %Na of the groundwater are presented in Table-1. Observation of the figures in the table indicate that the groundwater is excellent at location nos. NIL having %Na <20. The groundwater categorized as 'Good' are seen at no location which are having %Na 20-40. The groundwater is permissible at location - Balarampur, which are having %Na 40-60. The groundwater is categorized as 'Doubtful' (%Na 60-80) at locations- Balijagannathpur, Deulaparha, Chadhiya, Bhabanipur, Banamalipurpatna, Guptapur, Nathpur, , Naubarhi, Sanabasantapur, and Gangadharpur. However, at most of the locations the groundwater is 'Unsuitable' because they are having %Na >80. These locations are

Fatepur, Adalabad, Ora, Hunda, Gilinasi, Kanheipur, Patapur, Harichandanpur, Biripadar, Patharakata, Parala, Baghamunda, Bankijal, Baulapatana, Alupatana, Porhadhihi, Mirzapur, Gabakund, and Bhagabanpur.

# **CONCLUSION:**

Groundwater samples collected from 30 village locations showed wide range of variations in TDS and they are found to be enriched in Na<sup>+</sup>, Mg<sup>++</sup> and Cl<sup>-</sup> ions as compared to Ca<sup>++</sup>, K<sup>+</sup> and SO<sub>4</sub><sup>--</sup> ions. The mainlands are generally enriched in Ca<sup>++</sup> and HCO<sub>3</sub> whereas the coastal locations are enriched in Cl and Mg<sup>++</sup> ions. These phenomena coupled with occurrence of higher TDS (more than 1000 mg/l) clearly shows that saltwater intrusion phenomena is the main cause. The effect of saltwater intrusion is supported by the fact that Cl<sup>-</sup>/HCO<sub>3</sub> values are higher than 2 at many locations. The groundwater at location Fatepur, Adalabad, Gilinasi, Kanheipur, Biripadar, Patharakata, Parala, Baghamunda, Banamalipurpatna, Guptapur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Mirzapur, Gabakund, Bhagabanpur, have their TDS higher than 1000mg/l. On the other hand, Na<sup>+</sup> values higher than 200mg/l is prevalent at locationsat Fatepur, Adalabad, Ora, Hunda, Gilinasi, Kanheipur, Biripadar, Balijagannathpur, Deulaparha, Patharakata, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Nathpur, Bankijal, Baulapatana, Naubarhi, Porhadhihi, Gangadharpur, Mirzapur, Gabakund, and Bhagabanpur. Similarly higher values of Cl<sup>-</sup> (more than 200mg/l) are repeated at locations Fatepur, Adalabad, Gilinasi, Kanheipur, Biripadar, Balijagannathpur, Deulaparha, Patharakata, Chadhiya, Bhabanipur, Parala, Baghamunda, Banamalipurpatna, Guptapur, Nathpur, Bankijal, Baulapatana, Alupatana, Naubarhi, Porhadhihi, Gangadharpur, Mirzapur, Gabakund, and Bhagabanpur. The groundwater hydrochemistry doesn't allow the population to consume water at these location simply due to the fact that the concentration of Na<sup>+</sup>, TDS and Cl<sup>-</sup> are higher than the WHO limits. Though the local geology controls the chemistry of groundwater, higher levels of Na+, Mg++, TDS and Na<sup>+</sup> may be contributed by seawater which is all around. The concentration level of Na was also elaborately discussed so as to determine its suitability for irrigation. Since %Na plays a deteriorating role for irrigation, it has been determined accurately. It has been observed that most of the groundwater come under "Unsuitable" and "Doubtful" category. Only a very few locations are reported to be suitable for irrigation. It should therefore be concluded that saltwater intrusion is the main cause for leading the aquifer to be unsuitable for drinking and irrigation purpose.

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