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# Quality Characterization of Groundwater in some parts of Jajpur District, Odisha with Special reference to Drinking Water and Irrigation standards

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**ABSTRACT**

Groundwater is one of the most significant resources impacting human health in terms of drinking water quality. The purpose of this study is to analyse the quality of groundwater of different sources and compare it with World Health Organization (WHO) standards and Bureau of Indian Standards (BIS). Groundwater samples were collected from several places across the study area. During 2018 pre-monsoon season, twenty samples were taken from the tube wells. The samples were analysed for determining their physico chemical characteristics in order to identify quality problems and recommend safe drinking water point sources. In addition to determination of major ions such as Sodium ($Na^+$), Potassium ($K^+$), Magnesium ($Mg^{2+}$), Calcium ($Ca^{2+}$), Sulphate ($SO_4^{2-}$), Chloride ($Cl^-$), Carbonate ($CO_3^{2-}$), and Bicarbonate ($HCO_3$), the suitability was determined by estimating Electrical conductivity (EC), $H^+$ ion concentration (pH), Alkalinity, and Total dissolved Solid (TDS). The analysis results carried out showed the following concentration ranges pH (6.8-7.81), EC (103-1985 µs/cm), TH (133-466 mg/l), TDS (77-1469 mg/l), Ca (31-127 mg/l), Mg (9.97-436.2 mg/l), Na (10.3-88.3 mg/l), K (0.68-59 mg/l), $HCO3^-$ (,96.5-436.2 mg/l), $Cl^-$ (23.59-127.8 mg/l), $SO_4^{2-}$ (15-57 mg/l), and alkalinity (92-289 mg/l). The Water Quality Index (WQI) technique is used to classify water quality in a region and ascertain if it is suitable for drinking. Out of 20 groundwater samples, 13 samples represented good quality water, 6 samples indicate poor quality water, and 1 sample indicated water to be unfit for consumptions for drinking purpose. Based on the physico chemical analyses results, different parameters are calculated for irrigation purposes like Percentage Sodium, Sodium Absorption Ratio, Salinity Index, Soluble sodium percentage, Residue Sodium Carbonate, Kelley's ratio and Magnesium Hazard Ratio. From the results it is found that most of the water samples are categorised under suitable condition for drinking and irrigation purposes and few samples are unsuitable for drinking and irrigation purposes.

***Key words :*** *Physico chemical Study, WQI, Groundwater quality*

## Introduction

Out of the total fresh water reservoir available on earth, nearly 97% of all freshwaters (excluding glaciers and ice caps) is ground water. The remaining 3% comprises mainly of surface water which occur in lakes, rivers, wetlands, and soil moisture. Groundwater serves as major source of drinking water across the world. Groundwater mainly occurs as sub surface water which moves slowly through aquifer unlike the surface water of the stream. So there is enormous chance of contamination as it comes in contact with the surrounding rock or sediment. Groundwater also gets contaminated by various man-made anthropogenic activities at the surface (or at depth). Besides the drinking purpose,

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Groundwater is also used for irrigation purpose to grow crops. In this study, groundwater is analysed for its suitability in drinking purpose and irrigation as well.

## Study Area

The study area (Fig. 1) lies between 20$^0$34′57" and 21$^0$08′52" N latitude and 85$^0$41′21" and 86$^0$37′26" E longitudes and in the survey of India toposheets they are exposed in 73L/5 and 73L/6. The district is bounded by Dhenkanal district on its east, Kendrapada district on its west, Keonjhar and Bhadrak districts on its North, and Cuttack on its south. The Geographical area of the district is 2888 square kilometer. A hot and humid climate is observed during April and May months, whereas in December and January, the climate remains cold. The Brahmani, the Baitarani, their tributaries and distributaries form the main drainage system in the study area. Good fertile soil is observed in the study area. Geologically the district is essentially covered in the northwestern and southwesternarts under hilly areas comprising the Metasediments of Gorumahisani Group and Eastern Ghat Super group with basic and ultramafic intrusion. The different geomorphic features in the study area are hills, pediments, peneplains, valleys and the structural features constitute lineaments, faults, and joint and parallel drainage pattern (District Survey Report of Jajpur district Odisha, 2018).

## Methodology

Altogether 20 ground water samples were collected from a part of Jajpur district during the pre-monsoon season in June 2018. One-liter pre-washed polyethylene bottles with tightly fitting covers are used for the collection of samples. At the time of sampling for the current study, Colour, test, odour, temperature, depth of tube wells, EC (Electrical Conductivity) using conductivity meter, pH using

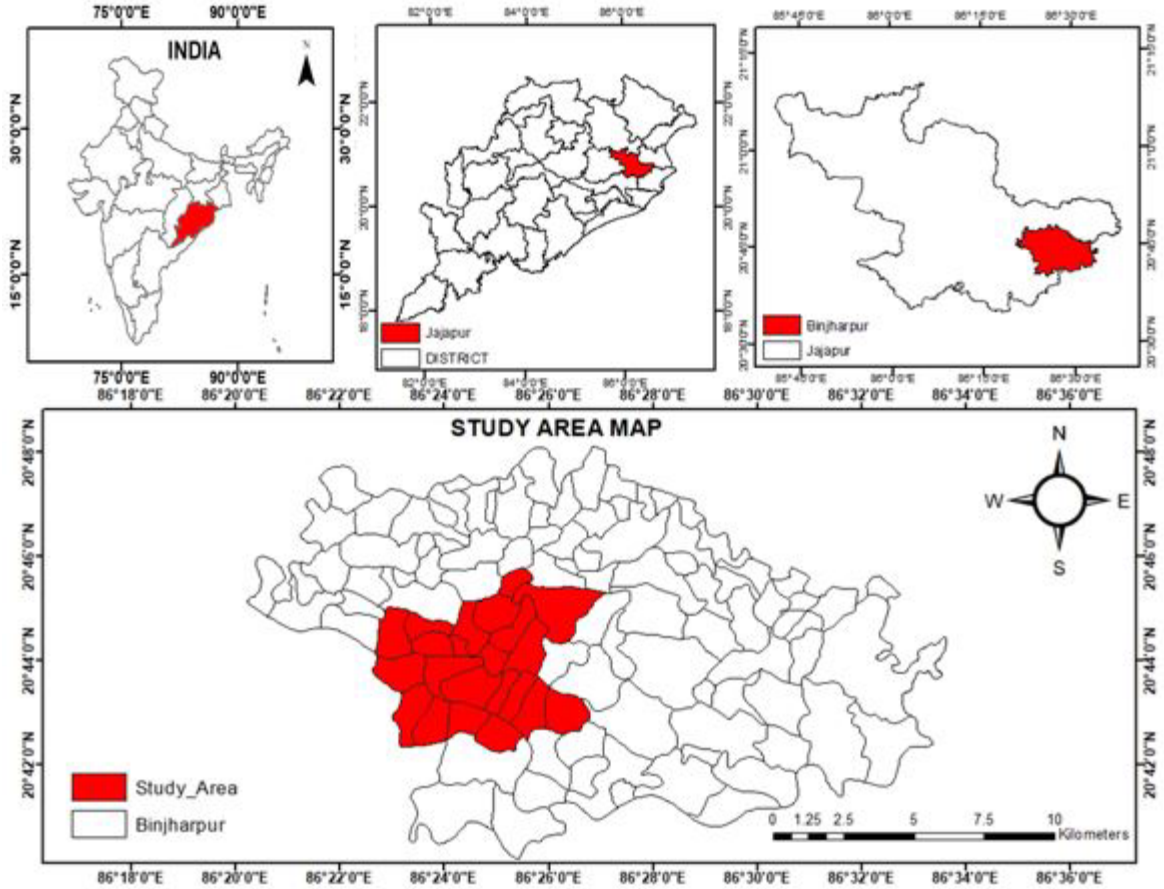


**Fig. 1.** Location map of the study area

pH meter and TDS (Total Dissolved Solids) using a water analyser kit (Systronics 371) were all documented. GPS readings were also recorded for each sample locations and altitudes. Local geology and rock types are also observed in the study area. $Mg^{2+}$, $Ca^{2+}$, $Cl^{-}$, $CO_3^{2-}$, $HCO_3^{-}$, and $SO_4^{2-}$ were analysed by standard titration methods. $K^{+}$ and $Na^{+}$ were measured using the flame photometer (Systronics 128), as per the methods (Table 1) described by the American Public Health Association (APHA, 1995). Samples are analysed within a week of sampling at the chemical laboratory of our department, Sambalpur University. Water Quality Index after Brown *et al.* (1972) is calculated easily and used for overall description of the quality of water bodies in the study area. The result is expressed in comprehensible manner such as "very good", "good", "poor" for its suitability for drinking purposes. SAR, RSC, %Na, Salinity Index, SSP, KR and MH were calculated for irrigation purposes. The characteristics of groundwater quality are compared to the Bureau of Indian Standards (BIS) for drinking water.

## Results and Discussion

The finding of the Physico-chemical test was analysed to determine the appropriateness of groundwater in the study region for drinking and irrigation uses. By comparing the measured values of several water quality indicator guideline of the BIS 1998 for drinking and irrigation purposes in Table 1. The major ions such as $Na^{+}$, $K^{+}$, $Mg^{2+}$, $Ca^{2+}$, $SO_4^{2-}$, $Cl^{-}$, $CO_3^{2-}$ and $HCO_3^{-}$ and some major physico-chemical parameters such as TDS, EC and pH.SAR, Salinity Index, %Na, RSC, SSP, KR, MH were calculated for irrigation are discussed below.

### Groundwater Quality Analysis for Drinking

### General Parameter Analysis

The result of physico chemical parameter analysis of the collected samples is given in Table 2.

**pH** plays an important role in quality of ground water. The pH values of the collected samples vary between 6.58 and 7.81, indicating a slightly acidic to alkalinity in nature. The pH values of all the water samples in this study are within the permissible range 6.5-8.5.

**Electrical Conductivity (EC)** measures the capacity of water to conduct electric current through it. It mainly measures the dissolved ionic substances in the water sample. In the study area, EC values

**Table 1.** Physiochemical prameter of BIS guideline

| Sr No. | Category of parameter | Characteristics | Analytical method | Unit | BIS Max. Permissible limit (1998) |
|---|---|---|---|---|---|
| 1. | General | pH | Electrode | 6.5-8.5 | |
| 2 | | EC | Conductivity meter | mS/cm | 3000 |
| 3 | | TDS | TDS meter | mg/l | 2000 |
| 4 | | Total hardness (as $CaCO_3$) | EDTA titrimetric | mg/l | 600 |
| 5 | Major cations | Sodium (Na*) | Flame photometric | mg/l | 200 |
| 6 | | Potassium (K+) | Flame photometric | mg/l | 200 |
| 7 | | Calcium (Ca2+) | EDTA titrimetric | mg/l | 200 |
| 8 | | Magnesium (Mg2+) | EDTA titrimetric | mg/l | 100 |
| 9 | Major anions | Bicarbonates ($HCO_3^{-}$) | Titrimetric | mg/l | NA |
| 10 | | Chlorides ($Hl^{-}$) | Titrimetric | mg/l | 1000 |
| 11 | | Nitrates ($NO_3^{-}$) | Titrimetric | mg/l | 45 |
| 12 | | Sulfates ($SO_4^{2-}$) | Barium chloride | mg/l | 400 |
| 13 | | Boron (B) | Curcumin method | mg/l | - |
| 14 | Irrigation water | Salinity | | % | NA |
| 15 | | SAR | | - | NA |
| 16 | | RSC | | mew/l | <1.25 |
| 17 | | %Na | | % | <20 or 20 - 40 |
| 18 | | PI | | % | Class 1 or 2 |
| 19 | | KI | | - | <1.0 |
| 20. | | MH | | % | Below 50% |
| 21 | | SSP | | - | NA |

(Source: Pillai, G., & Khan, I. A. (2016))

ranged from 103 to 1985 µs/cm. The EC values of all the water samples are within the permissible limit of 3000 µs/cm.

**Total Dissolved Solid (TDS)** is a measure of all the dissolved substances in water. In this study the TDS value ranged from 77 to 1469 mg/l. The TDS measurements of all samples are within the permissible limit of 2000 mg/l as mentioned in BIS guideline (Table 1).

**Total hardness** is chemically expressed as the total concentration of $Ca^{2+}$ and $Mg^{2+}$ as milligram per liter equivalent of $CaCO_3$ Total hardness values resulted ranged from133 to 466 mg/l. The total hardness measurements for all the samples are below the permissible limit of 600 mg/l recommended by the BIS for drinking water (Table 1).

**Sodium ($Na^+$)** and **Potassium ion ($K^+$)** concentration value varies from 10.3 to 88.3 mg/l and 0.68 to 59 mg/l respectively. The sodium ion ($Na^+$) concentration values for all the samples are below the permissible limit of 200 mg/l. Out of 20 samples, 12 samples have high potassium ($K^+$) content above the permissible limit of 10 mg/l; only eight (S1, S3, S5, S11, S14 to S17) samples are below the permissible limit of 10 mg/l.

**Calcium ($Ca^{2+}$)** and **Magnesium ion ($Mg^{2+}$)** concentration value varies from 31 to 127 mg/l and 9.97 to 36.23 mg/l respectively. The Calcium and Magnesium ion concentration values of all the water samples are within the permissible limit of 200 mg/l and 100 mg/l respectively as recommended by the BIS (1998) for drinking purpose.

**Bicarbonate ion($HCO_3^-$)** concentration value varies from 96.5 to 436.2 mg/l.

**Chlorides** are in the value ranged from 23.59 to 127.8 mg/l which is below the permissible limit of 1000 mg/l (BIS 1998).

The **Sulphate concentration ($SO_4^{2-}$)** of all the samples in the study area ranges from 15 to 57 mg/l which is below the permissible limit of 400 mg/l.

**Water Quality Index (WQI) Analysis**

Water quality includes chemical, physical and biological characteristics of water. The result of the water quality analysis is expressed as "very good", "good", "poor" in terms of its suitability for drinking purposes. The Bureau of Indian Standards (BIS 1998) for drinking water have been considered for the calculation of WQI. Water Quality Parameters must have standard limits as prescribed by WHO/BIS/ICMR. Water quality parameters, such as temperature, pH, turbidity, dissolved oxygen, biochemical oxygen demand, nitrates and total solids are taken into consideration for generating water quality index (WQI) (Ro$^o$u *et al.,* 2013, I. Pi$^o$tea *et al.,* 2013;

**Table 2.** Physicochemical analysis result

| Location | pH | EC | TDS | TH | Na | K | Ca | Mg | $HCO_3$ | Cl | $SO_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 7.66 | 376 | 286 | 183 | 26.1 | 6 | 45 | 17.01 | 326 | 49.7 | 32 |
| S2 | 7.57 | 875 | 657 | 157 | 19.3 | 13.7 | 43 | 11.9 | 436.2 | 34.7 | 37 |
| S3 | 7.44 | 546 | 410 | 163 | 41.5 | 7.6 | 31 | 20.7 | 378.7 | 51.7 | 28 |
| S4 | 7.38 | 103 | 77 | 211 | 34.6 | 12.4 | 65 | 11.7 | 202.4 | 26.81 | 20 |
| S5 | 7.52 | 715 | 523 | 222 | 19.9 | 6.93 | 58 | 18.7 | 96.5 | 40.02 | 34 |
| S6 | 7.39 | 224 | 166 | 174 | 14.3 | 11.6 | 41 | 17.46 | 126.6 | 36.8 | 28 |
| S7 | 7.53 | 176 | 131 | 166 | 10.3 | 27 | 36 | 18.62 | 163.2 | 47.42 | 15 |
| S8 | 7.36 | 701 | 515 | 133 | 39 | 10.3 | 35 | 11.1 | 117.3 | 93.91 | 15 |
| S9 | 7.22 | 566 | 425 | 209 | 27 | 15 | 50 | 20.4 | 205.9 | 78.52 | 46 |
| S10 | 6.97 | 907 | 681 | 208 | 88.3 | 59 | 53 | 18.37 | 347.2 | 127.8 | 57 |
| S11 | 6.89 | 1985 | 1469 | 303 | 55 | 7.1 | 91 | 18.4 | 294.6 | 117.32 | 41 |
| S12 | 7.81 | 852 | 631 | 263 | 76 | 44 | 83 | 13.53 | 199.8 | 74.7 | 54 |
| S13 | 7.64 | 235 | 177 | 159 | 26.3 | 15.4 | 47 | 9.97 | 135 | 29.92 | 41 |
| S14 | 6.58 | 792 | 594 | 169 | 29 | 0.68 | 40 | 16.91 | 135 | 36.82 | 24 |
| S15 | 7.81 | 989 | 742 | 169 | 71 | 3.3 | 51 | 10.05 | 139.7 | 40.61 | 25 |
| S16 | 7.49 | 901 | 667 | 157 | 59.2 | 2.4 | 37 | 15.51 | 128 | 23.59 | 42 |
| S17 | 7.63 | 788 | 591 | 466 | 25 | 4.6 | 127 | 36.23 | 269.7 | 89.62 | 50 |
| S18 | 7.36 | 695 | 522 | 272 | 56.7 | 30.1 | 83 | 15.61 | 193.9 | 102.8 | 33 |
| S19 | 7.41 | 889 | 667 | 340 | 48.7 | 36.4 | 104 | 19.61 | 275.6 | 89.5 | 51 |
| S20 | 7.69 | 694 | 507 | 281 | 56 | 21.1 | 83 | 17.93 | 116.7 | 83.9 | 47 |

Iticescu *et al.,* 2013). WQI is calculated as per the "weighted arithmetic index method" (Brown *et al.,* 1972).

$$WQI = \frac{\sum WnQn}{\sum Wn}$$

Where,

Wn = unity wight factor of $n^{th}$ water quality parameters and

Qn = sub-index for water quality parameters

From the Water Quality Index, water types can be classified into different categories. (Table 3).

In the study area the WQI ranges from 31.79 to 369.33 meq/l. Out of 20 groundwater samples, 13samples represent good quality water, 6 samples indicate poor quality water, and 1 sample indicates water as unfit for consumptions.

**Groundwater Quality Analysis for Irrigation**

The quality of groundwater is also analysed for irrigation purposes. Calculation of SAR, KR, and MH, salinity Index, % Na, SSP, and RSC in Table 4 are the basic parameters for evaluating water quality for irrigation purposes.

**Salinity Index**

Salinity index are classified on the basis of EC values which are shown in (Table 5). All the collected samples during pre-monsoon of 2018 are classified from low to high salinity class of water. 45% samples belong to high salinity category. High salinity (class 3) in the study area shows that the water is suitable for irrigation purposes.

**Sodium Absorption Ratio (SAR)**

The Sodium Absorption Ratio is an important water quality parameter for measuring suitability of water for agriculturalpurposes. (Reeve *et al.,* 1954).

The formula for calculating the sodium adsorption ratio (SAR) is

**Table 3.** Classification of Water based on WQI

WQI developed by Brown *et al.,* (1972)

| Water Quality Index | Water Quality | No of samples |
|---|---|---|
| 0-25 | Excellent | - |
| 26-50 | Good | 13 |
| 51-75 | Poor | 6 |
| 76-100 | Very Poor | |
| >100 | Unfit for consumption | 1 |

**Table 4.** Groundwater quality value for irrigation

| Location | SAR | %Na | SSP | RSC | KI | MH |
|---|---|---|---|---|---|---|
| S1 | 4.69 | 34.10 | 29.62206333 | 263.99 | 0.420899855 | 0.000222222 |
| S2 | 3.68 | 37.54 | 26.01078167 | 381.3 | 0.35154827 | 0.000232558 |
| S3 | 8.16 | 48.71 | 44.527897 | 327 | 0.80270793 | 0.000322581 |
| S4 | 5.59 | 37.99 | 31.08715184 | 125.7 | 0.451108214 | 0.000153846 |
| S5 | 3.21 | 25.91 | 20.60041408 | 19.8 | 0.259452412 | 0.000172414 |
| S6 | 2.65 | 30.70 | 19.65365585 | 68.14 | 0.2446117 | 0.000243902 |
| S7 | 1.97 | 40.57 | 15.86568084 | 108.58 | 0.188575613 | 0.000277778 |
| S8 | 8.13 | 51.67 | 45.82843713 | 71.2 | 0.845986985 | 0.000285714 |
| S9 | 7.58 | 37.36 | 27.72073922 | 135.5 | 0.383522727 | 0.0002 |
| S10 | 14.8 | 67.36 | 55.30155947 | 275.83 | 1.237214516 | 0.000188679 |
| S11 | 7.31 | 36.20 | 33.45498783 | 185.2 | 0.50274223 | 0.00010989 |
| S12 | 10.9 | 55.41 | 44.05031009 | 103.27 | 0.787320004 | 0.000120482 |
| S13 | 7.6 | 42.26 | 31.58400384 | 78.03 | 0.461646481 | 0.000212766 |
| S14 | 5.61 | 34.27 | 33.75625655 | 78.09 | 0.509576524 | 0.00025 |
| S15 | 12.9 | 54.89 | 53.76751231 | 78.65 | 1.162981163 | 0.000196078 |
| S16 | 11.6 | 53.98 | 52.9943604 | 75.49 | 1.127404304 | 0.00027027 |
| S17 | 2.77 | 15.35 | 13.28162355 | 106.47 | 0.15315812 | 7.87402E-05 |
| S18 | 8.08 | 46.81 | 36.5076299 | 95.29 | 0.574992394 | 0.000120482 |
| S19 | 6.21 | 40.77 | 28.26301433 | 151.99 | 0.393981069 | 9.61538E-05 |
| S20 | 4.96 | 43.30 | 35.68470018 | 15.77 | 0.554839988 | 0.000120482 |

$$SAR = \frac{Na^{+}}{\left\{\frac{Ca^{2+} + Mg^{2+}}{2}\right\}^{0.5}}$$

Where Sodium, Calcium and Magnesium concentration are expressed in meq/l.

The SAR values of the collected groundwater samples from the study area are given in (Table 6 During pre-monsoon period, the SAR value of all the samples ranges from 1.97 to 14.78 meg/l. SAR value of 16 samples are found to be below 10 meq/l which are classified as excellent for irrigation purpose (class S1).

**4.2.3. %Na**

Percent sodium plays an important role to assess the suitability of water for irrigation purpose (Wilcox, 1948). The result of percent sodium of groundwater samples from the study area are given in Table 7. %Na value of all the samples varies from 15.35 to 67.36 mg/l. One samples has an excellent water classes, eight samples have good water class, ten samples have a permissible water class and just one sample has a doubtful water class.

$$\%Na = \left(\frac{Na^{+} + K^{+}}{\left(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}\right)}\right) * 100$$

**Soluble Sodium Percentage (SSP)**

The Soluble Sodium Percentage aids in permeability classification of irrigation water. $Ca^{2+}$ and $Mg^{2+}$ ions found in clay particles have a tendency to exchange Sodium ions contained in irrigation water. This lowers the permeability of the material, lowering its quality. The proportion of soluble sodium percentage in irrigation wateris used to classify it (Todd 1959).

**Table 8.** Groundwater quality based on RSC.

| RSC (meq/l) | Remark on quality | Samples |
|---|---|---|
| <1.25 | Good | — |
| 1.25-2.50 | doubtful | — |
| <2.50 | unsuitable | 20 |

**Table 5.** Classification of water samples based on of EC.

| EC (µS/cm) | Water salinity | Range (no. of samples) | Percent |
|---|---|---|---|
| 0 - 250 | Low | 103-235 (4 samples) | 20% |
| 251 - 750 | Medium | 376-715 (7 samples) | 35% |
| 751 - 2250 | High | 788-1985 (9 samples) | 45% |
| 2251 - 6000 | Very High | - | - |
| 6001 - 10,000 | Extensively High | - | - |
| 10,001 - 20,000 | Brines weak concentration | - | - |
| 20,001 - 50,000 | Brines moderate concentration | - | - |
| 50,001 - 100,000 | Brines high concentration | - | - |
| >100,000 | Brines extremely high concentration | - | - |

**Table 6.** Classification of waters based on SAR values.

| SAR values | Sodium hazard class | Remark | Range and no. of Sample |
|---|---|---|---|
| <10 | S1 | Excellent | 1.97 to 8.16 (16 samples) |
| 10 - 18 | S2 | Good | 10.93 to 14.78 ( 4 samples) |
| 19 - 26 | S3 | Doubtful/fair poor | —— |
| >26 | S4 | Unsuitable | —— |

**Table 7.** Percentage Sodium water class

| Sodium (%) | Class | Range (No of samples) |
|---|---|---|
| <20 | Excellent | 15.35 (1sample) |
| 20 - 40 | Good | 25.91 to 37.99 (8 samples) |
| 40 - 60 | Permissible | 4.57 to 55.41 (10 samples) |
| 60 - 80 | Doubtful | 67.36 (1 sample) |
| >80 | Unsuitable | —— |

**Table 9.** Kelly's ratio

| | KR/K% | |
|---|---|---|
| Groundwater samples | <1 | >1 |
| | Suitable | Unsuitable |
| Pre-monsoon | 17 samples | 3 samples |

$$SSP = \left( \frac{Na^+}{(Ca^{2+} + Mg^{2+} + Na^+)} \right) * 100$$

The soluble sodium percentage values of the water samples in this study are from 13.28 to 55.30 meq/L

**Residual Sodium Carbonate (RSC)**

The suitability of groundwater for irrigation is also affected by the excess amount of Carbonate and Bicarbonate concentration in comparison to the Calcium and Magnesium ions present in water (Richards, 1954). The excess Bicarbonate and Carbonate is alluded to as Residual Sodium Carbonate.

$RSC = (CO_3 + HCO_3) – (Ca+Mg)$

The RSC value of the collected samples ranges from 15.77 to 381.3 meq/l (Table 8). Based on the RSC values <2.50 meq/l, all the samples are classified as unsuitable for irrigation purposes.

**Kelly's Index (KI)**

Kelly (1940) introduced a factor to assess the suitability of water for irrigation purpose using the concentration of Sodium against Calcium and Magnesium (Table 9).

Kelly's ratio = $Na^+/(Ca^{2+}+Mg^{2+})$

In this study, Kelly's ratio varies from 0.15 to 1.23 meq/. Only three samples (S10, S15 and S16) are found unsuitable for irrigation purpose.

## Conclusion

In the present study in parts of Jajpur district, the result of physicochemical parameters analysis of groundwater samples is within the permissible limit as compared to Bureau of Indian Standards (BIS 1998) for drinking purpose. WQI value of all the samples ranges from 31.79 to 369.33 meq/l. 13 samples represent good quality water, 6 samples indicate poor quality water, and only 1 sample indicates water to be unfit for consumptions for drinking purpose. Out of the various indices calculated for the suitability of water for irrigation purpose, most of the samples are found suitable for irrigation purpose whereas very few of them are found unfit for irrigation purpose.

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