ISSN: 0975-833X

*Available online at http://www.journalcra.com*

*International Journal of Current Research*
*Vol. 9, Issue, 08, pp.55434-55442, August, 2017*

**INTERNATIONAL JOURNAL OF CURRENT RESEARCH**

**RESEARCH ARTICLE**

# GROUND WATER QUALITY ASSESSMENT USING CANADIAN WATER QUALITY INDEX AROUND JURUDI MINING AREA, ODISHA, INDIA

**[1]Bibhuti Naik, [2,]*Papu Kumar Naik and [1]Sanjaya Kumar Pattanayak**

[1]Department of Environmental Science, Sambalpur University, Burla-768019, Odisha, India
[2]Centre for the Environment, Indian Institute of Technology Guwahati, Guwahati-781039, Assam, India

**ARTICLE INFO**

***Article History:***
Received 22nd May, 2017
Received in revised form
27th June, 2017
Accepted 16th July, 2017
Published online 31st August, 2017

***Key words:***

Ground water,
Hydro-geochemical Facies,
Piper Plot,
Water Quality Index,
Correlation Coefficient.

**ABSTRACT**

The present research was aimed at assessing the ground water quality of the iron ore region around Jurudi, Keonjhar district of Odisha, India. In this study, five locations were fixed in and around the human habitation and sampling were done in three different seasons of a year to compare the seasonal variation. The samples were analyzed for the ground water quality parameters such as pH, temperature, conductivity, turbidity, total alkalinity, total hardness, chloride, calcium, magnesium, sulfate, nitrate, phosphate, total dissolved solid, sodium, potassium, copper, iron, manganese, aluminum, zinc, lead, cadmium, and chromium. The study revealed that for parameters like iron, manganese, lead, cadmium, chromium (mainly heavy metals) the concentration levels are above the Bureau of Indian standard. Bulk of the groundwater samples are characterized as magnesium bicarbonate type hydro-geochemical facies with a few mixed type facies. The concentration level of some parameters in the groundwater is variable with the change in the seasons. The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) values for irrigation and aquatic life are 90 and 91 respectively suggesting that the water is good for these purposes. The drinking water used by the people residing in the area around Jurudi is portable as indicated by the CCME WQI value of 79 suggesting that the water is fair for this purpose. The results of the case study indicated that this water quality index is very simple and could be used as an effective tool to characterize the drinking source water quality.



**Citation: Bibhuti Naik, Papu Kumar Naik and Sanjaya Kumar Pattanayak, 2017.** "Ground water quality assessment using Canadian water quality index around Jurudi mining area, Odisha, India", *International Journal of Current Research*, 9, (08), 55434-55442.

## INTRODUCTION

Water resources have been the most exploited natural system, since man strode the earth. Today, the scarcity of water has intensified the competition for water resources all over the world (Goel, 2011). Water pollution is relatively a new problem and increases the stress arising as a result of unprecedented population growth, urbanization, and industrialization (Almasri *et al.,* 2004). Thus the water, which is available must be used carefully. Day by day, as the mining activity increases, which give a huge impact on the environment and water quality which possess the effect on human as well as forwildlife. Ground water plays a crucial role as a source of drinking water for millions rural and urban family, especially in semiarid and arid regions (Adhikary *et al.,* 2010). In India ground water is also intensively used for irrigation and industrial purposes. With the rising concentration of various inorganic, organic and biological contaminants in ground water, there is rising concern about its effect on human health (Dixit *et al.,* 2005). A variety of industries contribute to concentrations of different pollutants in ground water. Ground water contamination is of particular concern in India. The chief source of drinking water in the country is ground water. It is recognized that minerals and metals are the foundation of the economic development and welfare of the society. However, their exploration, excavation and mineral processing directly break upon and affect the other natural resources like land, water, air, flora and fauna, which are to be conserved and optimally utilized in a sustainable manner. Ground water chemistry determines its use for domestic, irrigation and industrial purposes. This mandates investigations of water quality of the study area (Jerry, 1986). Mining affects a huge area of the land and affect the quality of surface and underground water by adding contaminants and toxic compounds making it unsafe for drinking and industrial usage, disturbing the hydrology of the area (Roy *et al.,*2003). The major sources of liquid effluents were: surface run-off, mine water pumped put during drainage operation, spent water from handling plants, dust extractors and dust suppression systems, effluents from preparation and beneficiation plants,

**Corresponding author:* **Papu Kumar Naik**
Centre for the Environment, Indian Institute of Technology Guwahati, Guwahati-781039, Assam, India.

and leaches/wash-off from waste/tailing dumps. Most of the mines discharge their effluent into a mud retaining impoundment (MRI) which is built for flood water (Chen *et al.,* 2007). Chemical characteristics of surface, groundwater and mine water from the upper catchment to evaluate the major ion chemistry, geochemical processes controlling water composition and suitability of water for domestic, industrial and irrigation uses (Kumar *et al.,* 2004). Many other authors also studied the assessment of ground water quality and found that the industrial area and mining activity are significantly affecting the natural quality of water (Ramkrishna *et al.,* 2009; Bhuiyan *et al.,* 2010; Chapolikar *et al.,* 2010; Frederick *et al.,* 2011; Prasad *et al.,* 2013). In India, Sundergarh, Keonjhar region contains rich and vast iron ore deposits. Mining activity is in progress at Tensa, Jamda-Koida, Badbil and Joda area. One of the active mining sectors is around Jurudi in Keonjhar district of Odisha. This area is affected by mining activity. The people of the villages in this region use groundwater for the purpose of drinking. Since the environment is affected, it is necessary that the water quality of the region be assessed so that appropriate measures can be taken to supply safe drinking. With the above backdrop the research was carried out in the region around Jurudi of Keonjhar district with the primary objective to assess the groundwater quality of the region. Groundwater samples were collected during post-monsoon and pre-monsoon (2014) seasons from the Jurudi area. The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) is considered to be a promising tool with a high potential for extensive use all over the world that has attracted attention of water quality experts and researchers due to its flexible structure and simple calculations. Here, to achieve an efficient drinking water quality index (DWQI) for assessment of drinking source water quality the CCME WQI tool is used (CCME*,* 2006). Ground water was classified according to the variables discussed above. Among the water quality indices, the CCME WQI characterizes drinking source water quality by comparing the measured levels of input water quality parameters to relevant guideline or standard values as benchmarks regardless of any subjective rating curves (Lumb *et al.,* 2006). Qualitative analysis and World Health Organization/ environmental Protection Agency (WHO/EPA) water quality standards (WHO, 1971) is used for calculating water quality indices. All of the water quality measurements were performed according to the instructions of Standard Methods (APHA, 2012).

## MATERIALS AND METHODS

### Study area and sampling

The sampling was carried out by selecting five locations in and around the iron mines, at Jurudi in Keonjhar district of Odisha located at 21$^o$ 56’ 04.7” N - 21$^o$ 57’ 31.7” N latitudes and 85$^o$ 26’ 04.7” E - 85$^o$ 29’ 29.4” E longitudes. Among the five sites three are from the settlement areas and two are from mine lease area viz. i) Settlements: 1. JurudiBasti (21$^o$ 56’ 24.6” N 85$^o$ 26’ 10.1” E), 2. Hansabeda Village (21$^o$ 55’ 54.8” N85$^o$ 25’ 00.5” E), 3. Jaribahal Village (21$^o$ 56’ 24.40” N85$^o$ 25’11.91” E), ii) Mine lease: 1. JajangBasti (21$^o$ 56’ 33.0” N 85$^o$ 26’ 05.8” E), 2. Kamalpur Village (21$^o$ 56’ 25.53” N 85$^o$ 26’1.88” E).Field samplings were carried out in three different phases at an interval of three months, from June 2014 to December 2014 for water quality variables and water quality index. Sampling were completed in three different seasons: pre-monsoon (June), monsoon (September) and post-monsoon (December). During sampling, GPS coordinates were recorded and again after three monthintervals sampling were done for the fixed sites. The different sampling points with sampling number are given in Table 1. Location map showing the sampling points are given in Fig. 1. The ground water samples from well and tube wells were collected in three plastic bottles: 1 liter, 500ml and 125ml containers. The 125ml containers were only for the metals analysis. The collected samples were immediately transferred and analyzed in the Laboratory. For each sample, total 22 numbers of different physicochemical parameters of groundwater were measured using standard procedures prescribed for water analysis (*APHA,* 2012). These physicochemical parameters include the potential of hydrogen (pH), temperature (T), conductivity (EC), turbidity, total dissolve solid (TDS), total alkalinity, acidity, total hardness, Ca, Mg, Cl, $SO_4$, $NO_3$, Fe, Mn, Na, K, Cu, Zn, Pb, Cd and Cr. Water temperature was measured on the site using a mercury thermometer while other parameters were determined in the laboratory within 48–72 h of the sampling following standard methods (*APHA*, 2012). Parameters like pH, EC and turbidity were measured by electrometric method at 25˚C by using a multi parameter ion meter (Thermo Orion 5 Star). Total alkalinity and acidity were determined by the titrimetric method. Total hardness, calcium and magnesium were determined by EDTA titrimetric method. Total dissolve solid was measured gravimetrically. Chloride was determined by argentometric method. Sulfate and nitrate were measured using a double beam UV–Vis spectrophotometer (Perkin Elmer Lambda 45) by turbidimetric and phenol disulphonic acid method respectively. Sodium and potassium were analyzed using a flame photometer (CL-378 Elico India) and other metals were analyzed through Atomic Absorption Spectroscopy (AAS) model Varian-AA240. Statistical analysis such as bar diagram and correlation coefficient were plotted with the obtaining data. Moreover, Piper plots (Ravikumar *et al.,* 2011) and Canadian water quality index (CCME, 2006) was analyzed with the obtaining data.

### Water Quality Index

A water quality index (WQI) combines the measures of several water quality variables in such a way as to produce a single score that is representative of quality impairments or suitability of use (Dunnette *et al.,* 1979) in other words WQI summarize large amounts of water quality data into simple terms. The WQI tells us whether the overall quality of water bodies poses a potential threat to various beneficial uses of water. The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) provides a flexible index template, adaptable to the site specificity (Hurley *et al.,* 2012). The CCME WQI is an objective-based index that compares measured water quality values to guidelines to produce a score ranging from 0, representing worst quality, to 100, representing best quality which is described in Table 2. The CCME provides detailed information regarding index calculation and application (CCME*,* 2006). Index scores are calculated as follows:

### Index Calculations

This index is based on three attributes of water quality that relate to water quality objectives: scope factor ($F_1$), frequency factor ($F_2$) and amplitude factor ($F_3$). F1 (scope) is the number of water quality variables that do not meet objectives in at least one sample during the time period under consideration, related to the total number of variables measured.

$$F_1 = \frac{\sum_{i=m}^{m} V_i}{\sum_{i=n}^{n} V_i} \times 100 \cdots\cdots\cdots\cdots\cdots (1)$$

F2 (frequency) represents the number of individual measurements that do not meet the objectives, relatives to the total number of measurements made on all samples from the time period of interest.

$$F_2 = \frac{\sum_{i=m}^{m} T_i}{\sum_{i=n}^{n} T_i} \times 100 \cdots\cdots\cdots\cdots\cdots (2)$$

Where $V_i$and $T_i$ are number of variables and number of tests. m and n are representing the number of failed attempts and total number of attempts.

F3 (amplitude) is the amount by which measurements which do not meet the objectives depart from those objectives. $F_3$is then calculated by an asymptotic function that scales the normalized sum of the excursions (*NSE*) from objectives to yield a range between 0 and 100, which is given as:

$$F_3 = \frac{NSE}{0.01NSE + 0.01} \cdots\cdots\cdots\cdots\cdots (3)$$

$$NSE = \frac{\sum_{i=n}^{n} E_i}{\sum_{i=n}^{n} T_i} \cdots\cdots\cdots\cdots\cdots (4)$$

Where $E_i$is called extraction of objective. Once the factors have been obtained, index scores are calculated as follows:

$$CCWE\ WQI = 100 - \left( \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right) \cdots\cdots\cdots\cdots (5)$$

This CCME WQI has been used to characterize the quality of water for several intended uses, including agriculture, the protection of aquatic life and treated drinking water (Khan *et al.,* 2004; Lumb *et al.,* 2006).

## RESULTS AND DISCUSSION

### Environmental variables

The physicochemical analysis of samples from five stations collected during pre-monsoon, monsoon and post monsoon seasons were carried out. In this study, changes in water quality were explored over the different season to assess the ground quality for different purpose. Analytical results of parameters obtained from the water samples are shown in Table 3. All the analyzed results are within the permissible limit of the bureau of Indian standard (BIS) for drinking water. Apart from a few parameters mainly heavy metals and pH blink outside the permissible limits. As the research area is a mines belt, i.e. mainly iron and manganese, here water could leach toxic metal ions such as iron, manganese and others from the aquifer by plumbing fixture and piping. These activities enhance the lower in pH of that particular area and as it mainly happens in rainy season the pH is lower in rainy as compared to other seasons. More one reason of this lowering of pH is that in sedimentary form, iron occurs as pyrite and in oxidizing conditions pyrite is oxidized, as described by the following equation:

$$FeS_2 + \frac{7}{2}O_2 + H_2O \rightarrow Fe(OH)_3 + 2H^+ + 2SO_4^{2-} \ldots (6)$$

This reaction shows acid formations which express the acidic nature of groundwater. Thus, the decreasing of pH value in groundwater sample in dry season in relation to rainy season could be explained by the oxidizing conditions. Based on the results shown in Table 3, the heavy metals contamination in the summer is different from the rainy and winter. The main reason for this seems to be the uneven effect of dilution in different seasons and different release profiles. For the element Pb, Cr, Zn, Cu and Cd concentration in groundwater is less than the maximum acceptable level. In some place the concentration is relatively high, but the aquifer seems to have the ability to assimilate the pollution very well when the sources in the soil take through dilution and absorption. For the heavy metals, the level of contamination is high and also the ability of assimilation is low especially in summer seasons. Table 4 shows the minimum and maximum value of individual parameter during the whole year and statistical analysis, i.e. mean, median and standard deviation of the 22 water quality parameters for the study area.

**Table 1. Different sampling points with sampling number**

| Sl.No | Sampling Site | Sampling No | | |
|---|---|---|---|---|
| | | Pre-monsoon | Monsoon | Post-monsoon |
| 1 | Kamalpur Village | S1 | S6 | S11 |
| 2 | JajangBasti | S2 | S7 | S12 |
| 3 | JurudiBasti | S3 | S8 | S13 |
| 4 | Hansabeda Village | S4 | S9 | S14 |
| 5 | Jaribahal Village | S5 | S10 | S15 |

**Table 2. CCME WQI scoring system**

| Rank | Score | Details |
|---|---|---|
| Poor | 0-44.9 | Measurements generally depart from desirable levels and water quality does not meet any criteria for use as a source of drinking water |
| Marginal | 50-64.9 | Measurements often depart from desirable levels and water quality frequently violates criteria for use as a source of drinking water by a considerable margin |
| Fair | 65-79.9 | Measurements occasionally depart from desirable levels and water quality sometimes violates criteria, possibly by a wide margin, for use as a source of drinking water |
| Good | 80.-94.9 | Measurements rarely depart from desirable levels and water quality seldom violates criteria for use as a source of drinking water |
| Excellent | 95-100 | All measurements are within objectives for almost all of the time and water quality meets all criteria for use as a source of drinking water |

**Table 3. Water quality parameters of different location and seasons**

| Sl No | Parameters | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 | S13 | S14 | S15 | BIS Limit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | pH | 6.63 | 6.3 | 7.33 | 7.12 | 6.67 | 5.39 | 6.69 | 7.32 | 5.58 | 5.86 | 6.64 | 6.38 | 6.83 | 6.92 | 6.56 | 6.5-8.5 |
| 2 | Temperature(˚C) | 29.4 | 28.8 | 30.2 | 32.8 | 32 | 27.8 | 27.6 | 27.6 | 27.9 | 27.4 | 26.4 | 24.8 | 27.4 | 27.8 | 25.4 | -- |
| 3 | EC (µS/cm) | 193.2 | 167.5 | 165 | 186.4 | 162.7 | 100.2 | 90.7 | 90 | 150.4 | 201 | 198 | 176 | 184.1 | 201 | 175.4 | -- |
| 4 | Turbidity (NTU) | 2.3 | 2.8 | 1.2 | 1.8 | 2.1 | 2.4 | 1.4 | 1.2 | 1.3 | 2.9 | 3.2 | 1.8 | 1.6 | 2.8 | 1.2 | 5 |
| 5 | Total Alkalinity (mg/lt) | 56 | 60 | 52 | 64 | 60 | 44 | 20 | 32 | 48 | 40 | 84 | 56 | 72 | 76 | 52 | 600 |
| 6 | Acidity (mg/lt) | 6 | 4 | 8 | 4 | 16 | 16 | 24 | 28 | 22 | 16 | 16 | 24 | 36 | 36 | 14 | -- |
| 7 | Total Hardness (mg/lt) | 70.54 | 82.98 | 78.83 | 74.69 | 78.83 | 78.19 | 65.84 | 49.38 | 32.98 | 41.15 | 93.12 | 72.87 | 80.97 | 85.02 | 76.92 | 600 |
| 8 | Calcium (mg/lt) | 16.6 | 14.94 | 18.26 | 14.94 | 13.28 | 18.11 | 11.52 | 9.88 | 6.58 | 21.39 | 25.91 | 14.57 | 19.43 | 17.81 | 17.81 | 200 |
| 9 | Magnesium (mg/lt) | 7.06 | 11.09 | 8.06 | 9 | 11.09 | 8 | 8.99 | 5.99 | 3.99 | 3 | 6.89 | 8.85 | 7.87 | 9.84 | 7.87 | 30 |
| 10 | Chloride (mg/lt) | 8.36 | 9.29 | 10.22 | 10.22 | 8.36 | 5.53 | 7.37 | 11.95 | 10.13 | 13.83 | 9.83 | 22.33 | 8.04 | 7.15 | 8.04 | 1000 |
| 11 | Sulphate (mg/lt) | 6.43 | 2.89 | 1.09 | 1.96 | 1.23 | 23.57 | 7.34 | 3.42 | 34.41 | 7.34 | 0.76 | 1.39 | 0.22 | 1.06 | 0.37 | 400 |
| 12 | Nitrate (mg/lt) | 4.93 | 5.3 | 12.23 | 7.32 | 8.04 | 34.64 | 5.48 | 16.24 | 5.48 | 3.29 | 3.16 | 3.12 | 0.9 | 2.63 | 6.26 | 45 |
| 13 | TDS (mg/lt) | 118 | 106 | 102 | 116 | 112 | 64 | 55 | 60 | 100 | 124 | 128 | 118 | 118 | 130 | 104 | 2000 |
| 14 | Iron (mg/lt) | 0.38 | 0.33 | 0.27 | 0.19 | 0.22 | 0.58 | 0.27 | 0.12 | 0.42 | 0.18 | 0.47 | 0.31 | 0.35 | 0.25 | 0.29 | 0.3 |
| 15 | Manganese (mg/lt) | 0.102 | 0.104 | 0.097 | 0.092 | 0.020 | 0.064 | 0.039 | 0.032 | 0.053 | 0.015 | 0.125 | 0.321 | 0.062 | 0.010 | 0.061 | 0.3 |
| 16 | Sodium (mg/lt) | 15 | 10 | 11.2 | 10 | 11.2 | 6.5 | 6 | 10.9 | 10.8 | 16.3 | 8.9 | 10 | 13.8 | 13.5 | 10.3 | -- |
| 17 | Poptassium (mg/lt) | 10.3 | 3.6 | 5.7 | 6 | 5.7 | 1.2 | 2.7 | 1.3 | 1 | 5 | 3.9 | 4.3 | 8.4 | 8.4 | 5.1 | -- |
| 18 | Copper (mg/lt) | 0.34 | 0.077 | 0.039 | 0.129 | 0.071 | 0.34 | 0.071 | 0.058 | 0.063 | 0.027 | 0.278 | 0.071 | 0.05 | 0.028 | 0.017 | 1.5 |
| 19 | Zinc (mg/lt) | 0.194 | 0.045 | 0.066 | 0.013 | 0.029 | 0.089 | 0.018 | 0.009 | 0.002 | 0.056 | 0.104 | 0.066 | 0.061 | 0.008 | 0.018 | 15 |
| 20 | Lead (mg/lt) | 0.012 | 0.008 | 0.006 | 0.016 | 0.005 | 0.01 | 0.007 | 0.005 | 0.012 | 0.01 | 0.007 | 0.009 | 0.011 | 0.009 | 0.01 | 0.01 |
| 21 | Cadmium (mg/lt) | 0.004 | 0.003 | 0.005 | 0.002 | 0.004 | 0.004 | 0.001 | 0.002 | 0.001 | 0.002 | 0.003 | 0.002 | 0.003 | 0.003 | 0.001 | 0.003 |
| 22 | Cromium (mg/lt) | 0.062 | 0.045 | 0.018 | 0.066 | 0.021 | 0.044 | 0.002 | 0 | 0.051 | 0.023 | 0.049 | 0.056 | 0.022 | 0.012 | 0.023 | 0.05 |

**Table 4. Statistical analysis of water parameters**

| Parameters | Minimum | Maximum | Mean | Median | Standard Deviation |
|---|---|---|---|---|---|
| pH | 5.39 | 7.33 | 6.55 | 6.64 | 0.56 |
| Temp. | 24.8 | 32.8 | 28.2 | 27.8 | 2.1 |
| EC | 90 | 201 | 162.8 | 175.4 | 37.4 |
| Turbidity | 1.2 | 3.2 | 2 | 1.8 | 0.67 |
| TA | 20 | 84 | 54.4 | 56 | 16.05 |
| Acidity | 4 | 36 | 18 | 16 | 10.01 |
| TH | 32.92 | 93.12 | 70.82 | 76.92 | 16.31 |
| Ca | 6.58 | 25.91 | 16.07 | 16.6 | 4.57 |
| Mg | 3 | 11.09 | 7.84 | 8 | 2.19 |
| Cl | 5.53 | 22.33 | 10.05 | 9.29 | 3.82 |
| $SO_4^{3-}$ | 0.22 | 34.41 | 6.23 | 1.96 | 9.44 |
| $NO_3^-$ | 0.9 | 34.64 | 7.93 | 5.48 | 8.07 |
| TDS | 55 | 130 | 103.67 | 112 | 23.67 |
| Fe | 0.12 | 0.58 | 0.31 | 0.29 | 0.12 |
| Mn | 0.01 | 0.321 | 0.08 | 0.062 | 0.073 |
| Na | 3.8 | 16.3 | 10.29 | 10.3 | 3.14 |
| K | 1 | 10.3 | 4.84 | 5 | 2.66 |
| Cu | 0.017 | 0.340 | 0.111 | 0.071 | 0.108 |
| Zn | 0.002 | 0.194 | 0.052 | 0.045 | 0.049 |
| Pb | 0.005 | 0.016 | 0.009 | 0.009 | 0.003 |
| Cd | 0.001 | 0.005 | 0.003 | 0.003 | 0.001 |
| Cr | 0 | 0.066 | 0.033 | 0.034 | 0.021 |

**Table 5. Correlation coefficient (r) among analyzed water quality parameters for pre-monsoon**

| Correlation | pH | Temp. | EC | Turbidity | TA | Acidity | TH | Ca | Mg | Cl | $SO_4^{3-}$ | $NO_3^-$ | TDS | Fe | Mn | Na | K | Cu | Zn | Pb | Cd | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| Temp. | 0.50 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| EC | 0.03 | 0.04 | 1.00 | | | | | | | | | | | | | | | | | | | |
| Turbidity | -0.97 | -0.44 | 0.12 | 1.00 | | | | | | | | | | | | | | | | | | |
| TA | -0.29 | 0.55 | 0.21 | 0.44 | 1.00 | | | | | | | | | | | | | | | | | |
| Acidity | 0.00 | 0.36 | -0.54 | -0.18 | -0.12 | 1.00 | | | | | | | | | | | | | | | | |
| TH | -0.24 | -0.20 | -0.88 | 0.18 | 0.04 | 0.14 | 1.00 | | | | | | | | | | | | | | | |
| Ca | 0.53 | -0.45 | 0.17 | -0.55 | -0.81 | -0.41 | -0.23 | 1.00 | | | | | | | | | | | | | | |
| Mg | -0.50 | 0.15 | -0.67 | 0.47 | 0.53 | 0.35 | 0.79 | -0.78 | 1.00 | | | | | | | | | | | | | |
| Cl | 0.70 | 0.23 | -0.08 | -0.59 | 0.00 | -0.50 | 0.22 | 0.44 | -0.15 | 1.00 | | | | | | | | | | | | |
| $SO_4^{3-}$ | -0.45 | -0.53 | 0.76 | 0.49 | -0.12 | -0.39 | -0.65 | 0.19 | -0.53 | -0.53 | 1.00 | | | | | | | | | | | |
| $NO_3^-$ | 0.81 | 0.28 | -0.53 | -0.90 | -0.52 | 0.33 | 0.24 | 0.47 | -0.14 | 0.56 | -0.71 | 1.00 | | | | | | | | | | |
| TDS | -0.18 | 0.36 | 0.80 | 0.28 | 0.51 | -0.05 | -0.80 | -0.38 | -0.27 | -0.45 | 0.58 | -0.63 | 1.00 | | | | | | | | | |
| Fe | -0.53 | -0.92 | 0.29 | 0.49 | -0.49 | -0.34 | -0.18 | 0.41 | -0.36 | -0.45 | 0.81 | -0.47 | 0.01 | 1.00 | | | | | | | | |
| Mn | 0.08 | -0.55 | 0.48 | 0.04 | -0.23 | -0.94 | -0.17 | 0.68 | -0.54 | 0.47 | 0.45 | -0.16 | -0.12 | 0.52 | 1.00 | | | | | | | |
| Na | -0.13 | -0.36 | 0.57 | 0.07 | -0.47 | 0.06 | -0.75 | 0.35 | -0.69 | -0.61 | 0.82 | -0.29 | 0.49 | 0.67 | 0.13 | 1.00 | | | | | | |
| K | 0.08 | -0.07 | 0.76 | -0.08 | -0.28 | -0.02 | -0.94 | 0.31 | -0.79 | -0.44 | 0.77 | -0.26 | 0.68 | 0.44 | 0.14 | 0.93 | 1.00 | | | | | |
| Cu | -0.25 | -0.25 | 0.87 | 0.30 | -0.05 | -0.28 | -0.85 | 0.15 | -0.64 | -0.50 | 0.95 | -0.63 | 0.76 | 0.61 | 0.32 | 0.86 | 0.90 | 1.00 | | | | |
| Zn | -0.20 | -0.58 | 0.58 | 0.16 | -0.53 | -0.17 | -0.66 | 0.48 | -0.72 | -0.50 | 0.89 | -0.35 | 0.36 | 0.83 | 0.38 | 0.96 | 0.86 | 0.86 | 1.00 | | | |
| Pb | 0.15 | 0.29 | 0.87 | 0.06 | 0.52 | -0.67 | -0.63 | 0.01 | -0.42 | 0.27 | 0.41 | -0.44 | 0.69 | -0.07 | 0.48 | 0.10 | 0.38 | 0.54 | 0.13 | 1.00 | | |
| Cd | 0.22 | -0.38 | -0.40 | -0.41 | -0.92 | 0.49 | 0.04 | 0.54 | -0.30 | -0.22 | -0.03 | 0.56 | -0.47 | 0.33 | -0.16 | 0.44 | 0.23 | -0.06 | 0.41 | -0.73 | 1.00 | |
| Cr | -0.20 | 0.02 | 0.90 | 0.39 | 0.52 | -0.71 | -0.59 | -0.08 | -0.34 | 0.01 | 0.65 | -0.72 | 0.73 | 0.21 | 0.52 | 0.23 | 0.42 | 0.69 | 0.31 | 0.93 | -0.73 | 1.00 |

**Table 6. Correlation coefficient (r) among analyzed water quality parameters for monsoon**

| Correlation | pH | Temp. | EC | Turbidity | TA | Acidity | TH | Ca | Mg | Cl | $SO_4^{3-}$ | $NO_3^-$ | TDS | Fe | Mn | Na | K | Cu | Zn | Pb | Cd | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| Temp. | -0.43 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| EC | -0.49 | -0.34 | 1.00 | | | | | | | | | | | | | | | | | | | |
| Turbidity | -0.57 | -0.44 | 0.61 | 1.00 | | | | | | | | | | | | | | | | | | |
| TA | -0.76 | 0.48 | 0.51 | 0.35 | 1.00 | | | | | | | | | | | | | | | | | |
| Acidity | 0.85 | 0.06 | -0.57 | -0.91 | -0.54 | 1.00 | | | | | | | | | | | | | | | | |
| TH | -0.03 | 0.09 | -0.66 | 0.16 | -0.34 | -0.19 | 1.00 | | | | | | | | | | | | | | | |
| Ca | -0.36 | -0.57 | 0.43 | 0.96 | 0.12 | -0.79 | 0.33 | 1.00 | | | | | | | | | | | | | | |
| Mg | 0.25 | 0.20 | -0.87 | -0.29 | -0.60 | 0.22 | 0.88 | -0.10 | 1.00 | | | | | | | | | | | | | |
| Cl | 0.28 | -0.59 | 0.66 | 0.14 | 0.11 | 0.13 | -0.81 | 0.08 | -0.83 | 1.00 | | | | | | | | | | | | |
| $SO_4^{3-}$ | -0.77 | 0.87 | 0.14 | -0.07 | 0.75 | -0.32 | -0.14 | -0.30 | -0.16 | -0.38 | 1.00 | | | | | | | | | | | |
| $NO_3^-$ | -0.23 | 0.39 | -0.52 | 0.18 | 0.26 | -0.25 | 0.73 | 0.25 | 0.49 | -0.62 | 0.19 | 1.00 | | | | | | | | | | |
| TDS | -0.50 | -0.26 | 0.99 | 0.55 | 0.57 | -0.54 | -0.71 | 0.35 | -0.91 | 0.67 | 0.21 | -0.51 | 1.00 | | | | | | | | | |
| Fe | -0.78 | 0.77 | -0.16 | 0.16 | 0.52 | -0.52 | 0.46 | 0.05 | 0.31 | -0.78 | 0.80 | 0.61 | -0.14 | 1.00 | | | | | | | | |
| Mn | -0.46 | 0.91 | -0.50 | -0.24 | 0.35 | -0.11 | 0.48 | -0.30 | 0.49 | -0.84 | 0.74 | 0.66 | -0.46 | 0.90 | 1.00 | | | | | | | |
| Na | -0.05 | -0.54 | 0.85 | 0.43 | 0.36 | -0.22 | -0.76 | 0.32 | -0.93 | 0.93 | -0.19 | -0.50 | 0.86 | -0.54 | -0.74 | 1.00 | | | | | | |
| K | -0.03 | -0.86 | 0.68 | 0.66 | -0.21 | -0.43 | -0.20 | 0.68 | -0.38 | 0.53 | -0.52 | -0.53 | 0.60 | -0.49 | -0.80 | 0.62 | 1.00 | | | | | |
| Cu | -0.49 | 0.48 | -0.40 | 0.30 | 0.31 | -0.47 | 0.78 | 0.32 | 0.52 | -0.78 | 0.38 | 0.93 | -0.40 | 0.82 | 0.77 | -0.59 | -0.44 | 1.00 | | | | |
| Zn | -0.57 | -0.11 | 0.13 | 0.84 | 0.30 | -0.84 | 0.61 | 0.86 | 0.16 | -0.35 | 0.05 | 0.65 | 0.08 | 0.50 | 0.22 | -0.06 | 0.24 | 0.75 | 1.00 | | | |
| Pb | -0.94 | 0.44 | 0.63 | 0.41 | 0.79 | -0.70 | -0.28 | 0.15 | -0.46 | -0.08 | 0.82 | -0.06 | 0.66 | 0.63 | 0.35 | 0.21 | 0.04 | 0.21 | 0.28 | 1.00 | | |
| Cd | -0.37 | 0.10 | -0.17 | 0.56 | 0.37 | -0.55 | 0.64 | 0.61 | 0.24 | -0.39 | 0.08 | 0.91 | -0.18 | 0.51 | 0.40 | -0.19 | -0.16 | 0.87 | 0.88 | 0.07 | 1.00 | |
| Cr | -0.92 | 0.67 | 0.38 | 0.29 | 0.89 | -0.62 | -0.13 | 0.05 | -0.32 | -0.25 | 0.93 | 0.27 | 0.43 | 0.80 | 0.60 | 0.03 | -0.28 | 0.46 | 0.34 | 0.92 | 0.31 | 1.00 |

**Table 7. Correlation coefficient (r) among analyzed water quality parameters for winter**

| Correlation | pH | Temp. | EC | Turbidity | TA | Acidity | TH | Ca | Mg | Cl | $SO_4^{3-}$ | $NO_3^-$ | TDS | Fe | Mn | Na | K | Cu | Zn | Pb | Cd | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| Temp. | 0.99 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| EC | 0.69 | 0.75 | 1.00 | | | | | | | | | | | | | | | | | | | |
| Turbidity | 0.34 | 0.43 | 0.91 | 1.00 | | | | | | | | | | | | | | | | | | |
| TA | 0.63 | 0.73 | 0.91 | 0.86 | 1.00 | | | | | | | | | | | | | | | | | |
| Acidity | 0.69 | 0.73 | 0.32 | 0.07 | 0.31 | 1.00 | | | | | | | | | | | | | | | | |
| TH | 0.52 | 0.57 | 0.87 | 0.84 | 0.92 | -0.04 | 1.00 | | | | | | | | | | | | | | | |
| Ca | 0.27 | 0.33 | 0.60 | 0.63 | 0.77 | -0.30 | 0.91 | 1.00 | | | | | | | | | | | | | | |
| Mg | 0.25 | 0.22 | 0.12 | -0.01 | -0.19 | 0.62 | -0.39 | -0.73 | 1.00 | | | | | | | | | | | | | |
| Cl | -0.80 | -0.72 | -0.48 | -0.15 | -0.43 | -0.16 | -0.55 | -0.48 | 0.16 | 1.00 | | | | | | | | | | | | |
| $SO_4^{3-}$ | -0.36 | -0.30 | 0.14 | 0.39 | -0.04 | 0.05 | -0.15 | -0.36 | 0.56 | 0.71 | 1.00 | | | | | | | | | | | |
| $NO_3^-$ | -0.49 | -0.61 | -0.39 | -0.31 | -0.59 | -0.79 | -0.24 | -0.12 | -0.14 | -0.02 | -0.05 | 1.00 | | | | | | | | | | |
| TDS | 0.48 | 0.59 | 0.89 | 0.91 | 0.86 | 0.45 | 0.68 | 0.41 | 0.23 | -0.06 | 0.45 | -0.63 | 1.00 | | | | | | | | | |
| Fe | -0.15 | -0.04 | 0.26 | 0.46 | 0.56 | -0.41 | 0.64 | 0.85 | -0.85 | -0.01 | -0.20 | -0.20 | 0.28 | 1.00 | | | | | | | | |
| Mn | -0.85 | -0.77 | -0.49 | -0.12 | -0.38 | -0.28 | -0.46 | -0.33 | -0.03 | 0.98 | 0.63 | 0.00 | -0.08 | 0.16 | 1.00 | | | | | | | |
| Na | 0.79 | 0.77 | 0.22 | -0.14 | 0.17 | 0.92 | -0.08 | -0.30 | 0.55 | -0.44 | -0.26 | -0.58 | 0.18 | -0.53 | -0.56 | 1.00 | | | | | | |
| K | 0.86 | 0.83 | 0.31 | -0.07 | 0.25 | 0.89 | 0.02 | -0.21 | 0.51 | -0.54 | -0.30 | -0.55 | 0.22 | -0.49 | -0.65 | 0.99 | 1.00 | | | | | |
| Cu | -0.15 | -0.04 | 0.46 | 0.70 | 0.64 | -0.44 | 0.74 | 0.84 | -0.67 | 0.05 | 0.09 | -0.12 | 0.49 | 0.93 | 0.20 | -0.62 | -0.57 | 1.00 | | | | |
| Zn | -0.34 | -0.21 | 0.09 | 0.37 | 0.42 | -0.30 | 0.40 | 0.60 | -0.70 | 0.34 | 0.05 | -0.34 | 0.29 | 0.92 | 0.49 | -0.53 | -0.54 | 0.85 | 1.00 | | | |
| Pb | 0.21 | 0.14 | -0.55 | -0.82 | -0.50 | 0.46 | -0.63 | -0.57 | 0.24 | -0.18 | -0.51 | -0.13 | -0.58 | -0.57 | -0.25 | 0.67 | 0.61 | -0.83 | -0.52 | 1.00 | | |
| Cd | 0.65 | 0.76 | 0.79 | 0.72 | 0.91 | 0.63 | 0.67 | 0.48 | 0.05 | -0.23 | 0.09 | -0.87 | 0.89 | 0.37 | -0.22 | 0.42 | 0.45 | 0.42 | 0.37 | -0.26 | 1.00 | |
| Cr | -0.80 | -0.69 | -0.24 | 0.16 | -0.07 | -0.51 | -0.06 | 0.13 | -0.39 | 0.80 | 0.49 | 0.03 | 0.07 | 0.57 | 0.89 | -0.79 | -0.83 | 0.61 | 0.78 | -0.56 | -0.07 | 1.00 |

## Hydrochemicalfacies and Piper trilinear diagram

Hydrochemicalfacies are recognizable parts of different characters belonging to any genetically related system. These are distinct zones within a ground water system that possess characteristic combinations of anions and cations concentration categories (Younger, 2007). It describes the details of domination over anions and cations during pre-monsoon, monsoon and post monsoon. This concept is useful to develop a model for explaining the genesis and distribution of the principal ground water types (Bikundia *et al.,* 2012). Piper trilinear diagrams were generated using major cations and anions to establish the hydrogeochemical regime (Piper, 1944). The trilinear plots of the major cations and anions in the ground water samples of the study area are shown in Fig. 2. It shows that the magnesium bicarbonate type of water fully dominated in pre-monsoon and post-monsoon, accounting for 100% of the samples in both the seasons. In monsoon magnesium bicarbonate type dominated, accounting for 60% of the samples, whereas rest 40% is characterized under mixed type i.e. no cations and anions exceeding 50%. For anions concentrations, the $HCO_3^-$ type of water predominated (100%) in pre-monsoon and post-monsoon, whereas 40% of the samples are no dominant type in monsoon. Similarly, for cation concentration, 20% of the samples are characterized by calcium type whereas rest 80% in monsoon and 100% water samples of pre-monsoon and post-monsoon is characterized in no dominant type. There is no significant change in the hydro-chemical facies noticed during the analyzed seasons (pre-monsoon, monsoon and post-monsoon). This indicates that most of the ions are natural in origin.

The reason is ground water passing through igneous rocks dissolves only small quantities of mineral matters because of the relative insolubility of rock composition. Further the diamond shaped diagram categorized to characterization into 9 subdivisions. From this characterization, it is noticed that overall 86.67% of samples, including 100% samples of summer and winter and 60% samples of rainy season belong to the magnesium bicarbonate type subdivision whereas rest 13.33% samples of monsoon belong to the mixed type subdivision.

## Correlation matrix of water quality parameters

It measured the intimacy and the degree of linear association between independent and dependent variables (Singh *et al.,* 2012). The correlation coefficient (r) is a main pointer which conveys about how points fit to a straight line. If the ‘r’ value close to +1 or -1 indicates a close fit to a straight line or a strong correlation. A ‘r’ close to zero indicates a very poor fit to a straight line or little or no correlation. In the present study, the correlation coefficients among analyzed water quality parameters have been calculated for the three different season’s i.e. pre-monsoon, monsoon and post monsoon season. The degree of association between any two of water quality parameters as measured by the simple correlation coefficient (r) is presented as 22 × 22 correlation matrix (Tables 5,6& 7). In all cases, the high correlation between EC and TDS occurs because conductivity depends on TDS and the main constituents of TDS in water are ionic species.

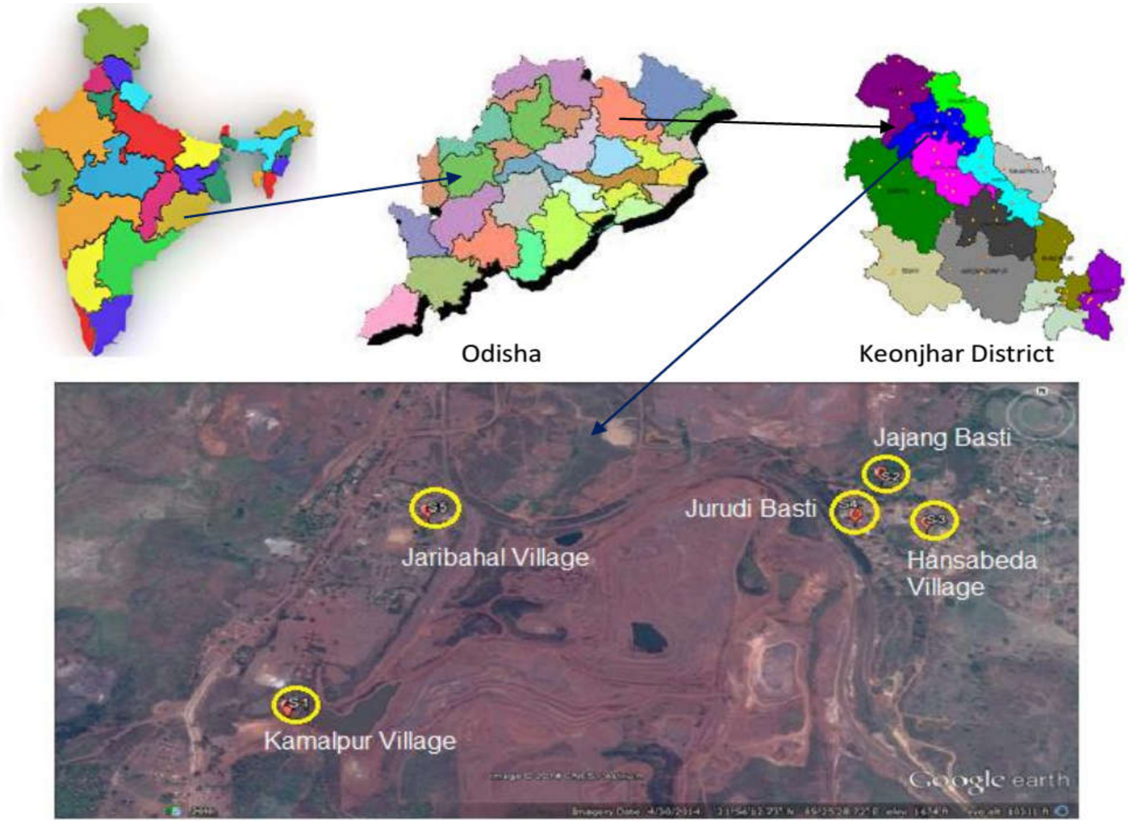


**Figure 1. Location map showing the sampling points**

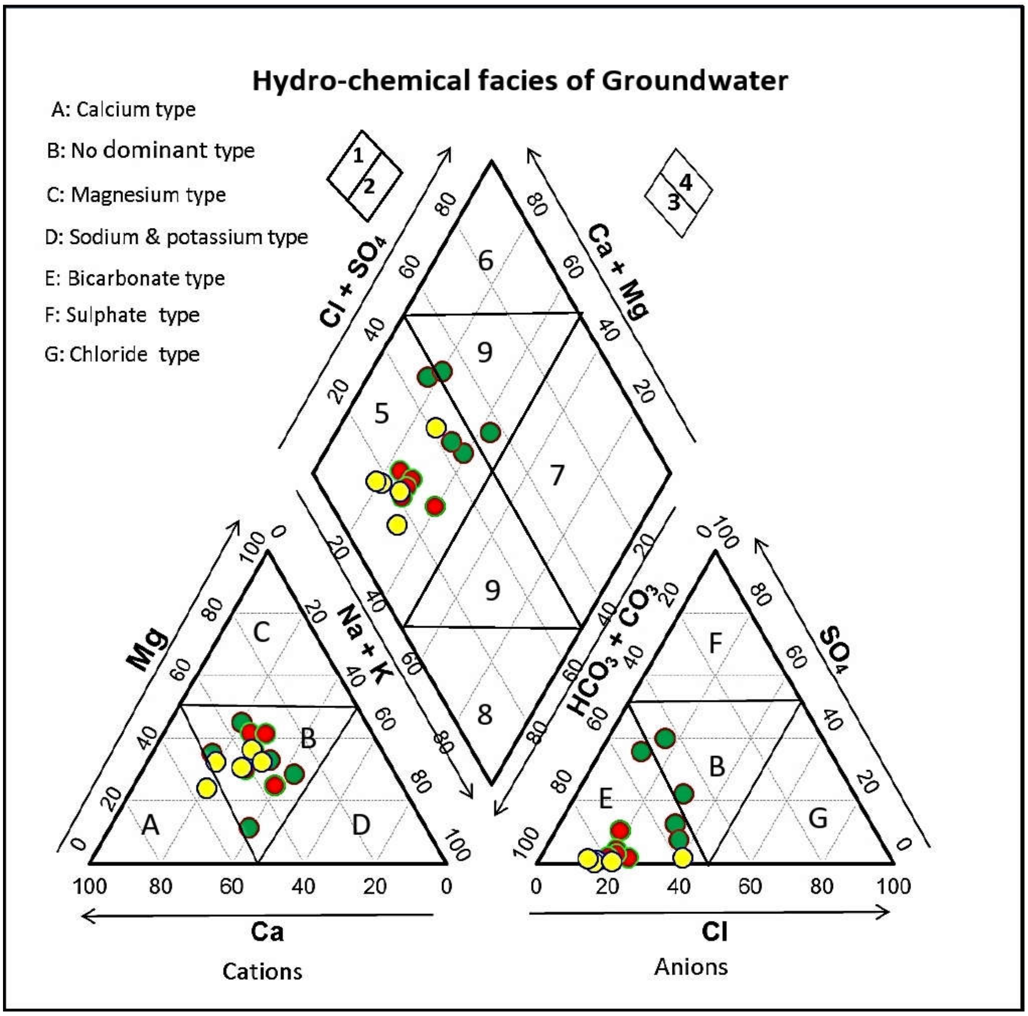


**Figure 2. Classification diagram for anions and cation facies in the form of major ions percentages**

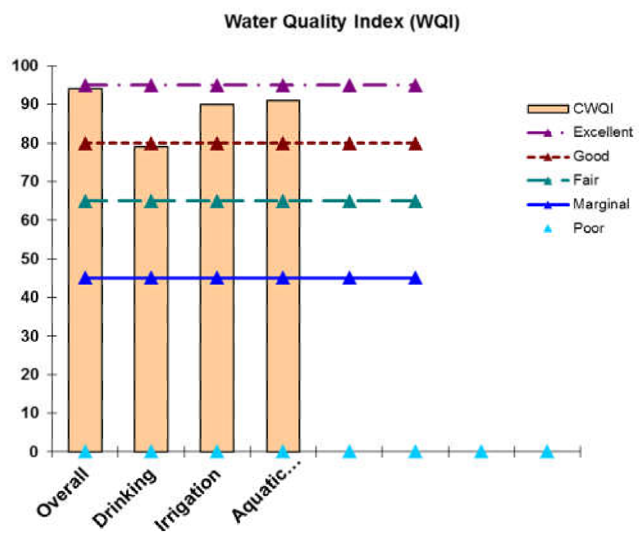


**Figure 3. The WQI chart for the analyzed parameters**

This information suggests that for a particular parameter, its correlation with other parameters vary with time in a year as the season changes. Such variability might have some linkages with the mining activity with the time span, which are needed to be explored. Taking into account the analytical uncertainty, no significant differences between seasons was recorded.

**Evaluation of ground water quality**

The ground water quality was accessed according to the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). The Water quality index was calculated by using the site specific Canadian water quality index (CWQI) calculator on line with the Indian water quality standards (*BIS,* 2012). From this data it is clear that four variables (Overall, drinking, irrigation and aquatic) were taken for the current study, where total 48 numbers of tests (physico-chemical parameters) were compared. Number of variables tested for Overall, drinking, irrigation and aquatic purposes are 18, 17, 6 and 7, respectively. The variable failed for overall, irrigation and aquatic purposes is pH, and that for drinking water purpose is iron. Variables with a higher normalized sum of excursions (NSE) are pH for irrigation and aquatic life, manganese for overall and iron in drinking water. The details of indexed data for overall purpose, drinking water purpose, irrigation purpose and aquatic life purpose are examined thoroughly. Using Eqs. (1), (2) and (3), we estimated the scope factor ($F_1$), frequency factor ($F_2$) and amplitude factor ($F_3$) respectively. Using, the value of water quality index (WQI) was calculated by using Eq. (5). Using these values, graphs are plotted as in Fig. 3. From this Fig. 3 it was observed that the analyzed water samples are not bad for drinking purposes. The overall drinking water quality is good with water quality index (WQI) value 94. The WQI values for irrigation and aquatic life are 90 and 91 respectively, suggesting that the water is good for these purposes. The WQI for drinking purpose is 79 suggesting that the water is fair for this purpose.

**Conclusion**

The analysis of groundwater samples collected from the different locations around Jurudi, Keonjhar district revealed that there was no fluctuation in the drinking water quality parameters like pH, EC, turbidity, TA, acidity, TH, Ca, Mg, Cl, $SO_4^{2-}$, $NO_3^-$, TDS, manganese, Cu, Zn with respect to the BIS drinking water permissible limit. All the analyzed data were within the permissible limit of Indian surface water quality standards relevant to irrigation, and Canadian standard for aquatic life. For parameters like Fe, Mn, Pb, Cd, Cr (mainly heavy metals) the concentration levels are above the BIS drinking water permissible limits for some groundwater samples. Heavy metals such as Pb, Cd and Cr all contribute separately to the groundwater contamination. Bulk of the groundwater samples is characterized as magnesium bicarbonate type hydro-geochemical facies with a few mixed type facies. The concentration level of some parameters in the groundwater is variable with the change in the seasons. The drinking water used by the people residing in the area around Jurudi is portable as indicated by the WQI value of 79 suggesting that the water is fair for this purpose.

**Acknowledgement**

The authors express their gratitude to the P.G. Department of Environmental Science, Sambalpur University and Centre for the Environment, Indian Institute of Technology Guwahati for their support. The authors are also thankful to Environmental Laboratory of Clean Viron Private Limited for their help in the field and laboratory analysis.

## REFERENCES

Adhikary P.P., Chandrasekharan H., Chakraborty D., Kamble K., 2010. Assessment of groundwater pollution in West Delhi, India using geostatistical approach. *Environ Monit Assess.,* 167, pp 599–615.

Almasri M.N., Kaluarachchi J.J., 2004. Assessment and management of long term nitrate pollution of ground water in agriculture dominated watersheds. *Journal of Hydrology,* 295, pp 225-245.

APHA, 2012. Standard methods for the examination of water and wastewater: American public health association, American water works association, water environment federation publication. 22nd edition. APHA, Washington D.C.

Bhuiyan Md. A.H., Islam M.A., Dampare S.D., Parvez L. and Suzuki S., 2010. Evaluation of hazardous metal pollution in irrigation and drinking water systems in the vicinity of a coal mine area of north-western Bangladesh. *Journal of Hazardous Materials,* 179, pp 1065–1077.

Bikundia D.S., & Mohan D., 2014. Major ion chemistry of the ground water at the Khoda Village, Ghaziabad, India. Sustainability of Water Quality and Ecology,3, pp 133-150.

BIS, 2012. Drinking Water Specification, Second Revision IS:10500: 2012. Bureau of Indian Standards, New Delhi, India.

CCME, 2006. A sensitivity analysis of the Canadian water quality index, Cannadian Council of the Minister of the Environment, Ontario.

Chapolikar A.D., and Ubale M.B., 2010. A correlation study on physicochemical characteristics of ground water in Thane-Belapur Industrial area, Mumbai. *Current World Environment,* 5 (1), pp 67-71.

Chen A., Lin C., Lu W. *et al*., 2007. Well water contaminated by acidic mine water from the Dabaoshan Mine, South China. Chemistry and toxicity, Chemosphere, 70, pp 248–255.

Dixit S., Gupta S.K., Tiwari S., 2005. Nutrient overloading of fresh water lake of Bhopal, India. *Electronic Green Journal,* 1(21).

Dunnette D.A., 1979. A geographically variable water quality index used in Oregon. *Journal of Water Pollution Control Federation,* 51 (1), pp 53-61.

Frederick A.A., 2011. Assessment of Ground Water Quality Status for the Tarkwa Mining Municipality in Ghana. International Journal of Environmental Sciences 2, 2.

Goel P.K., 2011. Water Pollution: Causes, effect and control Book, New age international Publisher, New Delhi.

Hurley T., Sadiq R., and Mazumder A., 2012. Adaptation and evaluation of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for use as an effective tool to characterize drinking source water quality. *Water research,* 46 (11), pp 3544-3552.

Jerry A.N., 1986. Basic environmental technology: water supply, waste disposal and pollution control. Wiley, New York.

Khan A.A., Paterson R., Khan H., 2004. Modification and application of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for the communication of drinking water quality in Newfoundland and Labrador. *Water Quality Research Journal of Canada,* 39 (3), pp 285-293.

Kumar J., Younger P., 2004. Water quality trends in the Tarkwa gold-mining district, Ghana. *Bulletin of Engineering Geology and Environment,* 63, pp 119-132.

Lumb A., Halliwell D., Sharma T., 2006. Application of CCME Water Quality Index to monitor water quality: a case study of the Mackenzie River basin, Canada. *Environ Monit Assess,* 113, pp 411-429.

Piper A.M., 1944. A graphic procedure in the geochemical interpretation of water analyses. *Trans Am Geophys Union,* 25, pp 914–928.

Prasad R.V., Tripathi and Kumar V., 2013. A Concise Report on the Status of Groundwater of Babhnan Town, Basti, UP, India. *Research Journal of Chemical Sciences,* 3 (9), pp 80-82.

Ramakrishna C., 2009. Studies on Ground Water Quality in slums of Visakhapatnam, *Asian Journal of chemistry,* 21 (6), pp 4246-4250.

Ravikumar P. and Somasekhar R.K., 2011. Geochemistry of groundwater, Markandeya river basin, Belgaum district, Karnataka State, India. *Chin J Geochemical,* 30, pp 51-74.

Roy M.P., Roy S.K. and Singh P.K., 2000. Impact of mining on environment - an appraisal. *The Indian Mining and Engineering Journal,* 42, pp 11-12.

Singh V.K., Bikundia D.S., Sarswat A., Mohan D., 2012. Groundwater quality assessment in village LutfullapurNawada, Loni, District Ghaziabad, Uttar Pradesh, India. Environ Monit Assess, 184, pp 4473–4488.

WHO, 1971. International standards for drinking water. World Health Organization, Geneva.

Younger P.L., 2007. Groundwater in the Environment: An Introduction. Blackwell Publishing, USA.

*******