Surface Water Quality Assessment based on Aquatic Benthic Macroinvertebrate in the tribal belt, Bailadila, Dantewada, India

Santosh Kumar[1], Sarika Sinha[2], Anjani Prasad Singh[3]

[1]*Civil Engineer, Aryawart Infra Projects, Indore*
[2]*Science Teacher,DAV, Bacheli, Chattisgarh,*
[3]*Research Scholar, Indian Institute of Technology (Indian School of Mines) Dhanbad*

Abstract - *Seasonal quantification of ground and surface water is essential for the strategic management of water resources for the sustainable development of any country. In the present study, surface water quality was assessed based on the presence of macro-invertebrates as key indicators. Water resources were evaluated based on hydrogeological exploration and hydrological of the area. Sector-wise water demand for a major group of crops, domestic and Iron ore mining industries with beneficiation were assessed. An average groundwater dynamic variation was reported at 14.21m, and the estimated quantity was found to be 808.67 million cubic meters. The study of surface water flow for consecutive three lean periods was calculated to vary from 782.83m^3/h to 775817.3 m^3/h in four main rivers which indicate the availability of sufficient water in the area. Hence, availability of sufficient water in the study area for Agriculture, Mining, and domestic consumption is recommended to conserve natural resources for sustainable development.*

Key Words: *Macro Invertebrate Water Quality Index (MWQI),* Bailadila Iron Ore Complex *(BIOM), ETo= Reference crop evapotranspiration, Surface water, Hydrogeological, sustainable development.*

1. INTRODUCTION

Water is scarce, precious resource for the existence of life on the earth and essential for domestic, irrigation, and industrial uses and sustainable development of an area (1). For the sustainable development and monitoring of water resources use in respect of social, economic, and environmental objectives integrated water resources management is a systematic process. It is understood that use of water resources are interdependent. This process promotes the coordinated development and management of water, land, forest, industries, and ecosystem to maximize the result of socio-ecnomic welfare in an equitable manner, without compromising the ecosystem sustainability. An integrated approach would minimize the conflict between the local tribal community and mining.

1.1 The Problem of the research and Purpose of the study:

In India, steel consumption in the last 5 years was ranging bound at 9-13% and expected to grow @10% till the year 2020. By 2019, it has been envisaged that the total demand for iron ore is likely to increase 290 million tons (Mt), both on account of domestic requirements (19Mt) and export (100Mt), hence, enhancement of the capacity of around 305 million tons per annum (MTPA) is required (at 95 % capacity utilization) by 2019-20. To meet this projected demand, the country has planned expansion of capacity on a large scale from its existing mines and the development of new mines. In this context, Bailadila mines have planned to expand its present iron ore production capacity of around 36 Mt to 67 Mt per annum by 2031-41 through the capacity expansion of existing mines, opening of new mines, beneficiation, and pellet plants.
With increasing production of iron ore, water demands also increase which ranged from 1 to 3 m3/ tonnes of iron ore processing. The main source of water used for different purposes in Bailadila is a perennial stream originated from springs. Water demands of these industries are fulfilled by these streams. The beneficiation plant at Bailadila has 8.0 Mt/annum of 90 % concentrate production. This plant needs a water demand of 519 m3/hr for the beneficiation of slime. The plant is bringing water from the Sabari River 55 km from the Bailadila sector which is a tributary of River Godavari. Keeping this view, it is intended to research this discipline for sustainable development.

2. MATERIALS AND METHODS

Study Area: The study area is located around Bailadila Iron Ore Complex (BIOM) around the Dantewada district of Chhattisgarh State in India and located in latitude 18°31'5.57" N to 18°52'39.85" N and longitude 80°53'54.09" E, to 81°24'5.12" E (Fig.1). The tribal population is 78.5 % and out of 42 tribes, the most populous tribe in the district is Gond followed by Kanwar, Oraon, Halba, and Bhattra (Census 2011). 65% of the geographical area is occupied by forest. As recorded during the study, the maximum temperature in summer rises to 37.7oC in May and June whereas the minimum temperature drops to 12.2oC in December during the winter season. The average temperature ranged from 19.4oC to 31.2oC. The minimum and maximum average annual rainfall in the area is 1831.40 mm and 4028.80 mm respectively with an average of 2651.33 mm in BIOM. The average relative humidity in the study area is 86.6 % during September and the minimum during April (34.7%). The monsoon season of the district faces heavy rains.

The regional geology of the study consists of the iron and tin ores of the Bailadila range belong to the Bailadila series, which are associated with slightly metamorphosed iron-ore bearing sedimentary rocks. Iron ore occurs as separate ore bodies on the crest of the two sub-parallel hills running north-south. The Bailadila iron ore series is represented at the bottom by current bedding bearing arkosic rocks followed by a sequence of partly clastic and partly tuffaceous formations.

Macroinvertebrates were sampled from the River/streams/Nalla originating Bailadila hill by employing a „D-frame" dip net having a mesh size of 0.5mm. They were collected from the running water by vigorously disturbing/dislodging the bottom substrata such as pebbles, broken logs, foliages, etc., immediately above the location where the net was placed. In the case of pools, the net was towed along the bottom as well as margins. The dislodged organisms along with the debris carried by the running water to the net were then transferred to a sorting tray and after initial sorting; the individuals were preserved in 70% ethyl alcohol in the field and later sorted and identified up to the maximum lowest taxonomic level possible under a stereo-zoom microscope in the laboratory following standard identification manuals. Wherever possible, different kinds of habitats such as pools, riffles, and cascades in a location were sampled to get a uniform representation of the aquatic fauna. For the present study, the family level identity of the invertebrates was considered and each family was assigned a pollution sensitivity score (BMWP Score) as referred in various literature (Armitage et al., 1983; Dudgeon, 1999 and Subramanian and Sivaramakrishnan, 2007b). Numerical abundance of individual macro-invertebrate taxa collected at different stations was recorded and from which % EPT taxa were calculated. Based on the Macro-invertebrate Water Quality Index (MWQI) developed by Bhat and Pandit (2010) assessment of water quality was done. The MWQI was calculated using the following formula:

$$MWQI = \frac{\sum N + 1}{(\sum N + 1) + (\sum N' + 1)} \qquad (1)$$

Where, N = ni (si-ms); N` = ni (si-ms). N is the multiple products of the density of the ith taxon and the positive relative sensitivity score; N` is the multiple products of the density of the ith taxon and the negative relative sensitivity score; n is the density of ith taxon having assigned pollution sensitivity score (s) ≥ median score (ms) (positive score); ni is the density of ith taxon having assigned pollution sensitivity score (s) < median score (ms) (negative score); 1 is the constant to account for samples in which taxa having a pollution sensitivity score more than the median score may be absent.

For the classification of water quality, eight index values between 0 and 1 are used to denote the distinct water quality classes mentioned in Table1.

Integrated water resources management is a systematic process for the sustainable development, allocation, and monitoring of water resource use in the context of social, economic, and environmental objectives. This process will promote the coordinated development and management of water, land, forest, industries, and ecosystem to minimize the resultant economic and social welfare in an equitable manner. An integrated approach would minimize the social issues of South Bastar Dantewada, Chhattisgarh. The rationale of the future strategy is to meet the challenge in such a manner that development is sustained.

Bailadila Dantewada Chhattisgarh is known for Iron Ore Mining and socioeconomic backward region on the globe.

Table-1: MWQI range and details of water quality characteristic assigned to individual range

Index range	Water quality	Degree of organic pollution
≥ 0.9000	Excellent	No apparent pollution
≥ 0.7000 – < 0.9000	Very good	Slight organic pollution
≥ 0.6000 – < 0.7000	Good	Some organic pollution
≥ 0.5000 – < 0.6000	Fair	Significant pollution
≥ 0.4000 – < 0.5000	Fairly poor	Significant organic pollution
≥ 0.3000 – < 0.4000	Poor	Very Significant pollution
≥ 0.2000 – < 0.3000	Very poor	High organic pollution
< 0.2000	Worst	Severe pollution

The adoption of Sustainable Water Management adoption is not only a technological problem but involves many other considerations relative to Climatic conditions, the social behavior of rural communities, economic constraints, or the legal and institutional framework that may favor the adoption of some measures and not others. In this research, according to the climatic condition of the area and the prevailing condition of heavy rainfall, the amount of water demand for different crops (Paddy, wheat, and ....) uses were calculated by calculating the average monthly rainfall transpiration of the study area. The crop water needs mainly depend on Climatic, crop types, and growth stages of the crops. The average monthly temperature and rainfall were recorded by Watchdog 2700 Weather Station from 2014-2018. From 1956 to 2018, rainfall data were used for the calculation of effective rainfall as given in Table 2.

Knowing the amount of water to be used by particular crop in a locality an estimate is made by the amount of water used or consumed by that same crop in other 8 agricultural stations. After analysis of tank, plot, filed and valley experiments in several western ststes, (Blaney et al 1950) it was found that even among many different locations and growing conditions there is barely any difference observed in K value for each crop when ample of water is available for plant growth. It has even been observed that over a wide range of conditions alfalfa has a K of about 0.85. Other crops have been studied and the K value has been found to be quite consistent. Values of K and the growing season or period used for crops grown in Oregon are listed in table 3. For some of the crops shown, the K values were entirely estimated, but are the best estimates available. As research is extended, these figures may be refined.

Table-2: Monthly temperature and rainfall variation

Monthly	Avg. Temp. (°C)	Min. Temp. (°C)	Max. Temp. (°C)	Rain fall (in mm)
Jan.	20.1	12.6	27.6	10.31
Feb.	22.7	15.2	30.3	7.81
Mar.	26.2	18.7	33.8	14.87
April	29.3	22.5	36.1	47.04
May	31.3	24.9	37.7	74.62
June	28.6	23.9	33.4	367.00
July	24.9	21.9	27.9	819.21
Aug.	24.7	21.7	27.8	779.87
Sep.	25.2	21.7	28.7	357.47
Oct.	24.3	19.8	28.8	133.47
Nov.	21.2	15.1	27.3	27.44
Dec.	19.4	12.2	26.7	11.98

At normal temperature and various rainfall conditions data have been computed for years for the amount of water consumed, water supplied by precipitation, and that supplied by irrigation to the crops. Irrigation water need for selected crops Oat/Barely/Wheat, Paddy, Maize/ Grains, Cabbage and Sorghum/ Jawar/ Bajara were calculated by using (C. Brouwer et al 1987, 1992;
A requirement for irrigation water:

$$IN = ETcrop + SAT. + PERC + WL - Pe \qquad (1)$$

Blarney – Criddle method was used to calculate reference crop evapotranspiration (ETo) using mean monthly measured temperature as equation (1).

$$ETo = p\,(0.46\,Tmean + 8) \qquad (2)$$

Where,
ETo= Reference crop evapotranspiration (mm/day);
T= mean daily temperature (oC), and
p= mean daily percentage of annual daytime hours which was calculated on the latitude of the area (Number of degrees North and South of the equator.

$$ETcrop = ETo \times Kc \qquad (3)$$

Where,
ET crop= Crop evapotranspiration or crop need (mm/day);
Kc= Crop factor and
ETo = reference evapotranspiration (mm/day).
The crop factor (Kc) values 0.35, 0.75, 0.45 1.15 for crop Oat/Barely/Wheat, 1.1, 1, 1.05 and 1 for paddy;0.4, 0.8, 1.15 and 0.9 for Maiza; 0.45, 0.75,1.05 and 0.9 for Caggage and 0.35, 0.75, 1.1 and 0.65 were used for calculation of crop evapotranspiration (mm/day) during initial, crop development, middle and final development phases.
Water is needed to saturate the root zone before sowing or transplanting. However, depending on soil type and rooting rooting depth amount of water depend. In this manual it is assumed that the amount of water needed to saturate the root zone is 200 mm.
According to the soil type percolation and seepage looses (PERC) losses depends. PERC will be low in case of clay soils and high in case of sandy soils. PERC losses varies between 4 to 8 mm. In this study, on average PERC= 6mm/day assumed in calculation.
During transplanting or sowing a water layer (WL) developed, which is to be maintained throughout the growing season. Hence, WL = 100 mm is assumed in the calculation of irrigation water need.
Using equation ($Pe = 0.8\,P-25$ if $P > 75$ mm/month) effective rainfall (Pe) was accessed.
($Pe = 0.6\,P-10$ if $P < 75$ mm/month) for January, February, March, April May, June, July August, September, October, November, and December rainfall data observed from the year 2013 to 2018 Where P = rainfall or precipitation (mm/month); Pe = effective rainfall or effective precipitation (mm/month).
Land detail was collected from concerned Patwari, Sachiv, land revenue department of Dantewada and Bijapur district.

Domestic and Industrial Water assessment

Depending upon the living conditions of a particular person the amount of water consumption varies. The minimum domestic consumption for rural villages and urban towns was assumed 40 l/p/d and 135 l/p/d under ordinary circumstances with a flushing system respectively. Along with it, the amount of drinking water is calculated separately for the rural area as 40 liters per day for the year 2011 after that urban and rural water demands are assumed 135 liters per day for a middle-class family as per code of practice. This research would minimize the conflict between the local tribal community, the mining and associated industries in the area.
As per the steel policy of India 2017, the Government of India has charted a road map to augment India's Steel production capacity to 300 Mtpa by 2030-31. Hence, to fulfill this vision, Bailadila mines have proposed to enhance the iron ore production capacity. BIOM has planned to increase

the production of 67 MTPA from Bailadila mining leases. BIOM proposes to augment its production capacity of iron ore to 67 million tonnes by 2021-22. Thus Water demand in the area will increase. Water demand depends on Climatic conditions and the quality of iron ore, Water demand of Baiadila has been calculated based on the last 20 Years production. It is found that 0.6 m3/ Tonne to 0.8 m3/ Tonne of water is required to wash the iron ore. The beneficiation plant at Kirandul has 8.0 MTPA of 90 percent concentrate production. This plant needs a water demand of 519 m3/hr for the beneficiation of slime. With the increasing production of iron ore, the water demand of the area also increased. Water demand for industrial use, such as beneficiation of Bailadila iron ore slime/fines, water demand range from 0.42 m3/ Tonne to 0.55 m3/Tonne iron of ore has been calculated based on last three years production data.

Water resource assessment

The water flow was measured by the current meter and by the float method. The methodology adopted for water flow measurement study consisting mainly of two aspects viz., monitoring the velocity of flow and estimating the area of nallah representatively at the point of measurement. Measurement of velocity was restricted to surface float as the water depth was shallow. Thus, nallah was divided into segments for velocity measurement. The depth was measured at vertical points of equidistant in cross-section. The discharge was calculated by multiplying the velocity and area of the channel. The velocity of flow was measured using a current meter made of Lawrence & Mayo of propeller type connected to an electronic commuter.

The flow was calculated as below

$$Q = \sum^{m}{}_{1} q = \sum^{m}{}_{1} (V1A1 + V2A2 + \ldots\ldots\ldots (4)$$

Where q is the flow of each segment; V1 is the velocity in the segment; A1 is the area of segment and m is the no. of the segment.

In this research, sampling locations for the purpose of monitoring were considered based on groundwater movement, watershed, land use pattern, and other hydrological conditions. During the field study, groundwater levels and water samples were collected from these locations to assess the groundwater levels and quality.

CGWB has carried out little hydrological investigations in the study area due to hilly terrain and also due to thick evergreen forest and the presence of local social elements in the study area. Within the study area, no data was available. SGWB has earlier monitored groundwater level and quality at limited location, but now the same has been suspended due to local anti-social elements. During the field investigations, groundwater levels were measured at 74 locations to assess the groundwater levels during winter, pre-monsoon, monsoon, and post-monsoon months from period 2014 to 2018. The water level fluctuation showed a decline in trends in all seasons shown in Figures 1-4. In the estimation of dynamic water resources, a mean value of groundwater level variations over five years in different seasons was evaluated as 14.213m.

The dynamic water resources/ replenishable groundwater resources were estimated using the water table fluctuation method following (GEC 2009). Specific yield values for weathered Phyllite, shales, Schist, Limestone, and associated rock are 1 to 3 %. In the study area, the average specific yield of 2 % was assumed for water resource estimation.

Dynamic water resource (m^3) =

$$\text{Area x Specific Yield (Sy) X Water table charge (Ds)} \quad (5)$$

The drainage system of SankaiNadi, MalingarNadi, Chintavaghu, and Talperu and Berudi Nadi, which are sub tributaries of river Godavari River. These form the intermittent elongated valley in a defined direction, indicating structure, lithological and topographical control. The drainage frequency and density of Marin, Sankani, MalangirChintavaghu, Talperu, and Berudi rives basin have been calculated.

Pumping and recovery test

To know the aquifer characteristics like transmissibility, discharge of the pumping wells, and drawdown, preliminary yield tests (PYT) were conducted at ten locations in different watersheds within the study area, based on observed groundwater movement. This recovery method has been used and the T value is estimated using the equation

$$T = 2.3\ Q/4\Pi\Delta s \qquad (6)$$

Where Q= Constant discharge, in m3/day, Δs - change in residual drawdown in m per log cycle of t/t', and T- Transmissibility in m2 per day. Transmissibility was estimated.

Geophysical methods such as-electrical, electromagnetic, seismic, and gravity –are used to explore the groundwater. Geophysically the location of groundwater may be determined in three ways: direct, stratigraphic, and structural (Bhattacharya and Patra, 1968; Elijah A. Ayolabi, 2005). The stratigraphic method which is relevant to this study implies locating water-bearing formations through distinguishing physical Properties imparted by the presence of water, giving rise to electrical resistivity contrasts. The electrical resistivity methods give fairly accurate results in groundwater investigation. In the field of ground water exploration (Pal and Majumdar, 2001; Majumdar and Pal, 2005; Narayanethkar et al., 2006), electrical resistivity method is assumed to be of considerable importance as it is inexpensive, easy in operation and its capacity to identify between fresh and saline water zones, this method is used worldwide. This method is used to estimate the thickness and electrical nature of formation which helps is providing information regarding groundwater potentialities (Griffiths and King, 1965; Parasins, 1966; Balakrishna, '1980).

Electrical Resistivity Tomography (ERT) Investigation

Electrical Resistivity Tomography (ERT) investigation has been carried out at 63 locations in the study area considering space availability for multi-electrode profile

cable layout as it requires a minimum 140 m length in a straight line. The total spread of each ERT profile was 140 m.
The ERT investigation has been carried out using SYSCAL PRO-96, IRIS instrument. It is a ten-channel multi-electrode automatic resistivity meter with high accuracy and multi-core cable equipment supports 5 maximum inter-electrode spacing physically. Vertical Electrical Soundings (VES) were conducted by adopting Schlumberger Configuration in different locations in the study. The depth of penetration was restricted to 70 m, VES data were analyzed both curve matching and curve break techniques, and results are tabulated in the table. From the analysis, it was noticed that the thickness of the overburden is up to 25 m and varies from place to place. It is clear that apparent resistivity is high in the Eastern portion of deposits when compared to another part, indicating lithology control and reduction in the overburden. VES tests were conducted at sixty different locations and data were analyzed for knowing the geo-electrical properties of subsurface formation information at bottom of hills. To know overview of subsoil and the presence of groundwater and minerals at a certain depth [1] the geoelectric method is intended. This method is intended to predict the electrical properties of medium or subsurface rock formations, especially their ability to conduct or inhibit electricity [2].
Electrical resistivity methods assumed considerable importance in the field of groundwater exploration (Pal and Majumdar, 2001; Majumdar and Pal, 2005; Narayanethkar et al., 2006) because of its inexpensive, easy operation and its capacity to identify between fresh and saline water zones, the method is used worldwide.
Electrical and electromagnetic techniques have been extensively used in groundwater geophysical investigations because of the correlation that often exists between electrical properties, geologic formations, and their fluid content (Flathe 1955; Zohdy et al. 1969; Flathe 1970; Ogilvy 1970; Zohdy et al, 1974; Fitterman et al 1986; McNeill et al 1990; Muchingami, I. et al., 2012; BarideMukundVasantrao et al. 201; Akhtar et al 2018).

3. RESULT AND DISCUSSION

Aquatic benthic macroinvertebrate diversity and water quality index:

Aquatic benthic macroinvertebrates were collected from a total of 7 sampling locations in the perennial streams originating from the mine lease areas of BIOM, during 2018. A total of 510 macroinvertebrate taxa representing 27 families under 10 invertebrate orders were collected and identified from the streams table 3. The invertebrate taxa (order), abundance was highest in Trichoptera (56.86%) followed by Ephemeroptera (17.84%), Diptera (15.49%), etc. and richness was highest in Diptera (7) followed by Odonata and Trichoptera (4 each) and Coleoptera (3) Dominant macroinvertebrate taxa (family) were Hydropsychidae, Baetidae, Chironomidae, and Polycentropodidae in their decreasing order of abundance).
The Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa account for more than half of the samples with Ephemeroptera represented by 2 families, Plecoptera represented by 1 family i.e., Perlidae, and Trichoptera by 4 families. From the abundance results of macroinvertebrates, moderate to a high abundance of Hydropsychidae taxa was observed in as many as three sampling stations i.e., Sw4, Sw5and Sw6 wherein Sw5 and Sw6 were reported as some polluted locations being affected mainly by tailing deposits as well as wash off from the active mining locations, In general, very good water quality was recorded at Stations Sw2, Sw3, Sw4 and Sw7 while excellent water quality recorded at Stations Sw1classification based on (Bhat et.al 2010). Although the sampling was limited, the results of the analysis of macroinvertebrate samples collected from 7 locations of the study area indicate the quality of the aquatic habitat, which is more or less in conformity with the general observations of the state of the study area. Although the study was limited to a minimum number of sampling, the MWQI index provided a clear understanding of the water quality of the locations sampled. Overall, the water sources of BIOM were found to be some deteriorated in quality, which might attribute to erosion from deposited tailings along the watercourse. Water quality of the sampling locations from the streams of BIOM showed in Table 4.

Table- 4: Water quality of the sampling locations from the streams of BIOM

Diversity Indices	Sampling station code						
	1	2	3	4	5	6	7
Taxa Richness	12	9	8	14	6	10	11
Individuals	101	26	24	234	153	307	35
Dominance D	0.4259	0.2615	0.3406	0.4627	0.686	0.5807	0.1378
Simpson 1-D	0.5741	0.7385	0.6594	0.5373	0.314	0.4193	0.8622
Shannon H	1.369	1.515	1.319	1.285	0.6771	0.8621	1.939
Evenness e^H/S	0.3278	0.5055	0.4677	0.2581	0.328	0.2368	0.6318
Fisher alpha	3.546	4.877	4.202	3.267	1.245	1.98	5.517

Dominant macroinvertebrate taxa (family) were Hydrophsychide, Baetidate, Chironomidae, and Polycentropodiade in their decreasing order of abundance shown in diversity indices of macrofauna recorded from the streams Table 5.

Water demand assessment:

Crop water assessment: The total crop water needs for Oat/Barely/wheat, Paddy, Maize/Grains, Cabbage, and Sorghum /Jawar were calculated 1438.5 mm/crop, 1702.1mm/crop, 1578.1 mm/crop, 1816.8 mm/crop 1560.2 mm/crop respectively includes ETcrop, PERC, saturation, and water Layer from field preparation for sowing seed to pre harvesting time. The irrigation water requirement for the crops like Oat/Barely/wheat was found to be 1391.13 mm/crop, (-) 56.72 mm/crop for paddy, (-) 593.39 mm/crop for Maize, 12898.44 mm/crop for Cabbage and (-) 280.48 mm/ crop for Sorghum/ Jawar/Bajara. The ETcrop, PERC, saturation, water layer, precipitation, effective precipitation, irrigation water requirement, and surplus water were calculated for selected crops.

Table- 5: Diversity indices of macrofauna recorded from the streams of BIOM

Sampling station code	Name of the sampling location	MWQI Range	Water Quality	Degree of Organic Pollution
Sw1	Berudi River	0.9320	Excellent	No apparent Pollution
Sw2	Malangir Nadi	0.86805	Very good	Slight organic pollution
Sw3	Galli Nalla	0.8780	Very good	Slight organic pollution
Sw4	JhirkaLawa Nalla	0.8476	Very good	Slight organic pollution
Sw5	Kirandul Nalla	0.6158	Good	Some organic pollution
Sw6	Bacheli Nalla	0.65025	Good	Some organic pollution
Sw7	Sankani River	0.7954	Very good	Slight organic pollution

Domestic water assessment: The amount of domestic water consumption per person varies according to the living condition of consumers. The minimum domestic consumption for rural villages and urban towns was assumed 40 l/p/d and 135 l/p/d under ordinary circumstances with a flushing system respectively. Water demand was forecasted, 9091.91 m3/day, 20658.47 m3/day, 24155.48 m3/day, and 28392.65 m3/l for the year 2011, 2021, 2031, and 2041 respectively.

Industrial water assessment: With the increasing production of iron ore, the water demand of the area also increased. The water demand of the area is increasing year by year due to the enhancement of mining capacity and opening of new mines as well as installation of mineral beneficiation plants. Water demand depends on the Climatic condition of area and the quality of iron ores. In this study water demand of Baiadila has been calculated based on the last 20 years available data. It was evaluated that Bailadila iron ore contains 60-65 % of fines with remaining Calibrated Lump Ore. It is found that 0.6 m3/ Tonne to 0.8 m3/ Tonne of water were required to wash the iron ore of Bailadila in monsoon season to overcome an obstacle in operation. In the study area, for conservation and optimum utilization of mineral resource 8.0 Million Tonne per annum (MTPA) of 90 percent concentrate production capacity beneficiation plant was installed. This plant needs a water demand of 519m3/hr for the beneficiation of slime. Water demand of beneficiation of Bailadila iron ore slime/fines, water demand range from 0.42 m3/Tonne to 0.55 m3/Tonne iron of ore has been calculated based on last three years production and process water is being recycled and reused.

Water demand depends on Climatic conditions and the quality of iron ore, Water demand of Baiadila has been calculated based on the last 20 Years data. It is found that 0.6 m3/ Tonne to 0.8 m3/ Tonne of water are required to wash the iron ore of Bailadila. The washing of 17 MTPA iron ore containing 65% fines requires 18416.67 m3/d of water for the year 2020. The forecasted requirement for the next subsequent ten years during the monsoon season was calculated to be 39000 m3/d for 35MTPA for the year 2031, 72583.33 m3/d for 67 MTPA for the year 2041.

The water requirement for the beneficiation of 8MTPA iron ores for the year 2020 was 12054.79 m3/d. The forecasted requirement for 65% of 36 MTPA for the year 2031 was calculated to be 35260.27 whereas, for the year 2041, it was forecasted to be 65623.29m3/d.

Water resources assessment in the study area

Surface water resource: In this research, surface water flow were measured during three consecutive lean periods 2015, 2016, and 2017 at 14 different locations shown in Table 6, it is found that mean discharge values were 782.83 m3/h, 775817.33 m3/h, 61664.33 m3/h, and 653393.33 m3/h in main rivers around Malangir, Sankani, Talperu, and Berudil respectively.

Table- 6: Water flow of streams/nalla/rivers measurement (in m3/h)

Years/ (streams / nalla/ rivers)	2015	2016	2017	Min.	Max.	Average
Dhobight stream	343.1	20	10	10	343.1	124.37
Kirandul Nalla	323.6	343.63	280.8	280.8	343.63	316.01
Madadi nalla	183.2	187.1266	0	0	187.1266	123.44
Koyar river	1376.7	1158.71	1037.9	1037.9	1376.7	1191.10
Malingar river	876.4	864.6909	607.4	607.4	876.4	782.83
Bangali camp Nalla	952.6	735.948	644.5	644.5	952.6	777.68
11 B Nalla	138.5	135.32	168.2	135.32	168.2	147.34
Jhirkalawa nalla	579832	594000	560592	560592	594000	578141.33
Sankani river	784529	775080	767843	767843	784529	775817.33
Talperu River	2219	2520	21965	2219	21965	8901.33
Galinalla	54360	53065	51963	51963	54360	53129.33
Galinnalla	61200	62831	60962	60962	62831	61664.33
Berudi river	774000	598680	587500	587500	774000	653393.33
Nakulnar nala	2240	2450	2100	2100	2450	2263.33

Groundwater resources: To find out the availability of groundwater resources within the study area pumping and recovery test were conducted at 16 locations in different watersheds within a study area based on observed groundwater movement. Transmissibility was estimated using Thei's recovery curve. It varies from 6.18to263.93m2/day and increases in the direction of groundwater flow. Discharge of abstraction structure varies from33.80m3/day to 853.92 m3/day as per observations, the residual drawdown varies from 0.11 m to 3.40 m. In the present study, an attempt was made to estimate the total ground resource available by following the groundwater resource estimation committee, Ministry of Water Resources Govt. of India recommendation (GEC 2009). To calculate the dynamic water resources (m3) in the study area 2845 sq. km, specific yield assumed 0.02, and average groundwater level variation was measured 14.21 meters during the study period from 2014 to 2018. The dynamic water resource estimated at 808.67 million cubic meters can be replenished by recharge from different sources such as from rainfall infiltration and irrigation return flow. In general, replenishable resources can be resourced with some research augmentation technologies.

Geological subsurface exploration: Vertical electrical soundings (VES) were conducted at different locations limiting AB/2 for 70 m depth. VES data were analyzed, both curve matching and curve break techniques for knowing subsurface information and result showed that apparent resistivity p1 were ranged from 25 to 890 Ohm-m and mean 234.5 Ohm-m, p2 ranged from 32 to 620 Ohm-m and mean 189.8 Ohm-m and p3 from 68 to 900 Ohm-m and mean 345.0 Ohm-m and its analogous earth formation layer depth H1 and H2 were ranged from 5 to 12 m, mean 9.0 m and 5 to 13m, mean 9.03 m. The depth of bedrock varied from 12 m to 22 m with a mean depth of 18 m in the study area. The thickness of the overburden varies from place to place and extends up to 25m. Apparent resistivity is high in the Eastern portion of deposits when compared to other parts, indicating lithological control (granitic gneisses) and reduction in the overburden. Apparent resistivity was on the lower side near deposits due to the mineralization of Ferro magnesium assemblage.

Based on groundwater level monitoring, it can be inferred that the divergent nature of flow was noticed in the ridge portion and the convergent nature of flow was noticed near the valley portion. Further groundwater flow directions were East, North East, and west of the iron ore bearing area but are locally controlled by the existing hydrogeological setup of terrain.

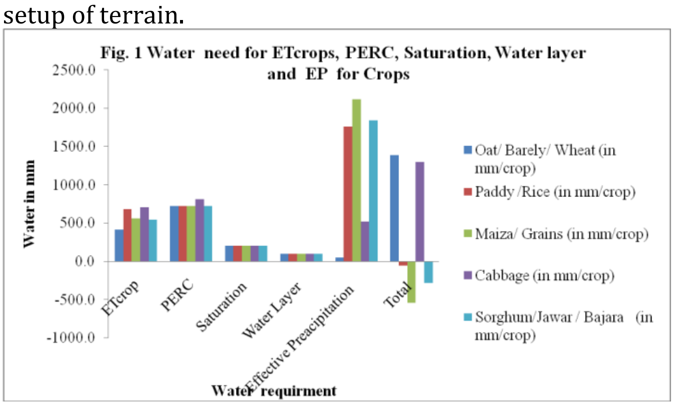

Fig -1: Water needs for ETcrops, PERC, saturation, water layer and ET for crops

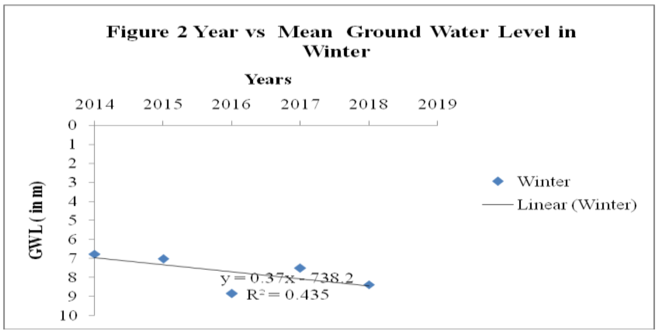

Fig -2: Year vs Mean Ground Water level in Winter

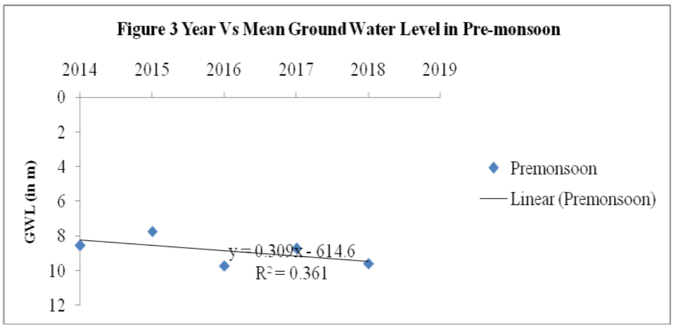

Fig - 3: Year Vs Mean Ground Water level in Pre-Monsoon

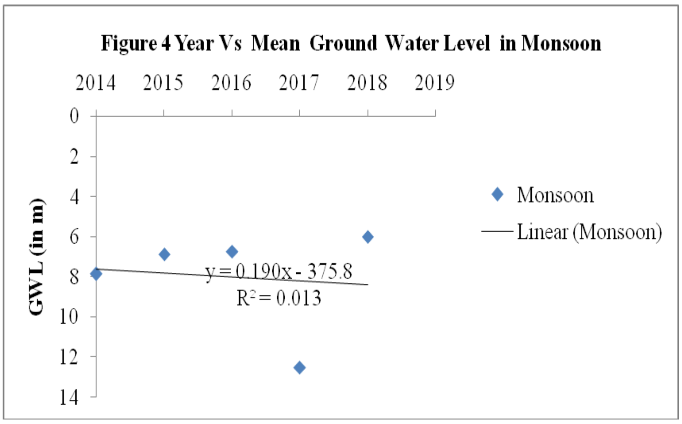

Fig - 4: Year Vs Mean Ground Water Level in Monsoon

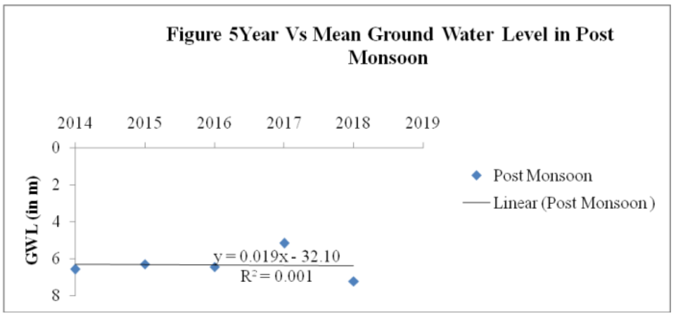

Fig - 5: Year Vs Mean Ground Water Level in Post Minsoon

4. CONCLUSIONS

The baseline data on benthic macroinvertebrates of the perennial streams of the Bailadia Iron Ore Mines were studied to access the quality of surface water, the abundance and richness of macroinvertebrates of the streams to provide insights of water quality by employing the Macroinvertebrate water quality index considering the industrialization and urbanization. The result reveals that 71.4 % of samples classified excellent to very good, 28.6 % of samples were good. However, inferior water quality was found at sampling locations 5 & 6, which may be due to the tailing of the iron ore deposit.

The irrigation water need for rabi crops like Oat/Barely/wheat was found to be 1391.13 mm/crop as rainwater precipitation is seasonally very less thus rainwater should be conserved for irrigation purpose during the lean period. Other than rabi crops, for Kharif crops, there is surplus water available for irrigation.

However, there is sufficient water available for domestic and industrial (mining and iron ore washing and beneficiation) use. Thus observing the socio-economic condition of the area, crops such as paddy, wheat/oat/barley, bazaar, Jawar may be encouraged as per spatial-temporal variation of temperature and rainfall, topography.

Groundwater flow in Kirandul and its nearby village was observed to have divergent nature of flow while Bacheli & nearby villages had convergent flow nature. Thus it is recommended to have a Rainwater harvesting structure may be implemented.

Table- 3: Results of the analysis of Benthic Macroinvertebrate sampling from the streams of Bailadila

Sl.no	Order/Class	Sl.no.	Family/Taxa	Genera/Taxa	BM WP Score	Sampling locations							Total abundance
						1	2	3	4	5	6	7	
1	Oligochaeta	1	Oligochaete		1	1	0	0	1	0	0	0	2
2	Arhynchop	2	Erpobdellida		3	0	0	0	0	0	3	0	3
3	Coleoptera	3	Curculionida	Blosyrus sp.	5	0	0	0	0	0	0	1	1
		4	Dytiscidae	Hydaticus sp.	5	0	1	0	0	0	0	0	1
		5	Gyrinidae	Larva	5	0	0	0	1	1	0	1	3
4	Decapoda	6	Gecarcinucid	Barytelphusa	6	0	0	0	8	0	3	0	11
		7	Palaemonida	Macrobrachium	6	0	0	0	5	0	0	0	5
5	Diptera	8	Athericidae		8	0	3	0	4	0	2	0	9
		9	Ceratopogon		4	0	0	0	3	0	0	1	4
		10	Chironomida		2	4	2	0	17	7	6	5	41
		11	Culicidae		2	0	0	0	1	0	0	0	1
		12	Simuliidae		5	9	0	0	0	6	0	0	15
		13	Tipulidae	Hexatoma sp.	5	3	1	0	0	0	0	0	4
		14	Tabanidae		5	1	0	0	2	0	2	0	5
6	Ephemeroptera	15	Baetidae		4	4	1	2	10	12	57	3	89
		16	Caenidae		7	1	0	0	0	0	0	1	2
7	Hemiptera	17	Gerridae	Tenagogonus sp.	5	2	0	1	0	0	0	2	5
		18	Naucoridae	Naucoris sp.	5	0	0	1	0	1	0	0	2
8	Odonata	19	Coenagrioni		6	0	1	0	0	0	0	0	1
		20	Corduliidae		8	0	0	0	0	0	1	0	1
		21	Gomphidae		8	0	3	0	1	0	2	0	6
		22	Libellulidae		8	2	1	0	0	0	4	0	7
9	Trichoptera	23	Hydropsychi		5	16	2	1	117	12	103	1	252
		24	Philopotami		8	3	0	1	2	0	0	2	8
		25	Polycentropo		7	6	0	2	13	0	0	4	25
		26	Rhyacophili		7	0	0	1	0	0	0	4	5
10	Plecoptera	27	Perlidae		10	0	0	2	0	0	0	0	2
Total Abundance						52	15	11	185	39	183	25	510
Total Richness						12	9	8	14	6	10	11	27

REFERENCES

[1] Flathe, H. Possibilities and Limitations in Applying Geoelectrical Methods to Hydrogeological Problems in the Coastal Areas of North West Germany.Geophysical Prospecting, 1955, vol. 3, pp. 95-110.

[2] Zohdy, A. A. R. The Use of Schlumberger and Equatorial Soundings in Groundwater Investigations near El Paso, Texas.Geophysics, 1969, v. 34, pp.713-728.

[3] Flathe, H. Interpretation of Geoelectrical Resistivity Measurements for Solving Hydrogeological Problems. In Morley, E. W. (ed.), Mining and Groundwater Geophysics: Geological Survey of Canada Economic Geological Report, 1970, no. 26, pp. 580-597.

[4] Ogilvy, A. A. Geophysical Prospecting for Groundwater in the Soviet Union, in Morely E. W. (ed.), Mining and Groundwater Geophysics: Geological Survey of Canada Economic Geological Report, 1970, no. 26,pp. 536-543.

[5] Zohdy, A. A. R., Eaton, G. P. and Mabey, D. R. Application of Surface Geophysics to Groundwater Investigation. U. S. G. S. Techniques of Water-Resource Investigation, Book 2, 1974.

[6] Fitterman, D. V. and Stewart, M. T. Transient Electromagnetic Sounding for Groundwater, Geophysics, 1986, vol. 51, no. 4, pp. 995-1005.

[7] McNeill, J. D. Use of Electromagnetic Methods for Groundwater Studies. In: Ward, S. H. (Ed.).Geotechnical and Environmental Geophysics, vol. 1: Review and Tutorial, Society of Exploration Geophysicists Investigations No.5, 1990, pp. 107-112.

[8] Groundwater Resource Estimation Committee (GEC). 2009. Ground water resource estimate methodoly ministry of water resource Government of India, New Delhi Ministry of Water Resources Government of India. http://cgwb.gov.in/documents/gec09.pdf