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# Water Quality Monitoring and Assessment along the Stretch of Baitarani Basin, Odisha [A Case Study]

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## *Abstract*

*Assessment of the hydro-chemical characteristics of water and its properties is important for surface water planning and management in the study area. It is not only the basic need for human existence but also a vital input for all development activities. The present hydro-geochemical study of water samples was carried out to assess their suitability for agricultural, domestic and drinking purposes. For this study, samples are collected from 13 locations during the pre-monsoon and post-monsoon sessions spanning over 20 years. Samples were analyzed for their physical and chemical properties using standard laboratory methods. Physical and chemical parameters of surface water such as PH, Turbidity, TDS, TSS, EC, DO, Alkalinity, BOD, TH,* $HCO_3^-$, $SO_4^{2-}$, $NO_3^-$, $PO_4^{3-}$, $Cl^-$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, *TC, FC, Fe and Cr were determined. Various water quality indices like SAR, RSC, RSBC, MH, KR, PI and PS have been calculated for each water sample to identify the irrigational suitability standard. All the PH values of the water samples are greater than 7 indicating slight alkaline water. . The results are also in good concordance with the maximum desirable limit of WHO (2008) and BIS (2012).According to most of these parameters, the surface water has been found to be well to moderately suitable for irrigation. EC values of all the water samples are below 750, indicating good quality of irrigation water. Plotting the values of conductivity (EC) and sodium absorption ratio (SAR) on the US Salinity diagram illustrated that most of the samples fall in the category C1S1 indicates medium salinity/low sodium and C2S1 indicates low salinity/low sodium in pre-monsoon and post-monsoon season. RSC values of all the samples are less than 1.25 meq/L, indicating that there is no complete precipitation of calcium and magnesium and the water samples are safe for irrigation purposes. SAR, KR, MH, PI, RSC and PS allow the water for use in irrigation purposes. For determination of the drinking suitability standard of surface water, parameters have been considered – TH, Piper's trilinear diagram and water quality index study. It has been found to be excellent in all sampling locations except one station which can be ignored in both seasons and hence poses no health risk which could arise due to excess consumption of calcium and magnesium. Hydro-geochemical facies in the form of Piper's trilinear diagram plot which helps in identification of the water type which can render a particular taste or odour to water, indicates that surface water is majorly of* $CaMgHCO_3$ *and* $NaHCO_3$ *type (fresh type) during both pre-monsoon and post-monsoon seasons barring a couple of samples which are of* $CaMgSO_4$ / $CaMgClSO_4$ *type in pre-monsoon. Water Quality Index study reveals that close to 92.30 % of the water samples are suitable for drinking during post-monsoon and pre-monsoon.Multivariate statistical analysis, including principal component analysis (PCA) and factor analysis (FA), were used to evaluate temporal and spatial variations in and to interpret large and complex water quality datasets collected from the Baitarani River Basin. The PCA/FA identified three factors that were responsible for explaining the data structure of 76.906 % and 79.530 % of the total variance of the dataset in pre-monsoon and post-monsoon season, allowing grouping of selected parameters based on common characteristics and assessing the incidence of overall change in each group. This study proposes the necessity and practicality of multivariate statistical techniques for evaluating and interpreting large and complex datasets, with a view to obtaining better information about water quality and the design of monitoring networks to effectively manage water resources.*

***Keywords:****Hydro-geochemical, US Salinity, Piper's trilinear diagram, Water Quality Index, Multivariate statistical analysis, Baitarani River, Irrigation, principal component analysis*

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## I. Introduction

Water is the material basis for the existence of earth creatures, and water resources are the primary condition for maintaining the sustainable development of earth's ecological environment. With the increasing consumption of water resources, the contradiction between the supply and demand of water resources has intensified, which puts forward greater requirement for the utilization and protection of surface water resources. The surface water quality of a region depends to a large extent on environmental factors (temperature changes, precipitation and soil erosion) and human input (discharge of municipal and industrial wastewater and over-exploitation of water resources), urban sewage and industrial wastewater is a continuous source of pollution, so effective control of sewage discharge is of great significance to the improvement of water quality.

Surface water runoff is a seasonal phenomenon that is mainly affected by the climate of the basin. In addition, seasonal changes in precipitation, surface runoff, interflow, groundwater flow and pumping in and pumping out have a strong influence on the river flow and the subsequent pollutant concentration in the river. Therefore, correct identification of potential sources of surface water quality pollution is the basis and prerequisite for water quality management.

Globally, there is an increasing awareness that water will be one of the most critical natural resources in future. Water scarcity is increasing worldwide and pressure on the existing water resources is increasing due to the growing demands in several sectors such as domestic, industrial, agriculture, hydropower generation etc. Therefore, the evaluation of water quality in various countries has become a critical research topic in the recent years.

The quality of water is defined in terms of its physical, chemical and biological parameters, and ascertaining its quality is important before use for various intended purposes such as potable, agricultural, recreational and industrial water usages, etc. It is assessed with the help of various parameters to indicate their pollution level. It is quite likely that any sample of water will exhibit various levels of contamination with respect to the different parameters tested.

In monitoring programs, generally relevant chemical, physical and biological factors are annually (or with less intervals) sampled and analyzed to sort out governing factors for the water quality variations. Generally, such monitoring gives a clue about the status of water quality that might be valid for a limited time and pre-specified objectives. However, these data may not give the indication of trends in water quality over time and across geographic areas. Traditional approaches to assessing water quality are frequently based on a comparison of experimentally determined parameter values with existing guidelines. In many cases, monitoring allows proper identification of contamination sources and may face legal compliance. However, it does not easily give an overall vision of the spatial in a watershed. Many attempts were made to present the water quality in understandable and acceptable ways using the water quality index (WQI).

The advantage of this approach, besides getting the information and data necessary, is also determined the general health or status of the system of concern. In this way, the index can be used to assess water quality relative to its desirable state (as defined by water quality objectives) and to provide insight into the degree to which water quality is affected by human activity.

In many arid and semi-arid countries water is becoming an increasingly scarce resources and planners are forced to consider any sources of water which might be used economically and effectively to promote further development. Thus, availability of good quality water for irrigation is threatened in many places and irrigated agriculture faces the challenge of using less water, in many cases of poorer quality, to irrigate lands that provide food for an expanding population.

The irrigation water needs can be met by using the available water more efficiently, but in many cases it will prove necessary to make increased use of municipal waste waters. The use of waste water in agriculture has potential for both positive and negative environmental impacts, with careful planning and management the use of waste water in agriculture can be beneficial to the environment. However, the direct and indirect use of untreated wastewater in irrigated agriculture is increasing as a result of increasing global water scarcity, inadequate and inappropriate wastewater treatment and disposal, increasing food insecurity and escalating fertilizer costs. Consequently, the reuse of wastewater for agriculture is highly encouraged and it is a common practice for many reasons, not least of which is nutrient value and environmental protection. Irrigation with treated municipal wastewater is considered an environmentally sound wastewater disposal practice compared to its direct disposal to the surface or ground water bodies.

Wastewater is a valuable source of plant nutrients and organic matter. Nevertheless, it may contain undesirable chemical constituents and pathogens that pose negative environmental and health impacts. At the same time, a number of risk factors have been identified in wastewater reuse, some of them are short term (microbial pathogens) where as others have long-term impacts that increase with the continued use of recycled water (salinity effects on soil). So, many guidelines have been developed to give a quality criteria and guidance on how treated wastewater (effluents) should be reused for irrigation purposes.

The amount of collected and treated wastewater is likely to increase significantly with population growth, rapid urbanization and improvement of sanitation service coverage. Hence, the use of treated wastewater in agriculture is one of the strategies adopted for increasing water supply in arid and semi-arid countries. Wastewater also has been used in agriculture for decades in many countries like India, Nepal, China, Spain and Italy. The reuse of water in agriculture is receiving great attention and increased recognition as a potential water source. It is generally accepted that wastewater use in agriculture is justified on agronomic and economic grounds but care must be taken to minimize adverse health and environmental impacts.

Water Contamination in urban environment is a major issue and is complicated by the large number of potential sources of contamination and the numerous distinct contaminants that can be found in a city. Studies on geochemical processes that control chemical composition of water which may leads to improved understanding of hydro chemical systems in such areas. Such studies contribute to effective management and utilization of the surface water resources. Exploitation has increased greatly, particularly for agricultural purpose. Water quality is an important as the quantity. Poor quality of water adversely affects the plant growth and human health. In order to understand the factors controlling the geochemistry of water in the study area, multivariate statistical technique was performed.

The characterization and interpretation of various water parameters is often a complex problem, factor analysis offers a powerful means of identifying the similarities among the variables present in the chemical budget of water. To identify the likely factors that cause the variations in hydro chemical compositions, multivariate statistical methods of analyzing hydro chemical data such as principal component factor analysis can be a very useful tool. Such analysis are especially useful because it brings out the relative significance of the combinations of chemical variables that can be evaluated and the subsequent interpretation is simplified since these are statistical tools which reduce and categorize complex sets of data into groups with similar characteristics. The conventional techniques of histograms and trilinear techniques (Dalton and Upchurch 1978) such as stiff and Piper plots which consider only the major and minor ions with equal emphasis to interpret the group of variables to evaluate the chemical nature of water has several limitations. In order to overcome these limitations of these conventional methods, factor analytical technique has been used to understand a number of geochemical processes by several professionals (Dawdy and Feth 1967; Hitchon and others 1971; Ashley and Lloyd 1978; Lawrence and Upchurch 1976, 1983; Seyhan and others 1985; Usunoff and Guzman 1989; Razack and Dazy 1990; Subbarao and others 1996; Jayakumar and Siraj 1997; Olmez et al 1994; Bakac 2000)

The statistical analysis of the basic geochemical data of the water using R mode factor analysis is a widely accepted technique for characterizing and interpreting a few empirical hydro chemical factors controlling the chemical budget of water. Reeder and others (1972) identified the likely weathering processes controlling the chemical composition of surface waters of the Mackenzie River drainage basin in Canada. Ashley and Lloyd (1978) used the factor analysis to evaluate the hydro geochemical process in the Santiago basin of Chile and the Derbyshire Dome of England. Lawrence and Upchurch (1983) also used the technique to delineate the zones of natural recharge to groundwater in the Floridan aquifer. Ruiz and others (1990) mentioned that the basic purpose of such an analysis is to study the hydro geochemistry of aquifers by simplifying the numerous and complex groundwater data into set of factors, few in number which can explain a large amount of the variance of the analytical data and also indicates the source of origin of various ions present in the water. Briz-kishore and Murali (1992) have delineated the areas prone to salinity hazard in Chitravati watershed of India. Similarly Syed Munaf and others (2005) used the multivariate factor analytical techniques to assess the water quality and source of contamination in an irrigation project at Al-Fadhli, Saudi Arabia. Many studies combining the effects of multiple water quality variables evaluating the water quality and the extent and nature of contamination have been undertaken (Shuxia et al. 2003). Chemical composition in water is determined by a number of factors such as precipitation, infiltration, groundwater flow patterns and characteristics of soil type of the aquifer.

Factor score studies reflect the station wise variation of the geochemical factors controlling the water chemistry**. Scores showing negative values denotes areas essentially unaffected by the said factors; most affected areas are denoted by extreme positive score and a near zero may be considered as areas affected to an average degree to unaffected** (Dalton and Upchurch 1978; Gupta and Subramanian 1994).The factor analysis is used in the present work, Eigen values and Eigen vectors of the correlation matrix are extracted after applying the varimax rotation and the least important among them are then discarded (Davis 2002). In general, factors showing Eigen values greater than 1 are taken up for interpretation of the results and in the present work also, the factor extraction has been done with a minimum acceptable Eigen value greater than 1 (Harman 1960).

When river gets polluted, its main source of water comes from urban sewage treatment plants and paper making sewage treatment plants. It not only plays an important role in assimilating or removing urban and industrial wastewater and farmland runoff, but is also the main inland water resources used for household, industrial and irrigational purposes. Therefore, it is necessary to prevent and control river pollution and have reliable water quality information for effective management. Given the spatial and temporal changes in river water chemistry, regular monitoring programmes are needed to reliably estimate water quality. This leads large and complex data matrices composed of a large number of physical and chemical parameters, which are often difficult to interpret, making it challenging to draw meaningful conclusions.

Multivariate statistical analysis is a branch developed from classical statistics and is a comprehensive analysis method. It can analyze the statistical laws of multiple objects and multiple indicators when they are related to each other, including principal component analysis and factor analysis. Multivariate statistical analysis is a suitable tool for multi-component chemical and physical measurements for meaningful data reduction and interpretation. It is a valuable tool for identifying factors and sources that may affect water systems and cause changes in water quality.

In such a study, a large amount of data is presented. The univariate statistical analysis, generally used to treat such data could therefore cause misunderstanding and error both in the interpretation and in those to whom the conclusions are presented (Ashley and Lloyd 1978). In order to avoid this problem, multivariate statistical techniques can be used instead, as they are unbiased methods which can help indicate natural associations between samples and/or variables (Wenning and Erickson, 1994). Thus highlighting information not available at first glance. The multivariate treatment of environmental data is widely used to characterize and evaluate surface and freshwater quality, and it is useful for evidencing temporal and spatial variations caused by natural and human factors linked to seasonality (Andrade et al 1992; Aruga et al 1995; Brown et al 1980; Eloseigui and Pozo, 1994; Grimalt et al, 1990; Librando, 1991; Reisenhofer et al 1998; Vega et al, 1998). However, these statistical methods have not attained a comparable diffusion in the case of water studies to date (Aruga et al., 1993; Ashley and Lloyd, 1978; Grammanco et al., 1998).

In this article, we took the Baitarani River as the research object for the first time, set up 13 main detection points along the river and detected and analyzed 22 physical and chemical parameters in water samples. The detection time lasted for 20 years. Principal Components Analysis was used, which allowed to reduce the dimensionality of a highly dimensioned data set by explaining the correlation amongst a large number of variables in terms of a smaller number of underlying factors (prinicipal components or PCs) without losing much information (Jackson, 1991; Meglen, 1992). Varimax ratoation (Knudson et al., 1977) has also been applied in order to find more clearly defined factors (called varifactors or VFs) which could be more easily interpreted.

The main objectives of this study are to

**a)** Assess thephysicochemicalpropertiesoftheriverwater.

**b)** Determinethe water quality of the Baitarani River, through WQIanalysis,andcreateWQImapbasedonGIS,

**c)** Discussthe suitability of the water for drinking, agricultural and industrial purposes.

**d)** Evaluate various agricultural parameters such as soluble sodium percentage (SSP), sodium adsorption ratio (SAR), Permeability index (PI), Kelly's ratio (KR) and Magnesium hazard (MH).

**e)** Multivariate statistical approaches have been used to identify the water quality variables that cause the spatial and temporal changes of river water quality and to determine the impact of water sources (natural and anthropogenic factors).

**f)** Box and whisker plots of the water parameters have also been drawn for the two seasons to show the variation of the given parameter values.

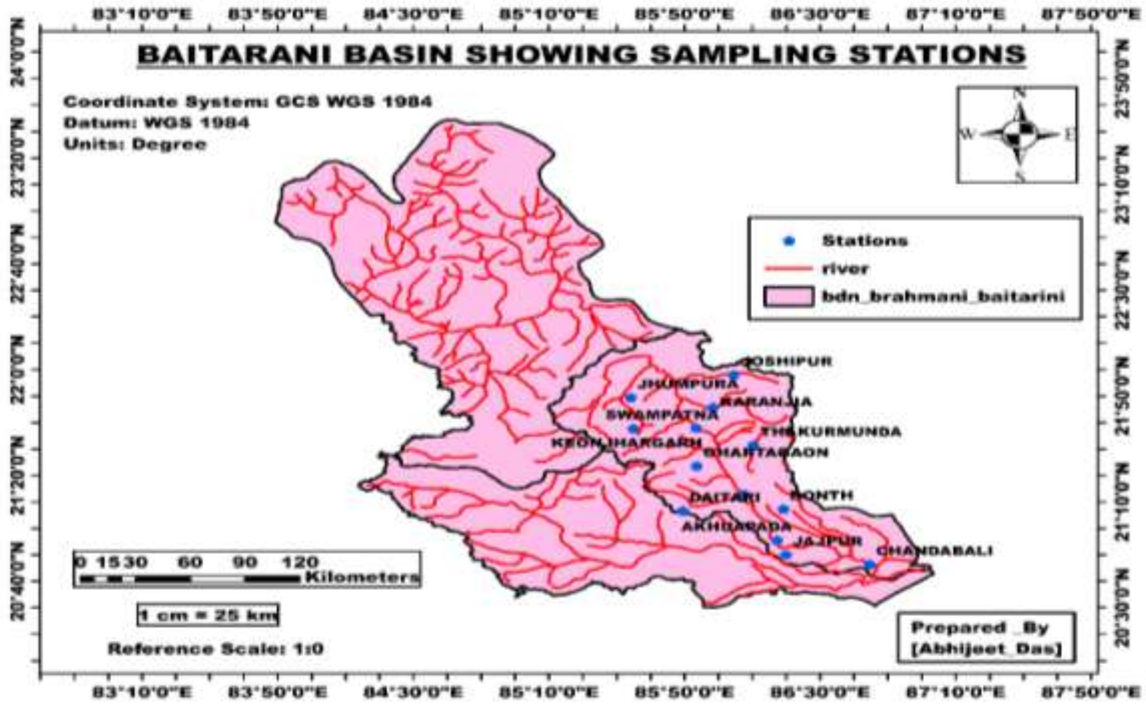
**g)** To know the hydro geochemical characteristics of the study area and water, the analytical values were plotted on piper diagram which help us to draw inference and to classify the water on the basis of hydro geochemical characteristics.

## II. Description Of The Study Area

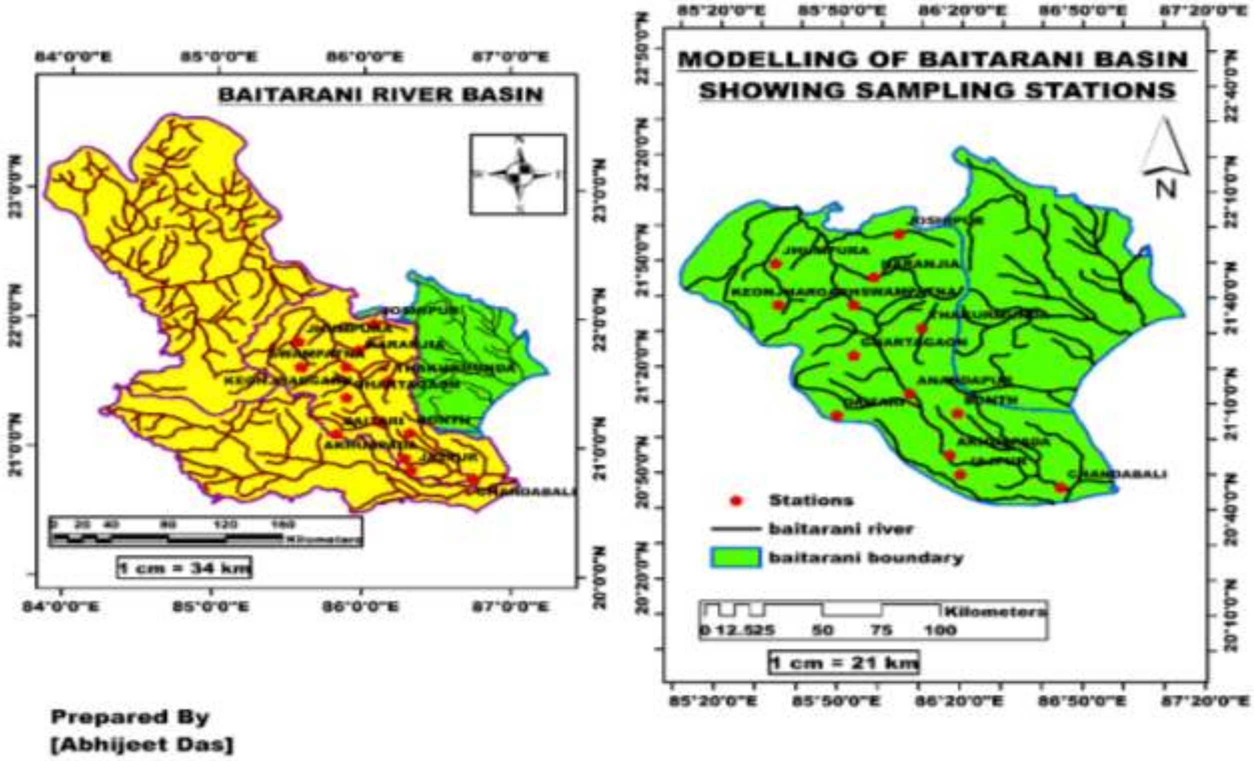
Baitarani River Basin has a total catchment area of 14,218 sq.km spreading over the two states of Odisha and Jharkhand in India. A major portion of the river basin with 13482 sq.km of catchment lies in the state of Odisha while Jharkhand have the rest of 736 sq.km. The river originates at the Gonasika / Gupta Ganga hills at 21°32'20'' N - 85°30'48 E and starts flowing over a stone which looks like the cow's nostril. The river at its origin has the elevation of 900 meters (3000 ft) above sea level. It originates at an elevation of 900 m above mean sea level from Guptaganga hills of Gonasika of Keonjhar district. The beginning portion of Baitarani acts as the boundary between Odisha Jharkhand states. It flows in a north-easterly direction for about 80 km and then takes a south-east direction for the next about 170 km to reach Jajpur. Here the river turns left to flow towards east and enter the littoral plain or delta. The river enters plains at Anandpur and creates deltaic zone below Akhuapada. The river traverses a total distance of 360 km in Odisha before joining with Dhamra River and finally into the Bay of Bengal, Deo, Salandi, Kanjhari, Musal, Arredi, Siri, Kukurkata, Kusei, Gahira and Remal are major tributaries of Baitarani River.

A major portion of the basin (94.8%) lies within the state of Odisha, while a small patch of up reach (5.2%) lies in Jharkhand state. The basin covers 8 revenue districts of the state. The main urban centres in Baitarani basin are keonjhar, Joda, Jajpur, Vyasana, Bhadrak, Anandpur, Chandabali and Dhamnagar.

The below (**Figure 1, 2**) showing monitoring stations of Baitarani basin by the application of GIS Software.



(**Figure 1**. Map of study area presenting Baitarani River along with sampling locations)



(**Figure 2**. Baitarani river network covering all sampling stations along the flow path)

## III. Methodology And Data Used

Dry, clean and sterilized plastic bottles were used to get fresh water for sampling. Before collection, the bottles were well rinsed. For the present study, water samples were collected in pre-monsoon and post-monsoon period of 2000 - 2019 from previously selected 13 (Thirteen) sampling stations (**Table 1**) in washed polypropylene bottles (manufactured by Tar son, India). The sampling stations were selected on the basis of uniform distance, with slight deviation depending upon the geographic condition and ease of access. Coordinates of the sampling stations were recorded by Global Positioning System (GPS). The collected samples were then stored in 500 ml preconditioned high density polythene bottles and were carefully sealed with proper labelling. For all samples, temperature, PH and EC were determined in the field with standard field equipment's like mercury thermometer and pocket pH meter. For quantitative chemical analysis of major ions in surface water, standard analytical chemistry procedures, comprising titrimetry and spectrophotometry, were employed following American Public Health Association guidelines (APHA 1995). Some samples were sent to water quality laboratory of Central Water Commission, Bhubaneswar for analysis of physico-chemical parameters like pH, turbidity, EC, TDS, TSS, total hardness, cations like $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$, and anions like $HCO_3^-$, $SO_4^{2}$- , $NO_3^-$, $PO_4^{3-}$. Analysis of heavy metals like Fe and Cr were done by AAS (Shimadzu AA6300) and ICP-OES (PerkinElmer Optima 2100 DV) in IMMT, Bhubaneswar.

**Table 1. Water Quality Monitoring Sites**

| SAMPLING CODES | MONITORING STATIONS |
|---|---|
| **1** | CHANDABALI |
| **2** | JAJPUR |
| **3** | AKHUAPADA |
| **4** | DAITARI |
| **5** | BONTH |
| **6** | ANANDAPUR |
| **7** | GHARTAGAON |
| **8** | THAKURMUNDA |
| **9** | SWAMPATNA |
| **10** | KEONJHARGARH |
| **11** | KARANJIA |
| **12** | JHUMPURA |
| **13** | JOSHIPUR |

To evaluate the suitability of the water quality for agricultural purposes, the parameters such as SAR, SSP, RSC, RSBC, MH, PI, PS and KR were calculated using standard formula mentioned in the text. The SAR values were plotted over the US Salinity diagram against the EC values (log scale axis); SSP values were plotted over the Wilcox diagram against EC values; the spread of PI, RSC and MH values have been represented in the form of spatial distribution maps for both seasons. Besides total hardness results, the suitability of surface water for drinking purposes has been determined by the use of hydro geochemical facies (Piper trilinear diagram) (Piper 1944) and water quality index study (Tiwari and Mishra 1985). GIS software packages 10.3 have been used to map and analyze the data for the evaluation of surface water data.

## IV. Analytical Methods

### Water Quality

Water quality index (WQI) is useful in assessing the suitability of river waters for a variety of uses such as agriculture, aquaculture and domestic use. It is used to relate a group of parameters to a common scale and combining them into a single number. The water quality index (WQI) is considered as an efficient mean to reflect the water quality comprehensively, integrating the different water quality parameters into a single-valued unit less integer (Sener et al. 2017; Wang et al. 2017). The raw analytical results of various water quality parameters with different values and units are transformed into a single value by a special type of mathematical averaging function (Cude 2001). Some researchers and some countries proposed different WQIs considering different water quality parameters, and the indices are applied worldwide. The WQI was first proposed by Horton (1965) and was used for drinking water quality analysis (Brown et al. 1970; Misaghi et al. 2017; Kumar et al. 2018). Later on, Pesce and Wunderlin (2000) also proposed a WQI method which is used by many researchers. Some WQIs proposed by some countries are National Sanitation Foundation Water Quality Index (NSFWQI) by USA, the Florida Stream Water Quality Index (FWQI), the British Columbia Water Quality Index (BCWQI) by Britain, the Canadian Water Quality index (CWQI) and the Oregon Water Quality Index (OWQI) as described by Cude (2001). WQI, here, has been calculated following the method given by Pesce and Wunderlin (2000) and is given by eq. (A).

$$\mathrm{WQI_{sub}} = k\frac{\sum_{i=1}^{n} C_i . P_i}{\sum_{i=1}^{n} P_i} \longrightarrow \boxed{A}$$

Where Ci is the normalized value assigned to each parameter and Pi is the relative weight of each parameter. K is a subjective constant and may have values ranging from 1.0 to 0.25 depending on the visual impression of river contamination of the researcher. The value 1.0 is assigned to water without apparent contamination, and 0.25 is assigned to highly contaminated water.

These parameters were compared with the standard guideline values, recommended by BIS-10500 (2012) and WHO (2006). WQI (Water quality index) was calculated (Kalavathy *et al.*, 2011), (Reza and Singh, 2005), (Mukherjee *et al*., 2012),(Ravikumar *et al*., 2013) for pre-monsoon and post-monsoon periods to assess the suitability of water for drinking purposes and for biotic communities (**Table 2**). For WQI calculation, total 22 parameters such as pH, turbidity, dissolved oxygen (DO), biological oxygen demand (BOD), total dissolved solids (TDS), total suspended solid (TSS), total hardness (TH), calcium (Ca) ions, magnesium (Mg) ions, total Fe, Cr, $SO_4^{2-}$ , $NO_3^-$ etc. were considered and desirable limit of each parameter was used as per BIS standard.

**Table 2. Water Quality Rating as per different Water Quality Index method**

| WQI LEVEL | WATER QUALITY RATING |
|---|---|
| 0-25 | EXCELLENT |
| 26-50 | GOOD |
| 51-75 | POOR |
| 76-100 | VERY POOR |
| >100 | UNFIT FOR DRINKING PURPOSES |

From the above table, it is clearly seen that the water quality index does not show exact degree of pollution, rather it is used to assess water quality trends for the management purpose. The WQI results represent the level of water quality in a given water basin. The computed WQI values are classified into five types, namely, excellent water (WQI<25) denotes lowest concern that generally meet state water quality standards, good water (26>WQ<50) depicts marginal concern, poor water (51<WQI<75), very poor water (76<WQI<100) both depicts moderate concern and water unsuitable for drinking (WQI>100) signifies highest concern as described by Ravikumar (2013), Mukherjee *et al.* (2012) and Dubey *et al.* (2014). Therefore, Baitarani River water ranges from “unfit for drinking” to “excellent” quality. To calculate the WQI, water quality variables i.e., **PH, Turbidity, TDS, TSS, EC, DO, Alkalinity, BOD, TH, $HCO_3^-$, $SO_4^{2-}$, $NO_3^-$, $PO_4^{3-}$, $Cl^-$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, TC, FC, Fe and Cr** were considered. The overall water quality index value for all the sampling stations is being shown in **Table 3**.

**Table 3: Water quality status and WQI values at sampling stations**

| STATION NUMBER | STATION NAME | WQI | | | |
|---|---|---|---|---|---|
| | | PRE-MONSOON | DESCRIPTION | POST-MONSOON | DESCRIPTION |
| 1 | CHANDABALI | 17.76 | EXCELLENT | 19.25 | EXCELLENT |
| 2 | JAJPUR | 45.49 | GOOD | 36.44 | GOOD |
| 3 | AKHUAPADA | 32.59 | GOOD | 30.87 | GOOD |
| 4 | DAITARI | 23.94 | EXCELLENT | 28.94 | GOOD |
| 5 | BONTH | 38.47 | GOOD | 35.20 | GOOD |
| 6 | ANANDAPUR | 39.29 | GOOD | 40.46 | GOOD |
| 7 | GHARTAGAON | 19.44 | EXCELLENT | 22.32 | EXCELLENT |
| 8 | THAKURMUNDA | 59.72 | POOR | 77.69 | VERY POOR |
| 9 | SWAMPATNA | 34.95 | GOOD | 32.29 | GOOD |
| 10 | KEONJHARGARH | 39.71 | GOOD | 34.70 | GOOD |
| 11 | KARANJIA | 40.00 | GOOD | 36.63 | GOOD |
| 12 | JHUMPURA | 42.22 | GOOD | 41.27 | GOOD |
| 13 | JOSHIPUR | 31.56 | GOOD | 34.79 | GOOD |

### Irrigation Water Qualities

The suitability of water for irrigation purpose depends on the physical and chemical properties of the water, especially on the dissolved salts. Plant roots uptake water that includes a little number of dissolved salts, leaving major portion of the salts at the root vicinity. Water naturally evaporates, and the dissolved salts are left in the soil complex. Within a few years, the gradual salt accumulation increases in the soil (Srinivasamoorthy et al. 2014), causing salinity hazard and toxicity. However, some dissolved salts or constituents are useful for plants growth. The suitability of irrigation water is assessed mainly in terms of the presence of undesirable dissolved salts or constituents, and in some limited cases assessed on plant nutrients (FAO 2008; Haritash et al. 2016). The major river water parameters, which help to decide the suitability for irrigation, are pH, EC, TDS, hardness, sodium, potassium, calcium, magnesium, chloride, sulphate, nitrate, carbonate, bicarbonate, etc. (Sundaray et al. 2009; Haritash et al. 2016). Some calculated indices that also help to assess the suitability of irrigation water are discussed in the following parts accordingly.

### Sodium adsorption ratio (SAR)

The percentage of the sodium ions is generally less than 5% of the total exchangeable ions. If this percentage increases to about 10% or more, the aggregation of soil grains breaks down. The soil becomes less permeable and of poorer tilth. High sodium soils are, therefore, plastic, sticky when wet, and are prone to form clods and they crust on drying. The proportion of sodium ions present in the soils, is generally measured by a factor called Sodium Absorption ratio (SAR) and represents the sodium hazards of water.It is also expressed as sodium content or alkali hazard is an important index for determining the suitability of water used in irrigation (Srinivasamoorthy et al. 2014). Excessive sodium in water imparts undesirable effects on the soil properties and decreases soil permeability (Kelly 1951; Sundaray et al. 2009). Higher salinity interferes with the osmotic activities, thus reduces the absorption of water and nutrients from the soil, impedes water from reaching the leaves of plants and prevents plant metabolism (Arumugam and Elangovan 2009). High sodium content in water leads to genesis of alkaline soil. The SAR is the measure of the relative proportion of sodium ions to the calcium and magnesium ions in a water sample. Actually, SAR reflects the sodium hazard and is computed using the formula in eq. (B) given by U.S. Department of Agriculture Salinity Laboratory in 1954 (Wilcox 1955; Hem 1970) as:

$$\mathrm{SAR} = \frac{\mathrm{Na}^{+}}{\sqrt{\frac{\mathrm{Mg}^{2+}+\mathrm{Ca}^{2+}}{2}}} \quad \longrightarrow \quad \boxed{\mathbf{B}}$$

Ionic concentrations are measured in meq/L. Based on the SAR values, water is classified into four classes, SAR < 10 is considered as excellent (sodium hazard class S-I), SAR = 10 – 18 is considered as good (sodium hazard class S – II), SAR = 19 – 26 is considered as doubtful/fair poor (sodium hazard class S – III), and SAR > 26 of water is considered unsuitable (sodium hazard class S – IV) (Richards 1954; Wilcox 1955)

**S – I** = can be used for all soils and for all crops
**S – II** = used in coarse grained or organic soil with good permeability
**S – III** = may be harmful to all the soils and do require good drainage, high leaching with gypsum.
**S – IV** = Not suitable (Very high sodium water)

Salts of calcium, magnesium, sodium and potassium present in irrigation water may prove injurious to plants. When present in excessive quantities, they reduce the osmotic activities of the plants and may prevent adequate aeration, causing injurious to plant growth. The effect of salts on plant growth depends largely upon the total amount of salts present in salt solution. The effect of sediment present in the irrigation water depends upon the type of irrigated land. When fine sediment from water is deposited on sandy soils, the fertility is improved. On the other hand, if the sediment has been derived from the eroded areas, it may reduce the fertility or decrease the soil permeability. Excessive suspended sediment may create trouble in canals and reservoir.

### Sodium percentage (Na %)

The irrigation water is also classified on the basis of soluble sodium content, because higher sodium content in irrigation water reduces the permeability (Todd 1980; Sundaray et al. 2009). Percentage of Na (Na %) is widely used to determine the suitability of water for agricultural purposes. This term is also referred to as the soluble sodium per cent (SSP) (Wilcox 1955). It is defined and is also calculated by the following eq. (C)

$$\mathrm{Na\%} = \frac{\mathrm{Na}^{+} \times 100}{\left(\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+} + \mathrm{Na}^{+} + \mathrm{K}^{+}\right)} \quad \longrightarrow \quad \boxed{\mathbf{C}}$$

All the concentrations are expressed in meq/L. Based on sodium per cent, water is classified as safe or unsafe. Na % > 60 is considered unsafe, and Na % < 60 is considered safe for agricultural activities (Eaton 1950; Ravikumar et al 2011).

**Residual sodium carbonate (RSC)**

Concentrations of carbonate and bicarbonate play an important role in determining the suitability of water for irrigation purposes. When the total carbonate concentration exceeds the total concentrations of calcium and magnesium and the excess carbonate (residual) concentration is too high, the carbonate ions combine with the calcium and magnesium ions to form a scale, a solid material, which then settles out of the water.As the calcium and magnesium settle out of the water as solid scales, the relative abundance of sodium increases creating deteriorating consequences on the plants.The quantity of carbonate and bicarbonate in excess of alkaline earth metals (calcium and magnesium) is denoted by 'residual sodium carbonate' (RSC) (Sundaray et al. 2009; Ravikumar et al. 2011). The term was proposed by Eaton (1950) and is determined by the method as suggested by Richards (1954). Residual sodium carbonate is calculated by the following formula i.e., eq. (D) (Wilcox 1955).

$$\mathrm{RSC} = \left(\mathrm{CO_3^{-2}} + \mathrm{HCO_3^-}\right) - \left(\mathrm{Ca^{2+}} + \mathrm{Mg^{2+}}\right) \qquad \longrightarrow \qquad \boxed{\mathbf{D}}$$

All the concentrations are expressed in meq/L.

According to Wilcox (1995) of US Salinity Laboratory, a RSC value of less than 1.25 meq/L is safe for irrigational activity, a value of 1.25 – 2.5 meq/L is marginally suitable, and a value greater than 2.5 meq/L is unsuitable for irrigation (Wilcox 1995).

**Residual sodium bicarbonate (RSBC)**

High concentration of bi-carbonate ions may result in precipitation of calcium and magnesium. Thereby, reducing concentration in water. This leads to increase in SAR value.Most of the natural waters do not contain carbonate ions in appreciable quantity, and bicarbonate ions do not precipitate magnesium an ion, so the alkalinity hazard, according to Gupta and Gupta (1987), will be determined by an index called residual sodium bicarbonate (RSBC) and is calculated by the following eq. (E) (Ravikumar et al. 2011).

$$\mathrm{RSBC} = \mathrm{HCO_3^-} - \mathrm{Ca^{2+}} \qquad \longrightarrow \qquad \boxed{\mathbf{E}}$$

The concentrations of various ions are expressed in meq/L.Generally, bicarbonate > 10 meq/L is likely affected plant growth in a number of ways. The values < 5 meq/L were considered satisfactory.

**Magnesium hazard (MH)**

Calcium and magnesium ions maintain a state of equilibrium in most natural water (Hem 1989). Calcium and magnesium are not chemically equivalent especially in the soil system. A higher concentration of Mg ion in water is usually due to the higher exchangeable Na ion present in irrigated soils. High concentration of Mg ion present in water adversely affects the soil quality, making the soil alkaline, which results in low crop yield (Sundaray et al. 2009). The adverse effect of magnesium in irrigated water is measured as the magnesium ratio. Paliwal (1972) introduced an index 'magnesium hazard' for determining the adverse effects of magnesium in irrigation water and is calculated as magnesium ratio (MH) using the (eq. F) (Sundaray et al. 2009; Ravikumar et al. 2011). The concentrations of calcium and magnesium ions are measured in meq/L.

$$\mathrm{MH} = \frac{\mathrm{Mg^+}}{\mathrm{Ca^{2+}} + \mathrm{Mg^{2+}}} \times 100 \qquad \longrightarrow \qquad \boxed{\mathbf{F}}$$

Since higher concentration of magnesium present in water adversely affects the soil quality and crop yield, magnesium hazard (MH) was also evaluated for all the water samples. The MH values above 50% adversely affect the crop yield and are not suitable for irrigation (Sundaray et al. 2009). MH values below 50% are suitable for irrigation purposes and hence it is considered to be safe.

**Kelly's index / Kelly's ratio (KI / KR)**

Suitability of water quality for irrigation purposes is also determined on the basis on Kelly's index. In Kelly's index, sodium measured against calcium and magnesium (Kelly 1940). KI is calculated by the following eq. (G) (Srinivasamoorthy et al. 2014)

$$\mathrm{KI} = \frac{\mathrm{Na^+}}{\mathrm{Ca^{2+}} + \mathrm{Mg^{2+}}} \qquad \longrightarrow \qquad \boxed{\mathbf{G}}$$

Where ion concentrations are expressed in meq/L.

Kelly’s index indicates an excess quantity of sodium in water. Therefore, water with Kelly’s index value less than one ($KI < 1$) is acceptable for irrigation, whereas value greater than one ($KI>1$) indicates excess sodium in water and value less than two ($KI < 2$) indicates sodium deficiency in water (Kelly 1940; Sundaray et al. 2009).

**Permeability index (PI)**

Permeability index (PI) is also used to determine the suitability of the irrigation water. The permeability of soil is affected by long-term exposure of irrigation water containing high quantity of sodium, calcium, magnesium and bicarbonate ions (Ravikumar et al. 2011; Srinivasamoorthy et al. 2014). Doneen (1964) introduced permeability index (PI) for assessing the suitability of irrigation water and is calculated by the following formula (Eq. H) (Arumugam and Elangovan 2009).

$$PI = \frac{\left(Na^{+} + \sqrt{HCO_3^{-}}\right) \times 100}{\left(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}\right)} \longrightarrow \boxed{H}$$

The concentrations are expressed in meq/L.

Water is classified into three classes based on the PI values. Class I ($PI>75\%$) is considered as suitable for irrigation, class II ($PI=25–75\%$) is considered as moderately suitable for irrigational uses, and class III ($PI < 25\%$) is unsuitable (Sundaray et al. 2009; Das and Nag 2015).

**Potential salinity (PS)**

Salts of low solubility in the irrigation water are precipitated out and accumulated on the soil by each successive cultivation. Only the highly soluble salts remain dissolved in the water and increase the salinity. Each year, the salinity of the river is gradually increasing and has now been recognized as a major problem to the downstream water users (Kumarasamy et al. 2013a). ‘Potential salinity is defined as the chloride concentration plus half of the sulphate concentration’ (Doneen 1962; Ravikumar et al. 2011) and it is calculated by the following eq. (I).

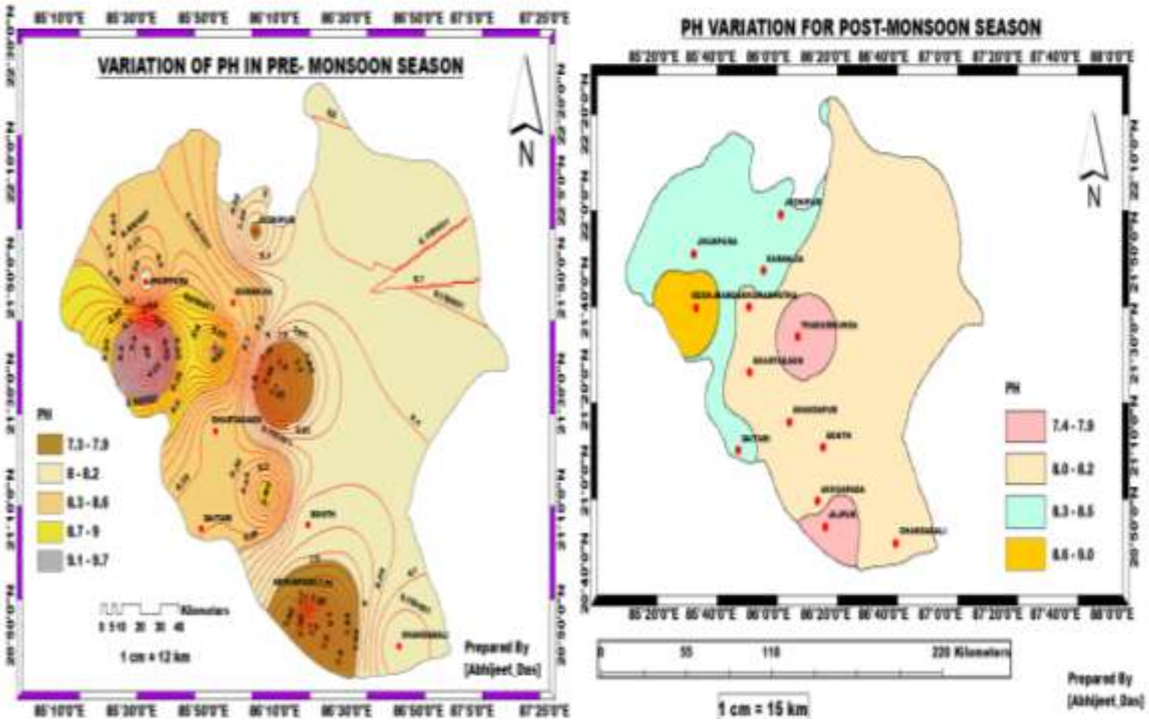
$$\text{Potential Salinity (PS)} = Cl^{-} + \frac{1}{2}SO_4^{2-} \longrightarrow \boxed{I}$$

The concentrations are expressed in meq/L.

It is generally more prominent in the estuarine zone than in the freshwater zone, due to the presence of excessive chlorides of the sea water (Kumarasamy et al. 2013a)

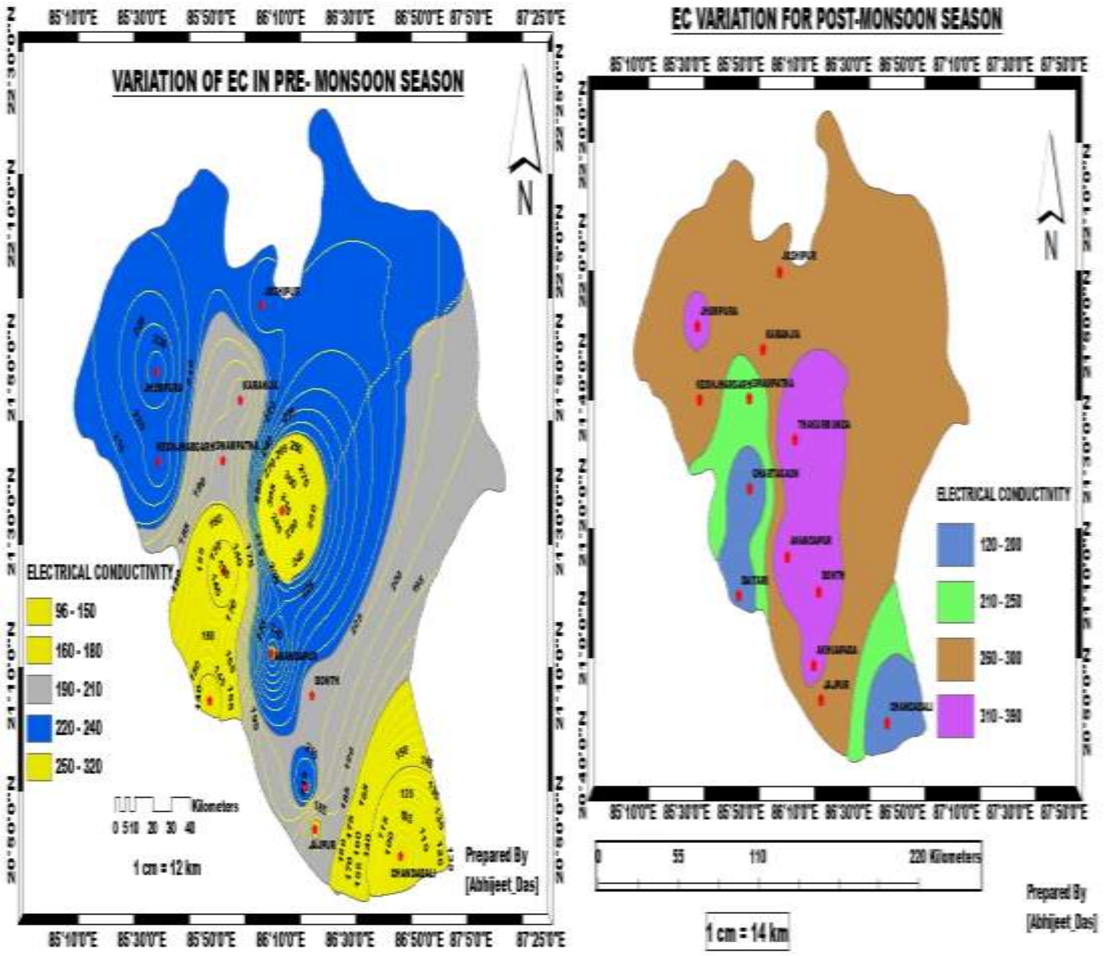
## V. Results And Discussion

In this study, water quality of Baitarani River water was calculated for each sampling stations and for two seasons i.e., Pre-monsoon and Post-monsoon over a period of 20 years (2000-2020). There was a little difference between parameter values measured in this study for the sampling stations as a result of the similar atmospheric conditions and source of water, yet there were significant differences according to the season. The normal PH range required for irrigation water is 6.5 – 8.4 (Ayers and Westcot 1976). The PH ranges for domestic and other purposes are: 6.5 – 8.5, maximum desirable limit; 6.5 – 9.2, maximum permissible limit by WHO (2008); and 6.5 – 8.5, maximum desirable limit by BIS (2012) (Singh et al 2008). All the PH values of the water samples are greater than 7 indicating slight alkaline water. The PH values**(Figure 3)** range from 7.3 to 9.7 in the pre-monsoon period and 7.4 to 9 in the post-monsoon period. Eleven (84.61 %) water samples out of 13 are in the normal ranges of PH and water of 3 (15.38 %) sampling stations are beyond the normal range and are not suitable for irrigational purposes of pre-monsoon period. 92.85 % water samples are in normal range and 7.14 % are not in the normal range of post-monsoon period. Sampling station number 6, 9, 10 in pre-monsoon period and sampling station 10 in post-monsoon period are not suitable for their elevated PH values. The results are also in good concordance with the maximum desirable limit of WHO (2008) and BIS (2012).



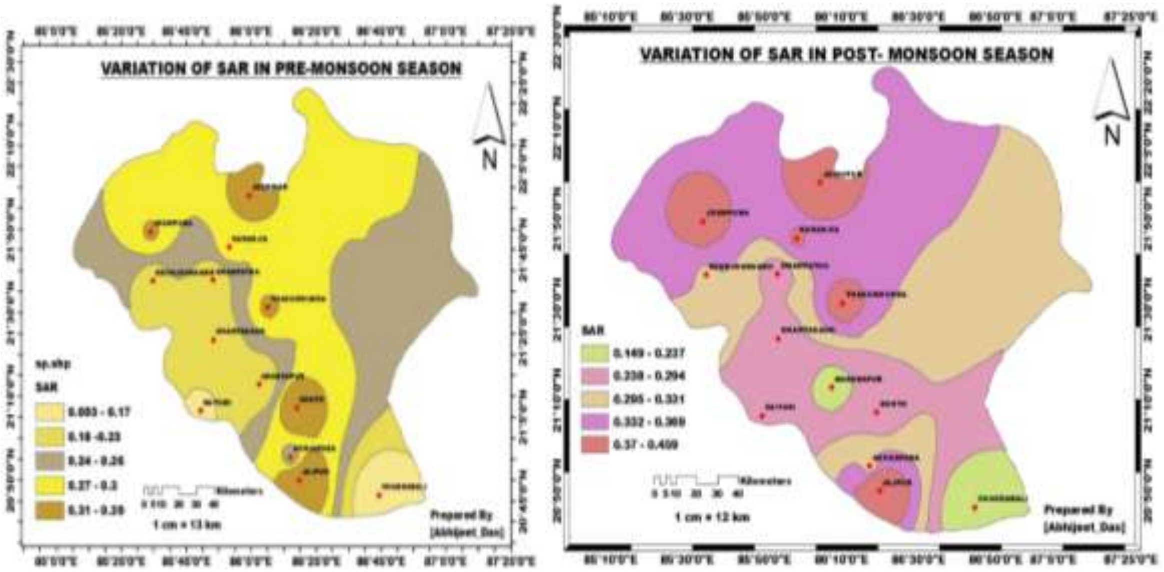
(**Figure 3.** Spatial variations of PH in pre-monsoon and post-monsoon season)

The EC, which indirectly signifies the concentration of salt content in water, is an important parameter for evaluating the suitability of water for irrigation purposes. In our study, EC values varied from 96 to 318 with a mean value of 197.62 in the pre-monsoon season and varied from 121 to 393 with a mean value of 261.54 in the post-monsoon season. EC values**(Figure 4)** of all the water samples are below 750, complying beautifully with both Richards's value and FAO regulation and indicating good quality of irrigation water.



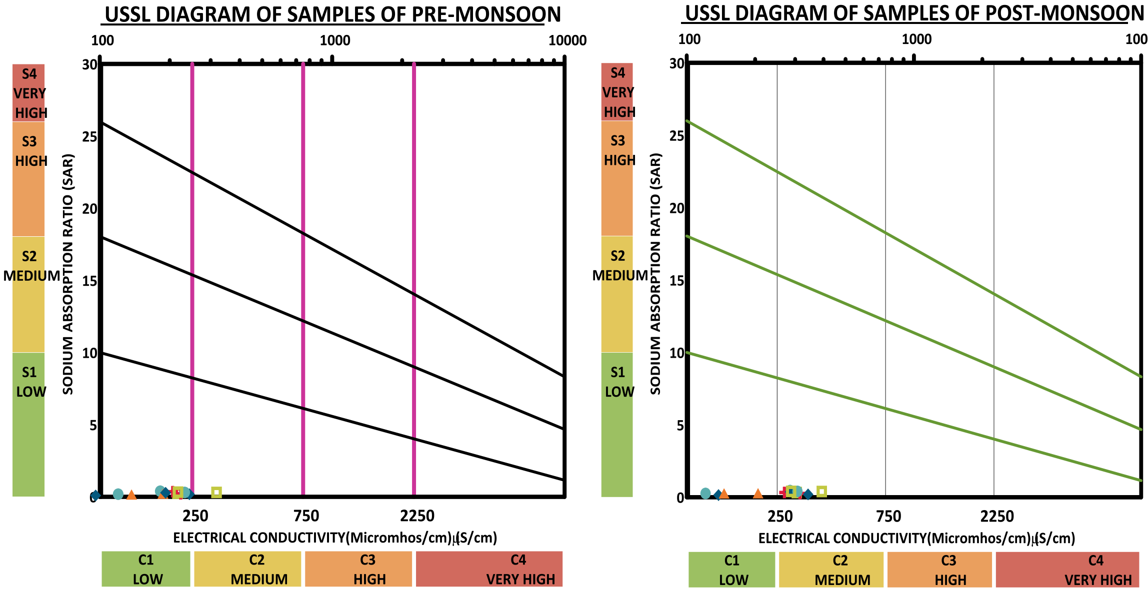
(**Figure 4.** Spatial variations of EC in pre-monsoon and post-monsoon season)

The waters are classified for irrigational purposes according to the SAR values (Richards 1954). The SAR values of the Baitarani River water range from 0.09 to 0.39 in pre-monsoon season and 0.15 to 0.46 in post-monsoon season. According to Richard’s classification, all the samples number 1 to 13 classified as “excellent” for irrigation (Sundaray et al 2009). Spatial variations of the SAR values of both the seasons along the sampling stations have been shown by geospatial map**(Figure 5)**.



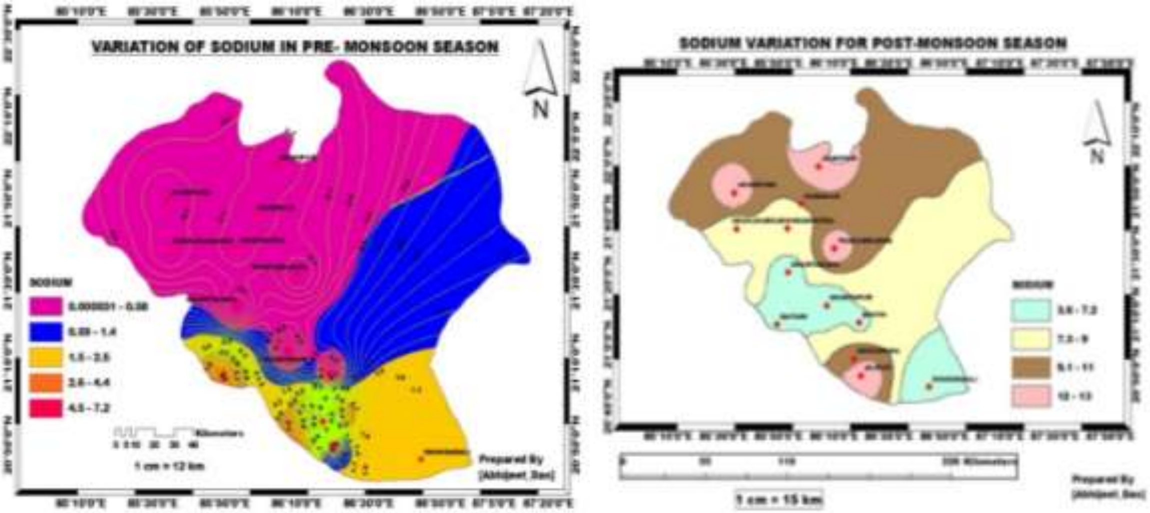
(**Figure 5.** Spatial variations of SAR in pre-monsoon and post-monsoon season)

US Salinity Laboratory (USSL) diagrams**(Figure 6)** were used to evaluate the suitability of water for irrigation use for both the seasons. These are made by plotting the sodium absorption ratio (SAR) values against electrical conductivities data on a two-dimensional graph (Richards 1954). In this study, only 1 sample (7.69 %) out of 13 samples of pre-monsoon season and 9 samples (69.23 %) out of 13 samples fall in the category of C2S1, indicating medium salinity/low sodium type water. Rest 12 samples (92.30 %) of pre-monsoon season and 4 samples (30.76 %) of post-monsoon season fall in the category in low salinity/low sodium types, indicating the water suitable for irrigation uses (Singh et al 2008; Harish et al 2016).



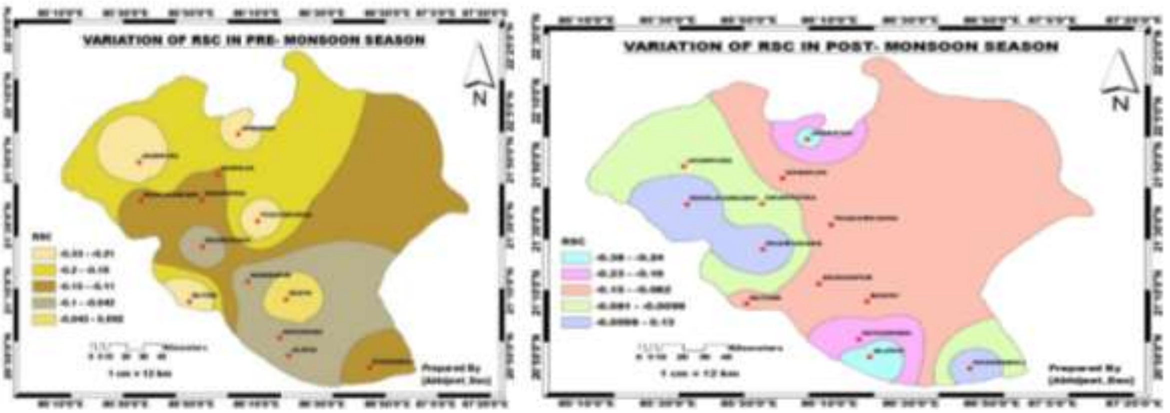
(**Figure 6.** US Salinity diagrams of pre-monsoon and post-monsoon season)

Baitarani River water samples are classified with respect to percent sodium. According to Wilcox 1995 classification, depending upon the sodium percentage**(Figure 7)** in case of pre-monsoon and post-moon are within the permissible limits and all sampling locations are fit for irrigation purposes and also for agricultural activities. Sometimes it is seen in case of monsoon season, the effect of dilution or the washing out of sodium with the flow of heavy water is not significant. The possible reason of higher sodium in post-monsoon water may be the input of sodium through surface runoff of the basin area.



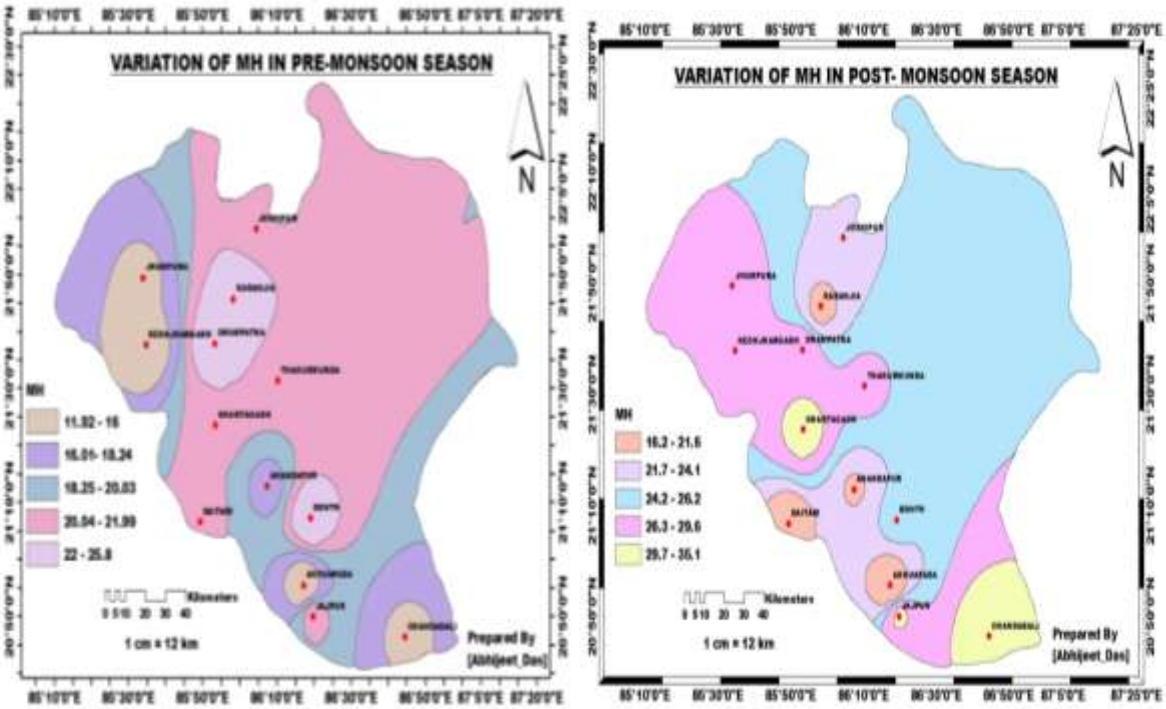
(**Figure 7.** Spatial variations of Na % in pre-monsoon and post-monsoon season)

In this study, the water samples have been found to have RSC values from -0.33 to 0.09 meq/L with a mean value of -0.15 meq/L in pre-monsoon and -0.38 to 0.13 with a mean of -0.10 meq/L in post-monsoon seasons. RSC values of all the samples are less than 1.25 meq/L, indicating the water samples are safe for irrigation purposes. Sometimes, the RSC values of water samples are negative, which indicate that the calcium and magnesium have not been precipitated out (Tiwari and Manzoor 1988). Exact variations of RSC values of both seasons have been shown by geospatial map**(Figure 8).**



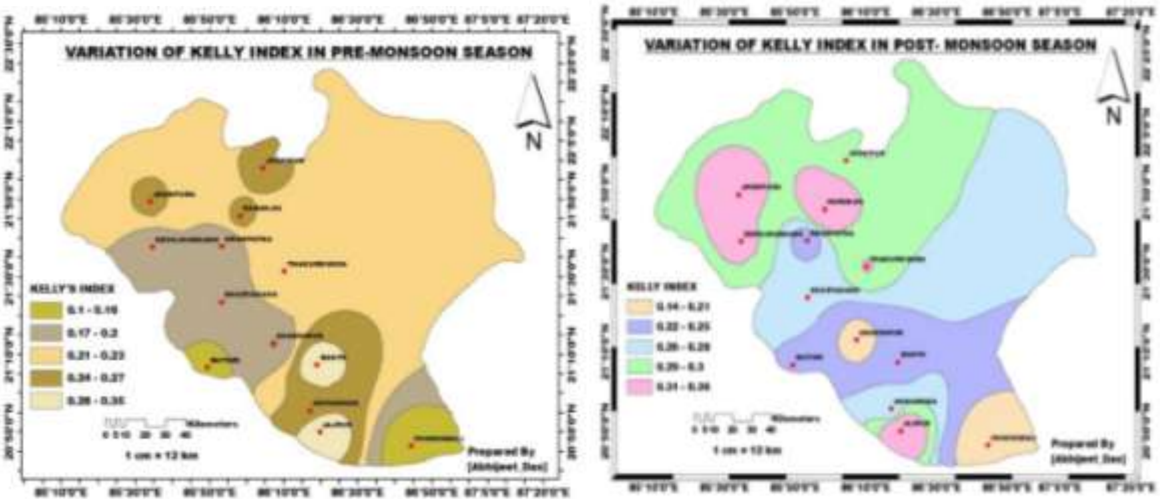
(**Figure 8.** Spatial variations of RSC in pre-monsoon and post-monsoon season)

Gupta and Gupta (1987) proposed the residual sodium bicarbonate (RSBC) index to express the alkalinity hazard. Generally, bicarbonate concentration greater than 10 meq/L is likely to affect the plant growth in a number of ways. The values of less than 5 meq/L were considered satisfactory (Ravikumar et al 2011). In this study, the RSBC values ranges from -0.16 to 0.29 with a mean of 0.01 meq/L in the pre-monsoon season and -0.09 to 0.34 with a mean of 0.12 in post-monsoon season. The values are below the satisfactory value in both the seasons and can be used safely for irrigational purposes. Since higher concentration of magnesium ion present in water adversely affect the soil quality and crop yield, magnesium hazard (MH) was also evaluated for all the water samples. The values range from 11.92 % to 25.81 % with a mean value of 19.42 % in pre-monsoon season and 16.20% to 35.12% with a mean of 25.70 % in post-monsoon season. MH values above 50 % adversely affect the crop yield and its productivity and are not suitable for irrigation (Sundaray et al 2009). All the values of this study of pre monsoon and post-monsoon season are below 50 % and hence suitable for irrigation activities. Geospatially, the variations of values are being shown in spatial map**(Figure 9).**



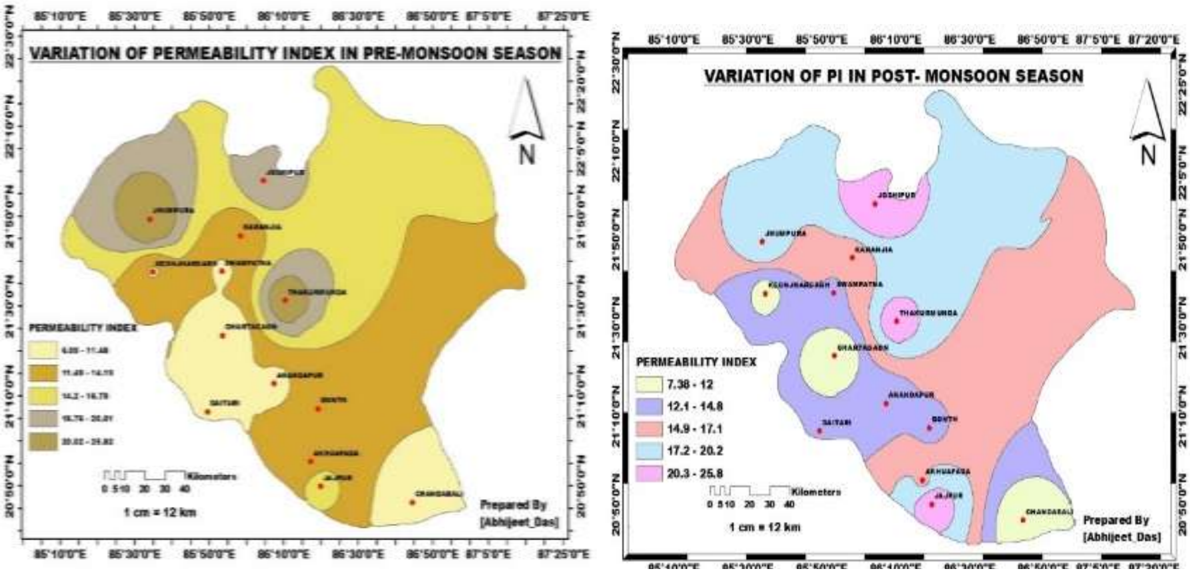
(**Figure 9.** Spatial variations of MH in pre-monsoon and post-monsoon season)

**Kelly's index** indicates relative sodium quantity against calcium and magnesium and helps us to determine the suitability of the water for agricultural purposes and irrigation too. The values of index less than 1 are suitable for irrigation, greater than 1 indicates excess sodium in water and not suitable for irrigation purposes, and values less than 2 signifies sodium deficiency in water and are not suitable for irrigation (Kelly 1940; Sundaray et al 2009; Srinivasamoorthy et al 2014). In this study, the values ranges from 0.10 to 0.35 with a mean of 0.21 in case of pre-monsoon season and values ranges from 0.14 to 0.36 with a mean of 0.27 in case of post-monsoon season. All the values are less than 1 and all sampling locations are suitable for irrigation and agricultural purposes and can be used for cultivation, land preparation in case of both pre and post-monsoon season. Geospatially, the variations of values are being shown in spatial map**(Figure 10).**



(**Figure 10.** Spatial variations of Kelly Index in pre-monsoon and post-monsoon season)

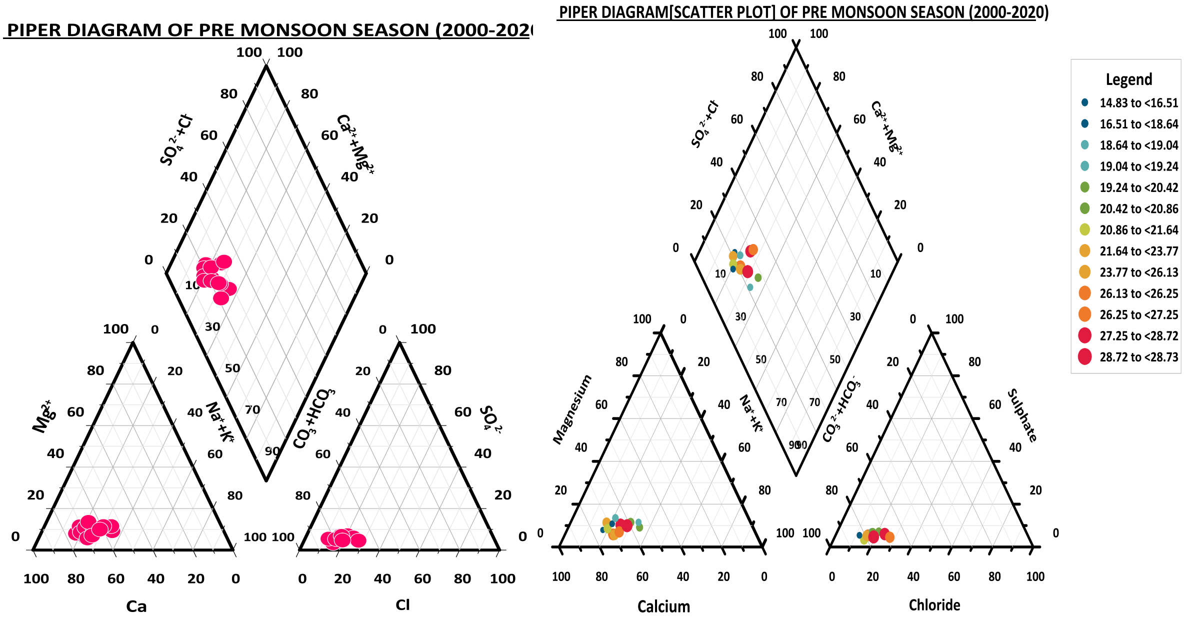
**Permeability Index (PI)** values of Baitarani River water ranged from 41.80 to 65.70 % in pre-monsoon season and from 30.04 to 60.68 % in the post-monsoon season. All the values lies in between 25 to 75 %, that depicts all sampling locations in pre and post monsoon season are suitable for moderate irrigation purposes i.e. it comes under Class II. Variations of PI values along the sampling stations are shown by geospatial map**(Figure 11).** According to PI analysis, post monsoon water is better than pre monsoon water, possibly because of the addition of large amount of fresh rain water. But in this study, all the seasons are moderate for all sampling stations.



(**Figure 11.** Spatial variations of Permeability Index in pre-monsoon and post-monsoon season)

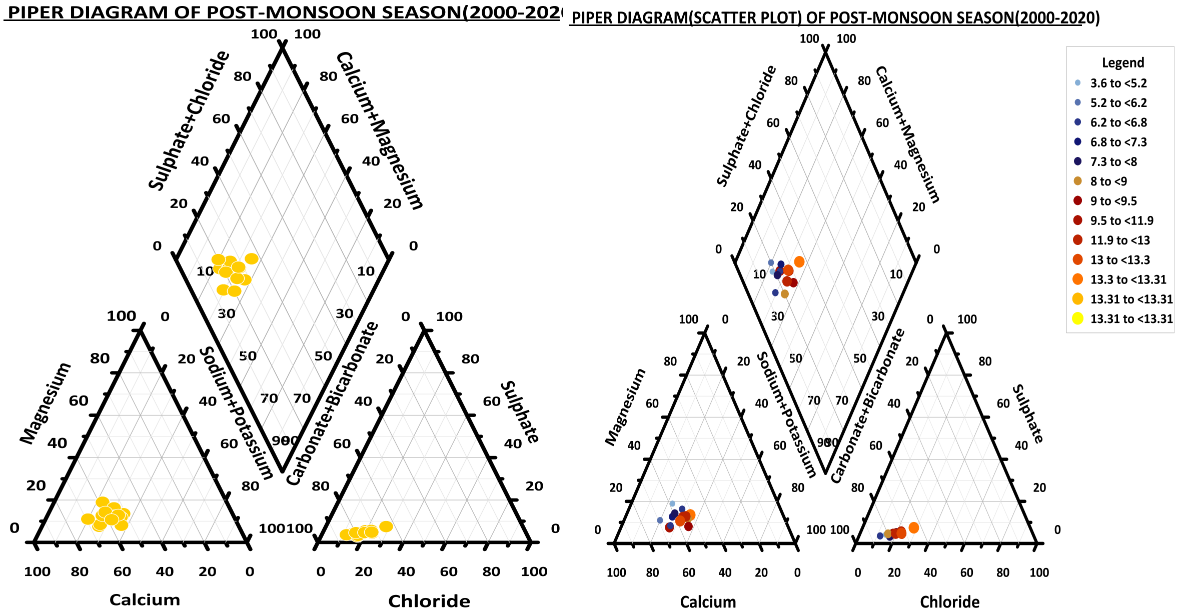
**Potential Salinity (PS)** of the water samples of the Baitarani River varied from 0.09 to 0.30 in the pre-monsoon season and from 0.07 to 0.26 in post-monsoon season. All the values are considerably fair low. It is very must significant in the estuarine region because of the high salt content from sea water. Doneen (1964) explained that suitability of water for irrigation is not dependent on the total concentration of soluble salts, as low solubility salts precipitate out and deposited on the soil every year. In this case, all are within the prescribed limits.

To know the hydro geochemical characteristics of the study area and water, the analytical values were plotted on piper diagram (Piper 1944). Piper trilinear diagram**(Figure 12, 13)** includes two triangles, one showing cations and other showing anions, and a diamond shaped area to show a combined position of cations and anions. The combined single position of the diamond shaped area helps us to draw inference and to classify the water on the basis of the hydro geochemical characteristics. The diamond shaped area of Piper diagram is divided into four major parts, each part representing and explaining a particular type of variation or domination of cations and anions. The four parts are calcium-magnesium-chloride-sulphate, sodium-potassium-chloride-sulphate, sodium- potassium-bicarbonate and calcium-magnesium-bicarbonate. All the samples of this study of both the seasons fall in the category of calcium-magnesium-bicarbonate representing a dominance of calcium, magnesium and carbonate ions in the water. The sources of this type of waters may be a typical shallow fresh water stations with rooted aquatic vegetation along the banks. Durov piper diagram**(Figure 14)** for pre-monsoon and post-monsoon are being drawn for clear explanation of all the sampling locations and it's a typical method which will classify the law behind the trilinear piper diagram and also exhibit same results as that of piper diagram results. Hence, all the sampling locations are safe and suitable for irrigation and cultivation purposes.


PIPER DIAGRAM OF PRE MONSOON SEASON (2000-202

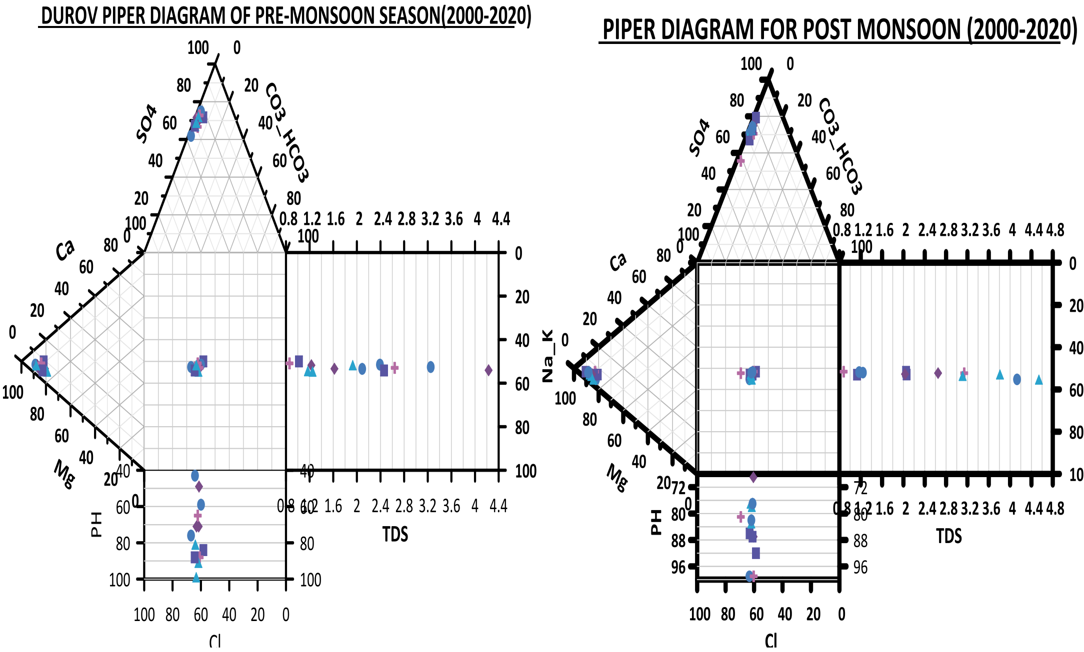
PIPER DIAGRAM[SCATTER PLOT] OF PRE MONSOON SEASON (2000-2020)

(**Figure 12.** Piper Diagram for Pre-monsoon season)


PIPER DIAGRAM OF POST-MONSOON SEASON(2000-202

PIPER DIAGRAM[SCATTER PLOT] OF POST-MONSOON SEASON(2000-2020)

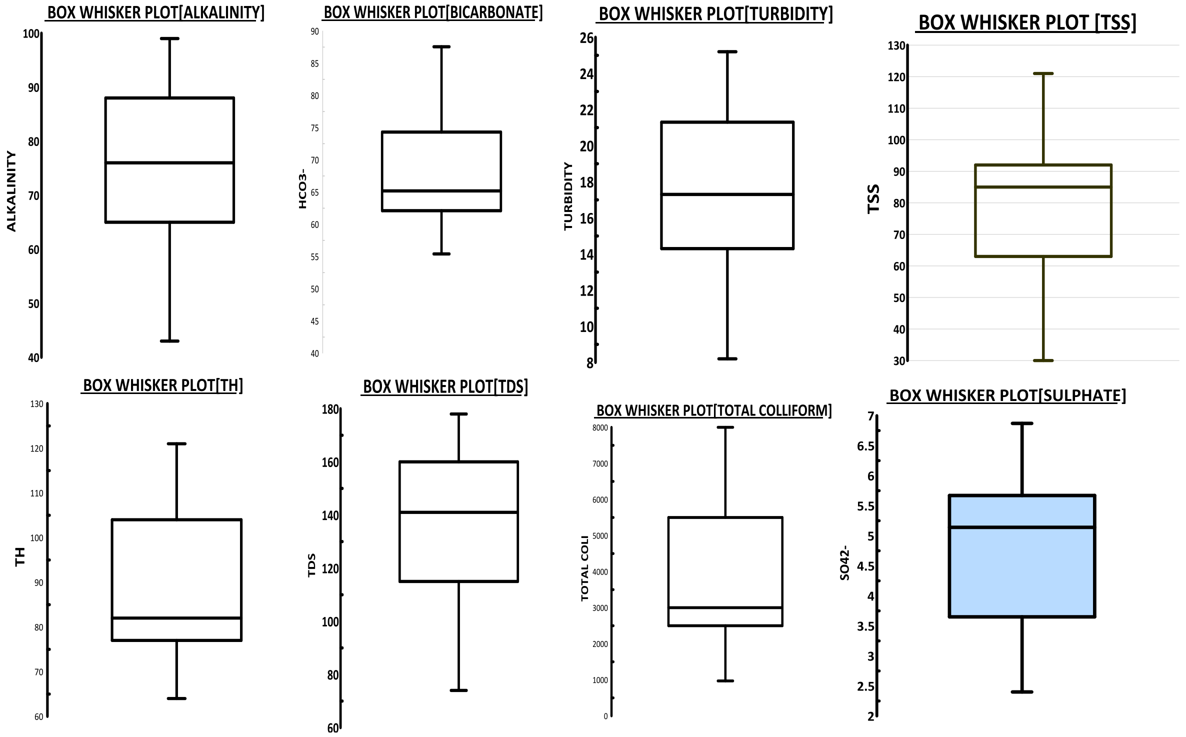
(**Figure 13.** Piper Diagram for Post-monsoon season)

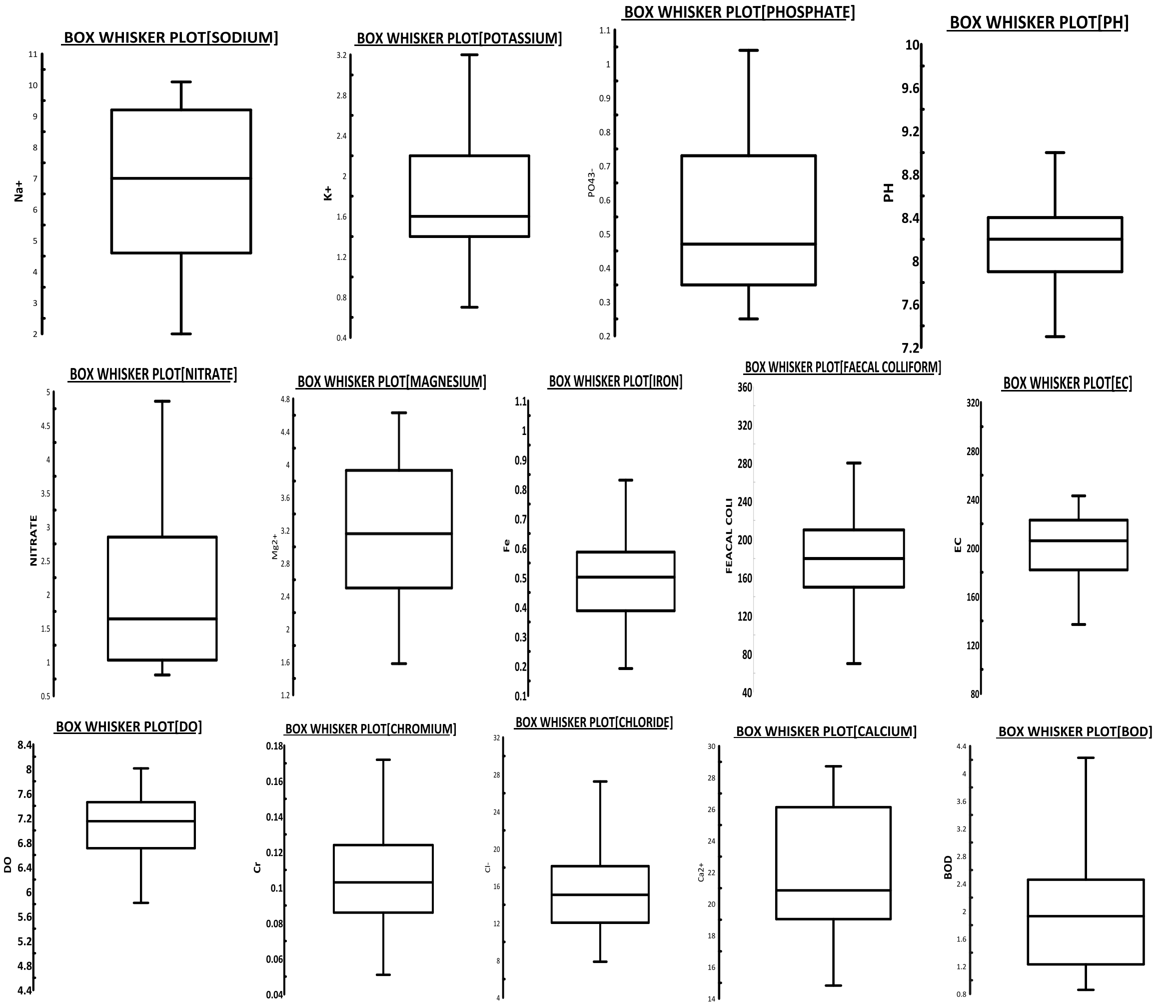


(**Figure 14.** Durov Piper Diagram for Pre-monsoon and Post-monsoon season)

The box-whisker plots**(Figure 15, 16)** of the water parameters have also been drawn for the two seasons to show the variations of studied parameter values. These parameters do not vary significantly along the sampling stations. Some parameters fairly vary and the concentration is greater in pre-monsoon than post-monsoon because of heavy water of monsoon and flow of water during rainy season homogenize the water of the river (Zhang et al 2009; Kumarswamy et al 2013b).

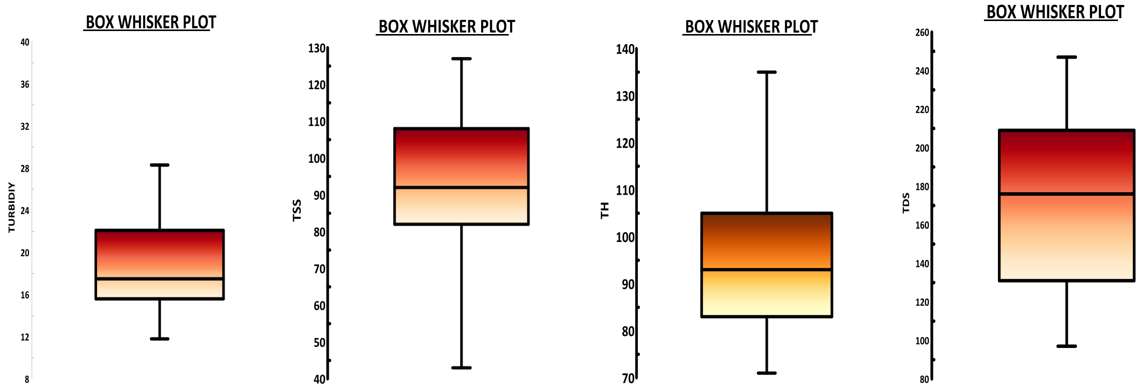
**Box plots of pre-monsoon analysis**

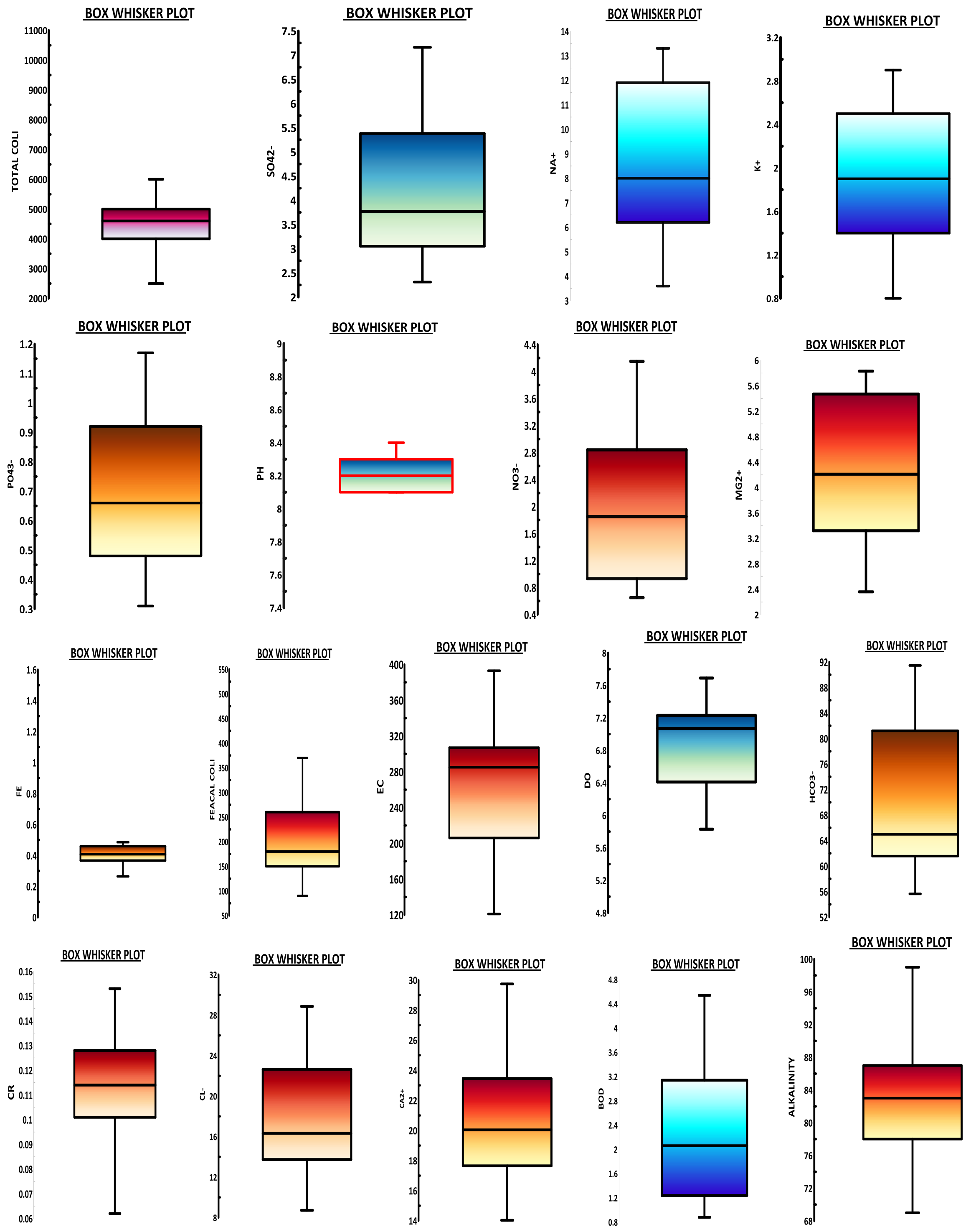




(**Figure 15**. Box-Whisker plots of Pre-monsoon season)

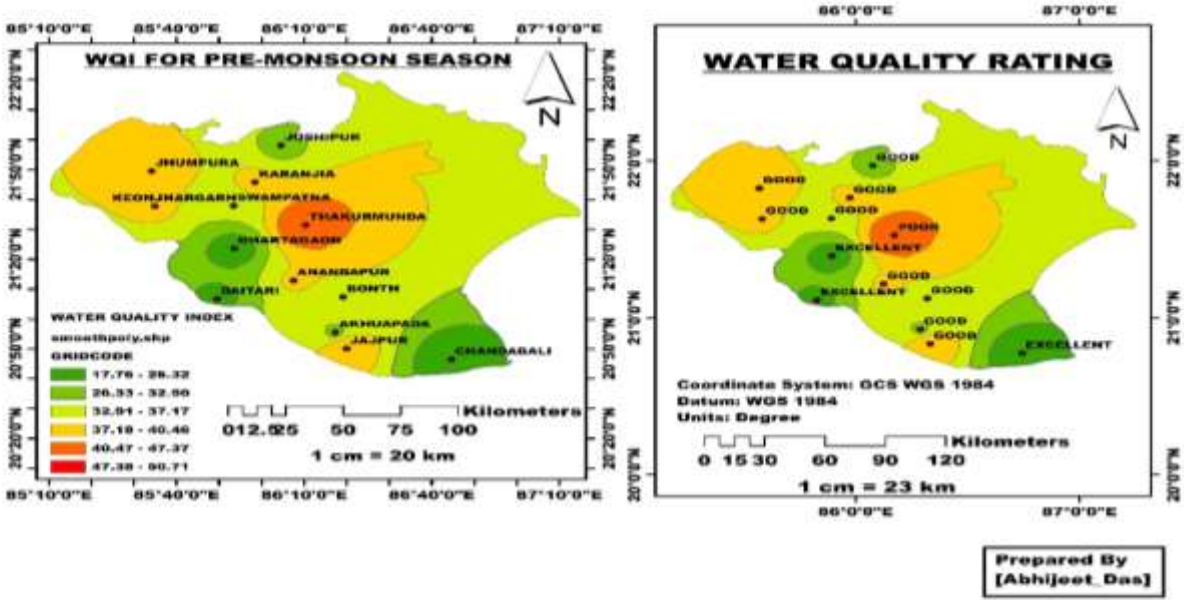
## Box plot of post-monsoon analysis



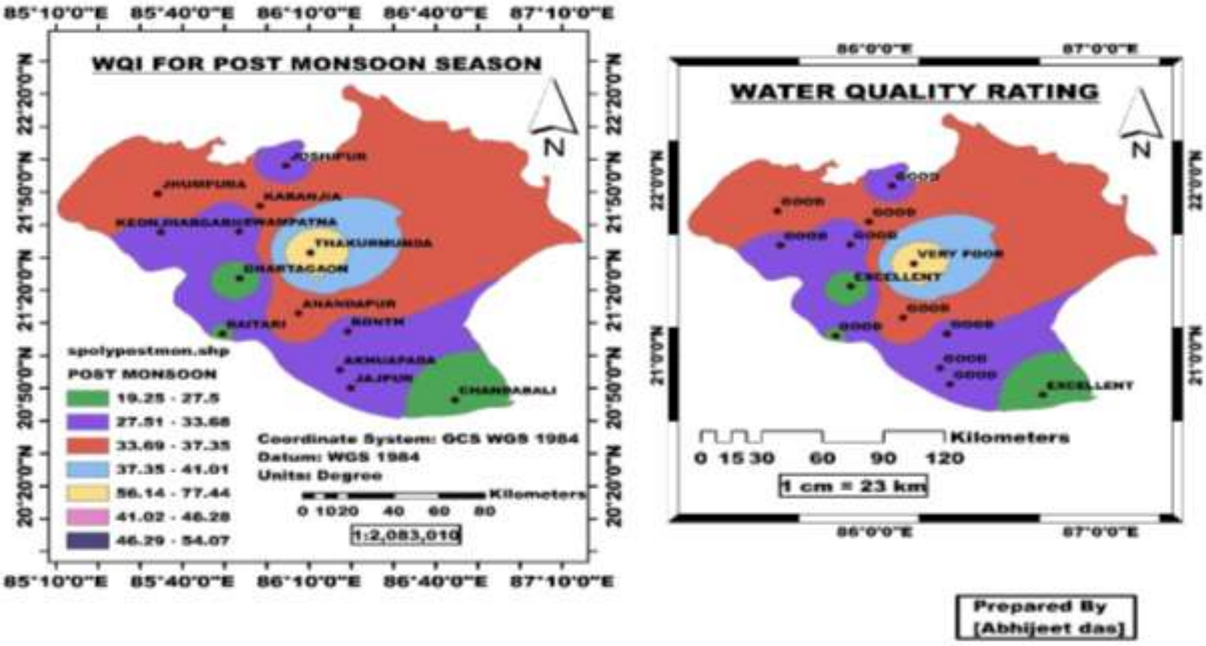


(**Figure 16**. Box-Whisker plots of Post-monsoon season)

The WQI values varied from 17.8 to 59.7 in the pre-monsoon season with a mean of 35.8 and in case of post-monsoon season, the values varied from 19.2 to 77.7 with a mean of 36.2 respectively. According the classification of water quality, WQI values into the following five classes, 0-25 signifies excellent, 26-50 signifies well (good), 51-75 signifies poor, 76-100 signifies very poor and > 100 signifies unsuitable for drinking purposes. Therefore, Baitarani River water ranges from poor to excellent in pre-monsoon season and very poor to excellent in case of post-monsoon season. Chandabali, Daitari and Ghartagoan comes under excellent, Jajpur, Akhuapada, Bonth, Anandpur, Swampatna, Keonjhargarh, Karanjia, Jhumpura and Joshipur comes under good quality and Thakurmunda signifies poor water quality in pre-monsoon season whereas Chandbali and Ghartagaon signifies excellent water and all other remaining sampling locations depicts good quality except Thakurmunda signifies very poor water quality in post-monsoon season. As it is situated in the downstream and is thought to receive the municipal effluents which deteriorates the quality and threatens the human health. Here water is almost static and pollutants did not get disperse. Quantitatively, all the stations exhibits good behavior in terms of WQI and it is due to the large pollutants is being diluted and washed away with heavy rain water in case of post-monsoon season. Hence, we can say post-monsoon is slightly better than pre-monsoon. The exact variations of the WQI of both the seasons are shown in the geospatial map (**Figure 17, 18**).



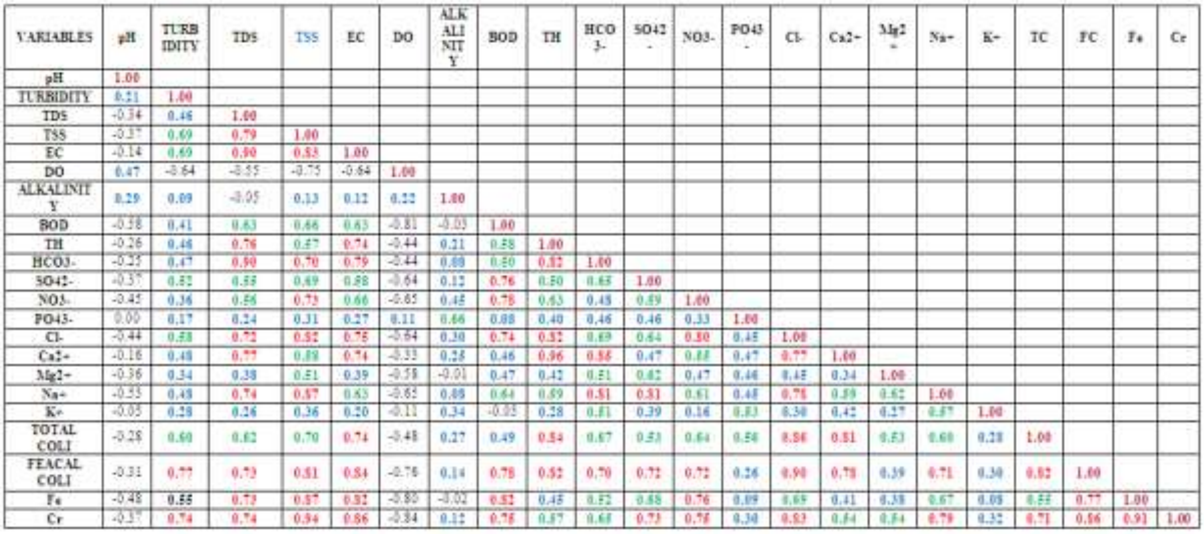
(**Figure 17.** Spatial variations of Water Quality Index for Pre-monsoon season)



(**Figure 18.** Spatial variations of Water Quality Index for Post-monsoon season)

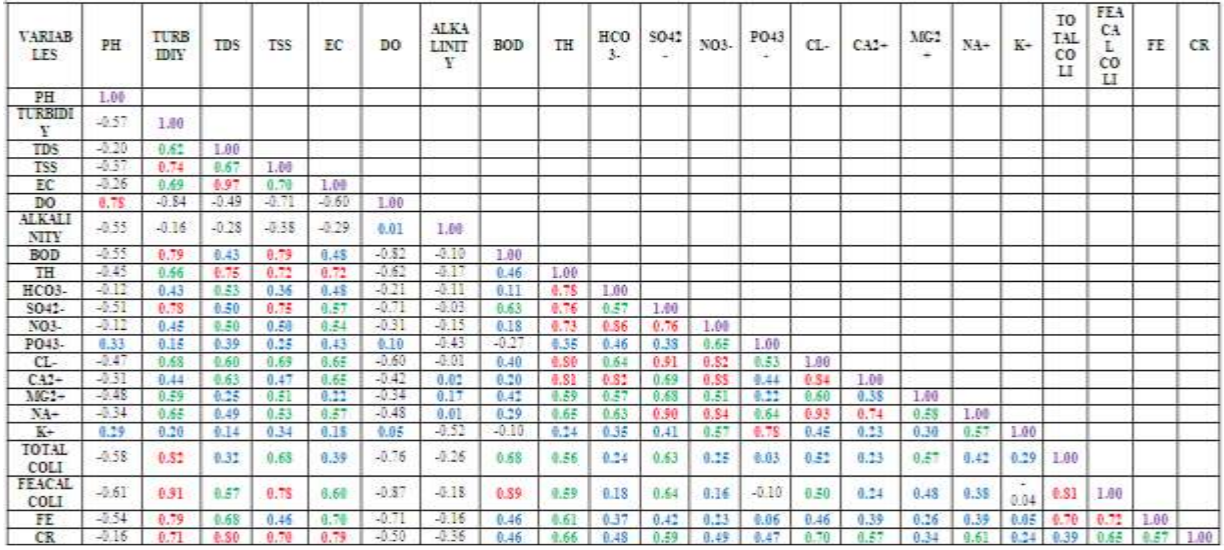
Pearson's correlation analysis is an important statistical tool to exhibit the degree of dependency of one variable to the others (Belkhiri et al. 2011). Actually, correlation coefficient is used to measure the interrelation and extent of associations among the variables. Correlation coefficients value +1 indicates a perfect relationship between the variables, and −1 indicates perfect relationship, but the variables vary inversely (Mudgal et al. 2009) and a zero value means no relationship between the variables (Mudgal et al. 2009) at a significant level of $p < 0.7$ are considered as strong correlation, whereas r values between 0.5 and 0.7 are considered as moderate correlation and r values < 0.3 are considered as weak correlation. Pearson's correlation matrixclearly represents the dependency of variables with each other.To identify the association between the variables and to estimate the strength of the relationship, Pearson correlation matrix is used which provides information about not only the strength but also the direction of a relationship. In Pre-monsoon and Post-monsoon season **(Table 4, 5)**, the values with red color were found to exist positively correlated or strongly correlated, values with green color signifies moderately correlated and ultimately, the values with blue color depicts weakly correlated. This signifies that the parameters change with direct proportionality. Some parameters were found to be in fair negative correlation signifying that these parameters change with inverse proportionality.

**Table 4. Pearson correlation matrix of pre-monsoon water parameters**



| VARIABLES | pH | TURBIDITY | TDS | TSS | EC | DO | ALKALINITY | BOD | TH | HCO3- | SO42- | NO3- | PO43- | Cl- | Ca2+ | Mg2+ | Na+ | K+ | TC | FC | Fe | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| TURBIDITY | 0.21 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| TDS | -0.34 | 0.46 | 1.00 | | | | | | | | | | | | | | | | | | | |
| TSS | -0.37 | 0.69 | 0.79 | 1.00 | | | | | | | | | | | | | | | | | | |
| EC | -0.14 | 0.69 | 0.90 | 0.53 | 1.00 | | | | | | | | | | | | | | | | | |
| DO | 0.47 | -0.64 | -0.55 | -0.75 | -0.64 | 1.00 | | | | | | | | | | | | | | | | |
| ALKALINITY | 0.29 | 0.09 | -0.05 | 0.13 | 0.12 | 0.22 | 1.00 | | | | | | | | | | | | | | | |
| BOD | -0.58 | 0.41 | 0.63 | 0.66 | 0.63 | -0.81 | -0.03 | 1.00 | | | | | | | | | | | | | | |
| TH | -0.26 | 0.46 | 0.76 | 0.57 | 0.74 | -0.44 | 0.21 | 0.58 | 1.00 | | | | | | | | | | | | | |
| HCO3- | -0.25 | 0.47 | 0.90 | 0.70 | 0.79 | -0.44 | 0.08 | 0.50 | 0.82 | 1.00 | | | | | | | | | | | | |
| SO42- | -0.37 | 0.52 | 0.55 | 0.69 | 0.58 | -0.64 | 0.12 | 0.76 | 0.50 | 0.63 | 1.00 | | | | | | | | | | | |
| NO3- | -0.45 | 0.36 | 0.56 | 0.73 | 0.66 | -0.65 | 0.45 | 0.78 | 0.63 | 0.48 | 0.59 | 1.00 | | | | | | | | | | |
| PO43- | 0.00 | 0.17 | 0.24 | 0.31 | 0.27 | 0.11 | 0.66 | 0.08 | 0.40 | 0.46 | 0.46 | 0.33 | 1.00 | | | | | | | | | |
| Cl- | -0.44 | 0.58 | 0.72 | 0.52 | 0.75 | -0.64 | 0.30 | 0.74 | 0.52 | 0.69 | 0.64 | 0.80 | 0.45 | 1.00 | | | | | | | | |
| Ca2+ | -0.16 | 0.48 | 0.77 | 0.58 | 0.74 | -0.33 | 0.25 | 0.46 | 0.96 | 0.56 | 0.47 | 0.88 | 0.47 | 0.77 | 1.00 | | | | | | | |
| Mg2+ | -0.36 | 0.34 | 0.38 | 0.51 | 0.39 | -0.58 | -0.01 | 0.47 | 0.42 | 0.51 | 0.62 | 0.47 | 0.46 | 0.45 | 0.24 | 1.00 | | | | | | |
| Na+ | -0.55 | 0.48 | 0.74 | 0.57 | 0.63 | -0.65 | 0.08 | 0.64 | 0.59 | 0.51 | 0.51 | 0.61 | 0.48 | 0.78 | 0.59 | 0.62 | 1.00 | | | | | |
| K+ | -0.05 | 0.28 | 0.26 | 0.36 | 0.20 | -0.11 | 0.34 | -0.05 | 0.28 | 0.51 | 0.39 | 0.16 | 0.53 | 0.30 | 0.42 | 0.27 | 0.57 | 1.00 | | | | |
| TOTAL COLI | -0.28 | 0.60 | 0.62 | 0.70 | 0.74 | -0.48 | 0.27 | 0.49 | 0.54 | 0.67 | 0.53 | 0.64 | 0.58 | 0.86 | 0.81 | 0.53 | 0.60 | 0.28 | 1.00 | | | |
| FEACAL COLI | -0.31 | 0.77 | 0.73 | 0.81 | 0.84 | -0.76 | 0.14 | 0.78 | 0.52 | 0.70 | 0.72 | 0.72 | 0.26 | 0.90 | 0.78 | 0.39 | 0.71 | 0.30 | 0.82 | 1.00 | | |
| Fe | -0.48 | 0.55 | 0.73 | 0.57 | 0.82 | -0.80 | -0.02 | 0.52 | 0.48 | 0.52 | 0.58 | 0.76 | 0.09 | 0.69 | 0.41 | 0.38 | 0.67 | 0.08 | 0.55 | 0.77 | 1.00 | |
| Cr | -0.37 | 0.74 | 0.74 | 0.94 | 0.86 | -0.34 | 0.12 | 0.78 | 0.57 | 0.68 | 0.73 | 0.76 | 0.30 | 0.93 | 0.64 | 0.64 | 0.79 | 0.32 | 0.71 | 0.86 | 0.91 | 1.00 |

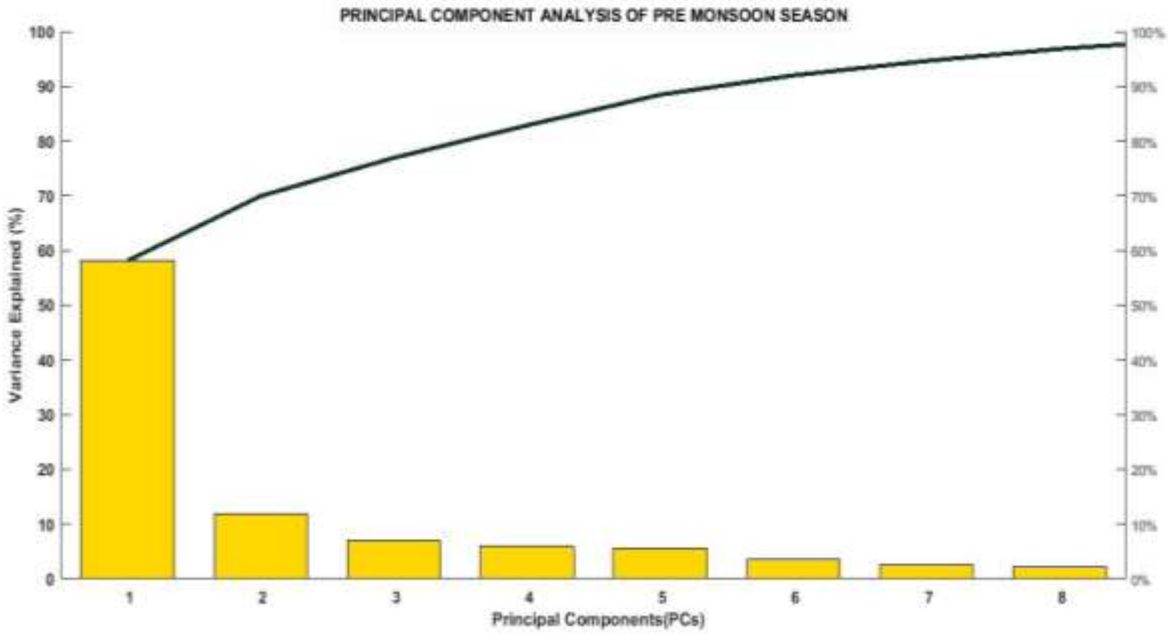
**Table 5. Pearson correlation matrix of post-monsoon water parameters**



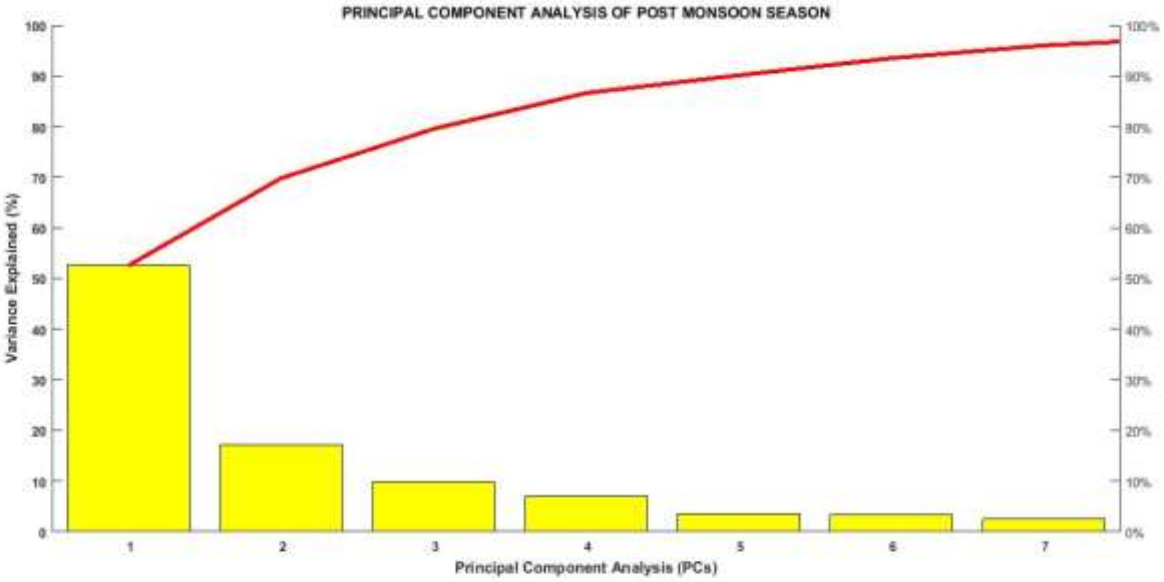
| VARIABLES | PH | TURBIDIY | TDS | TSS | EC | DO | ALKALINITY | BOD | TH | HCO3- | SO42- | NO3- | PO43- | CL- | CA2+ | MG2+ | NA+ | K+ | TOTAL COLI | FEACAL COLI | FE | CR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| TURBIDITY | -0.57 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| TDS | -0.20 | 0.62 | 1.00 | | | | | | | | | | | | | | | | | | | |
| TSS | -0.37 | 0.74 | 0.67 | 1.00 | | | | | | | | | | | | | | | | | | |
| EC | -0.26 | 0.69 | 0.97 | 0.70 | 1.00 | | | | | | | | | | | | | | | | | |
| DO | 0.75 | -0.84 | -0.49 | -0.71 | -0.60 | 1.00 | | | | | | | | | | | | | | | | |
| ALKALINITY | -0.55 | -0.16 | -0.28 | -0.38 | -0.29 | 0.01 | 1.00 | | | | | | | | | | | | | | | |
| BOD | -0.55 | 0.79 | 0.43 | 0.79 | 0.48 | -0.82 | -0.10 | 1.00 | | | | | | | | | | | | | | |
| TH | -0.45 | 0.66 | 0.75 | 0.72 | 0.72 | -0.62 | -0.17 | 0.46 | 1.00 | | | | | | | | | | | | | |
| HCO3- | -0.12 | 0.43 | 0.53 | 0.36 | 0.48 | -0.21 | -0.11 | 0.11 | 0.75 | 1.00 | | | | | | | | | | | | |
| SO42- | -0.51 | 0.78 | 0.50 | 0.75 | 0.57 | -0.71 | -0.03 | 0.63 | 0.76 | 0.57 | 1.00 | | | | | | | | | | | |
| NO3- | -0.12 | 0.45 | 0.50 | 0.50 | 0.54 | -0.31 | -0.15 | 0.18 | 0.73 | 0.56 | 0.76 | 1.00 | | | | | | | | | | |
| PO43- | 0.33 | 0.15 | 0.39 | 0.25 | 0.43 | 0.10 | -0.43 | -0.27 | 0.35 | 0.46 | 0.38 | 0.65 | 1.00 | | | | | | | | | |
| CL- | -0.47 | 0.68 | 0.60 | 0.69 | 0.65 | -0.60 | -0.01 | 0.40 | 0.80 | 0.64 | 0.91 | 0.82 | 0.53 | 1.00 | | | | | | | | |
| CA2+ | -0.31 | 0.44 | 0.63 | 0.47 | 0.65 | -0.42 | 0.02 | 0.20 | 0.81 | 0.82 | 0.69 | 0.85 | 0.44 | 0.84 | 1.00 | | | | | | | |
| MG2+ | -0.48 | 0.59 | 0.25 | 0.51 | 0.22 | -0.34 | 0.17 | 0.42 | 0.59 | 0.57 | 0.68 | 0.51 | 0.22 | 0.60 | 0.38 | 1.00 | | | | | | |
| NA+ | -0.34 | 0.65 | 0.49 | 0.53 | 0.57 | -0.48 | 0.01 | 0.29 | 0.65 | 0.63 | 0.90 | 0.84 | 0.64 | 0.93 | 0.74 | 0.58 | 1.00 | | | | | |
| K+ | 0.29 | 0.20 | 0.14 | 0.34 | 0.18 | 0.05 | -0.52 | -0.10 | 0.24 | 0.35 | 0.41 | 0.57 | 0.78 | 0.45 | 0.23 | 0.30 | 0.57 | 1.00 | | | | |
| TOTAL COLI | -0.58 | 0.82 | 0.32 | 0.68 | 0.39 | -0.76 | -0.26 | 0.68 | 0.56 | 0.24 | 0.63 | 0.25 | 0.03 | 0.52 | 0.23 | 0.57 | 0.42 | 0.29 | 1.00 | | | |
| FEACAL COLI | -0.61 | 0.91 | 0.57 | 0.78 | 0.60 | -0.87 | -0.18 | 0.89 | 0.59 | 0.18 | 0.64 | 0.16 | -0.10 | 0.50 | 0.24 | 0.48 | 0.38 | -0.04 | 0.81 | 1.00 | | |
| FE | -0.54 | 0.79 | 0.68 | 0.46 | 0.70 | -0.71 | -0.16 | 0.46 | 0.61 | 0.37 | 0.42 | 0.23 | 0.06 | 0.46 | 0.39 | 0.26 | 0.39 | 0.05 | 0.70 | 0.72 | 1.00 | |
| CR | -0.16 | 0.71 | 0.80 | 0.70 | 0.79 | -0.50 | -0.36 | 0.46 | 0.66 | 0.48 | 0.59 | 0.49 | 0.47 | 0.70 | 0.57 | 0.34 | 0.61 | 0.24 | 0.39 | 0.65 | 0.57 | 1.00 |

Principal component analysis (PCA) was conducted to analyze the compositional pattern of the variables on the entire data set to some influencing factors by avoiding some insignificant data (Wang et al 2015, 2017). In this study, the first three principal components (PCs)/ Factor loading analysis were considered for both the seasons to explain 76.906 % of the total variance of pre-monsoon and 74.906 % of the post-monsoon season.

Scree plots of two different seasons (**Figure 19, 20**) have also been used to depict the change of Eigen values of all the components (Helena et al 2000). It is evident from the above data sets, a conclusion may be drawn that factor 1 of pre-monsoon season dominantly contains TDS, TSS, EC, BOD, TH, $HCO^{3-}$, $SO_4^{2-}$, $NO_3^-$, $Cl^-$, $Ca^{2+}$, $Na^+$, TC, FC, Fe and Cr and PC1 of post-monsoon contains turbidity, TDS, TSS, EC, TH, Sulphate, Nitrate and Chlorideas dominant variables. In both the seasons, the variables are purely hydro chemical and are supposed to originate from the geological process, indicating geo-genic sources. In factor 2 for both the seasons includes DO, nitrate and potassium are dominant factors which are generally contributed by fertilizers (both agricultural and industrial), indicating anthropogenic influences (Helena et al. 2000).



(**Figure 19**. Scree plot of Pre-monsoon season)



(**Figure 20**. Scree plot of Post-monsoon season)

Results of factor analysis including factor loading matrix, Eigen values and total cumulative variance values are given in (**Table 6**).

**Table 6. Calculation of Eigen vectors and factor loadings for pre-monsoon season**

| EIGEN VECTORS/PRINCIPAL COMPONENT ANALYSIS | | | |
|---|---|---|---|
| **VARIABLE/PARAMETERS** | **F1** | **F2** | **F3** |
| PH | -0.117 | 0.285 | 0.472 |
| TURBIDIY | 0.188 | 0.014 | 0.367 |
| TDS | 0.236 | -0.027 | 0.153 |
| TSS | 0.256 | -0.062 | 0.008 |
| EC | 0.247 | -0.007 | 0.293 |
| DO | -0.214 | 0.330 | 0.007 |
| ALKALINITY | 0.048 | 0.444 | -0.075 |
| BOD | 0.222 | -0.264 | -0.094 |
| TH | 0.227 | 0.160 | 0.162 |
| HCO3- | 0.232 | 0.151 | 0.036 |
| SO42- | 0.222 | -0.028 | -0.246 |
| NO3- | 0.223 | -0.029 | -0.121 |
| PO43- | 0.118 | 0.462 | -0.293 |
| CL- | 0.257 | 0.053 | 0.004 |
| CA2+ | 0.219 | 0.240 | 0.192 |
| MG2+ | 0.168 | -0.007 | -0.359 |
| NA+ | 0.242 | 0.011 | -0.263 |
| K+ | 0.107 | 0.336 | -0.235 |
| TOTAL COLI | 0.232 | 0.163 | 0.086 |
| FEACAL COLI | 0.260 | -0.026 | 0.178 |
| FE | 0.231 | -0.253 | 0.027 |
| CR | 0.259 | -0.104 | 0.026 |
| EIGEN VALUE | 12.781 | 2.603 | 1.536 |
| VARIABILITY % | 58.096 | 11.831 | 6.980 |
| CUMMULATIVE % | 58.096 | 69.927 | 76.906 |

| FACTOR LOADINGS/COMPONENT LOADINGS | | | |
|---|---|---|---|
| **VARIABLE/PARAMETERS** | **F1** | **F2** | **F3** |
| PH | -0.419 | 0.460 | 0.585 |
| TURBIDIY | 0.670 | 0.022 | 0.455 |
| TDS | 0.842 | -0.043 | 0.189 |
| TSS | 0.914 | -0.100 | 0.010 |
| EC | 0.881 | -0.011 | 0.363 |
| DO | -0.763 | 0.533 | 0.009 |
| ALKALINITY | 0.171 | 0.716 | -0.093 |
| BOD | 0.792 | -0.425 | -0.116 |
| TH | 0.812 | 0.258 | 0.201 |
| HCO3- | 0.829 | 0.243 | 0.044 |
| SO42- | 0.794 | -0.045 | -0.304 |
| NO3- | 0.799 | -0.047 | -0.150 |
| PO43- | 0.421 | 0.746 | -0.363 |
| CL- | 0.919 | 0.086 | 0.005 |
| CA2+ | 0.781 | 0.388 | 0.238 |
| MG2+ | 0.600 | -0.011 | -0.445 |
| NA+ | 0.866 | 0.017 | -0.326 |
| K+ | 0.381 | 0.542 | -0.291 |
| TOTAL COLI (TC) | 0.830 | 0.262 | 0.107 |
| FEACAL COLI (FC) | 0.930 | -0.042 | 0.220 |
| FE | 0.826 | -0.408 | 0.034 |
| CR | 0.926 | -0.168 | 0.032 |
| EIGEN VALUE | 12.781 | 2.603 | 1.536 |
| VARIABILITY % | 58.096 | 11.831 | 6.980 |
| CUMMULATIVE % | 58.096 | 69.927 | 76.906 |

In pre-monsoon data set (**from Table 6**), the factor loadings are classified as “Strong”, “Moderate”, “Weak” and “Poor” on the basis of their absolute loading values > 0.70, 0.70 – 0.50, 0.50 – 30 and < 0.30 respectively (Lieu eta al, 2003, Wang et al 2017). 58.096 % of variances are explained by PC1, 11.831 % by PC2 and 6.980 % by PC3, respectively. Three factors that are indicated below explained 76.906 % of total variance.

**1.** **Factor 1:**

**a)** **Strong Loadings -** TDS, TSS, EC, BOD, TH, $HCO^{3-}$, $SO_4^{2-}$, $NO_3^-$, $Cl^-$, $Ca^{2+}$, $Na^+$, TC, FC, Fe and Cr.

**b)** **Moderate Loadings –** Turbidity and $Mg^{2+}$

**c)** **Weak Loadings** - Alkalinity, $PO_4^{3-}$, and $K^{+.}$

**d)** **Poor loadings** - Nil

**2.** **Factor 2:**

**a)** **Strong Loadings –** Alkalinity and Phosphate ion.

**b)** **Moderate Loadings –** DO, Calcium and potassium ion.

**c)** **Weak Loadings** – pH

**d)** **Poor Loadings** – Turbidity, TDS, TSS, EC, BOD, TH, Bicarbonate ion, Sulphate ion, Nitrate ion, Phosphate ion, Chloride ion, Magnesium ion, Sodium ion, TC, FC, Fe and Cr.

**3.** **Factor 3:**

**a)** **Strong Loadings –** Nil

**b)** **Moderate Loadings –** pH

**c)** **Weak Loadings** – Turbidity and EC

**d)** **Poor Loadings** – TDS, TSS, DO, Alkalinity, BOD, TH, $HCO_3^-$, $SO_4^{2-}$, $NO_3^-$, $PO_4^{3-}$, $Cl^-$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$, TC, FC, Fe and Cr.

In case of post-monsoon data sets, three factors that are indicated below explained 74.946 % of total variance. 52.540 % of variances are explained by PC1, 17.237 % by PC2 and 9.752 % by PC3, respectively. Results of factor analysis including factor loading matrix, Eigen values and total cumulative variance values are given in (**Table 7**).

**Table 7. Calculation of factor loadings and Eigen vectors for post-monsoon season**

| FACTOR LOADINGS/COMPONENT LOADINGS | | | |
|---|---|---|---|
| **VARIABLE/PARAMETERS** | **F1** | **F2** | **F3** |
| PH | -0.519 | 0.621 | -0.504 |
| TURBIDIY | 0.894 | -0.308 | -0.098 |
| TDS | 0.768 | 0.089 | -0.321 |
| TSS | 0.844 | -0.128 | -0.259 |
| EC | 0.808 | 0.069 | -0.315 |
| DO | -0.779 | 0.530 | -0.010 |
| ALKALINITY | -0.192 | -0.304 | 0.847 |
| BOD | 0.659 | -0.598 | -0.125 |
| TH | 0.890 | 0.103 | 0.087 |
| HCO3- | 0.660 | 0.467 | 0.252 |
| SO42- | 0.900 | 0.050 | 0.243 |
| NO3- | 0.730 | 0.572 | 0.250 |
| PO43- | 0.397 | 0.811 | -0.175 |
| CL- | 0.897 | 0.233 | 0.249 |
| CA2+ | 0.746 | 0.373 | 0.301 |
| MG2+ | 0.634 | -0.006 | 0.417 |
| NA+ | 0.815 | 0.355 | 0.278 |
| K+ | 0.353 | 0.652 | -0.189 |
| TOTAL COLI | 0.716 | -0.395 | -0.116 |
| FEACAL COLI | 0.770 | -0.567 | -0.221 |
| FE | 0.702 | -0.318 | -0.218 |
| CR | 0.788 | 0.112 | -0.326 |
| EIGEN VALUE | 11.559 | 3.792 | 2.145 |
| VARIABILITY % | 52.540 | 17.237 | 9.752 |
| CUMMULATIVE % | 52.540 | 69.778 | 79.530 |

| EIGEN VECTORS/PRINCIPAL COMPONENT ANALYSIS | | | |
|---|---|---|---|
| **VARIABLE/PARAMETERS** | **F1** | **F2** | **F3** |
| PH | -0.152 | 0.319 | -0.344 |
| TURBIDIY | 0.263 | -0.158 | -0.067 |
| TDS | 0.226 | 0.046 | -0.220 |
| TSS | 0.248 | -0.066 | -0.177 |
| EC | 0.237 | 0.036 | -0.215 |
| DO | -0.229 | 0.272 | -0.007 |
| ALKALINITY | -0.057 | -0.156 | 0.578 |
| BOD | 0.193 | -0.307 | -0.085 |
| TH | 0.261 | 0.053 | 0.059 |
| HCO3- | 0.194 | 0.240 | 0.172 |
| SO42- | 0.264 | 0.026 | 0.166 |
| NO3- | 0.214 | 0.294 | 0.171 |
| PO43- | 0.117 | 0.417 | -0.120 |
| CL- | 0.263 | 0.120 | 0.170 |
| CA2+ | 0.219 | 0.192 | 0.205 |
| MG2+ | 0.186 | -0.003 | 0.285 |
| NA+ | 0.239 | 0.182 | 0.190 |
| K+ | 0.104 | 0.335 | -0.129 |
| TOTAL COLI | 0.210 | -0.203 | -0.079 |
| FEACAL COLI | 0.226 | -0.291 | -0.151 |
| FE | 0.206 | -0.164 | -0.149 |
| CR | 0.231 | 0.058 | -0.223 |
| EIGEN VALUE | 11.559 | 3.792 | 2.145 |
| VARIABILITY % | 52.540 | 17.237 | 9.752 |
| CUMMULATIVE % | 52.540 | 69.778 | 79.530 |

1) **Factor 1:**

a) **Strong Loadings –** Turbidity, TDS, TSS, EC, TH, Sulphate, Nitrate, Chloride, Calcium, Sodium, TC, FC, Fe and Cr.

b) **Moderate Loadings –** BOD and Magnesium.

c) **Weak Loadings** – Phosphate and Potassium.

d) **Poor loadings** – PH, DO and Alkalinity.

2) **Factor 2:**

a) **Strong Loadings –** Nil

b) **Moderate Loadings –** PH, DO, Nitrate and Potassium.

c) **Weak Loadings** – Bicarbonate, calcium and Sodium.

d) **Poor Loadings** – Turbidity, TDS, TSS, EC, Alkalinity, BOD, TH, Sulphate, Chloride, Magnesium, TC, FC, Fe and Cr.

3) **Factor 3:**

a) **Strong Loadings –** Alkalinity

b) **Moderate Loadings –** Nil

c) **Weak Loadings** –Calcium and Magnesium

d) **Poor Loadings** – PH, Turbidity, TDS, TSS, EC, DO, BOD, TH, Bicarbonate, Nitrate, Sulphate, Phosphate, Chloride, Potassium, TC, FC, Fe and Cr.

## VI. Conclusion

The surface water quality of Baitarani River has been assessed for its irrigational and domestic suitability purposes. All the PH values of the water samples are greater than 7 indicating slight alkaline water. The results of PH are also in good concordance with the maximum desirable limit of WHO (2008) and BIS (2012). EC values of all the water samples are below 750, complying beautifully with both Richards's value and FAO regulation and indicating good quality of irrigation water. According to Richard's classification, all the samples number 1 to 13 classified as "excellent" for irrigation (Sundaray et al 2009). US Salinity Laboratory (USSL) diagrams were used to evaluate the suitability of water for irrigation use for both the seasons. Only 1 sample (7.69 %) out of 13 samples of pre-monsoon season and 9 samples (69.23 %) out of 13 samples fall in the category of C2S1, indicating medium salinity/low sodium type water. Rest 12 samples (92.30 %) of pre-monsoon season and 4 samples (30.76 %) of post-monsoon season fall in the category in low salinity/low sodium types, indicating the water suitable for irrigation uses (Singh et al 2008; Harish et al 2016).

According to Wilcox 1995 classification, depending upon the sodium percentage in case of pre-monsoon and post-moon are within the permissible limits and all sampling locations are fit for irrigation purposes and also for agricultural activities. RSC values of all the samples are less than 1.25 meq/L, indicating the water samples are safe for irrigation purposes. Sometimes, the RSC values of water samples are negative, which indicate that the calcium and magnesium have not been precipitated out (Tiwari and Manzoor 1988). RSBC values ranges from -0.16 to 0.29 with a mean of 0.01 meq/L in the pre-monsoon season and -0.09 to 0.34 with a mean of 0.12 in post-monsoon season. The values are below the satisfactory value in both the seasons and can be used safely for irrigational purposes. Since higher concentration of magnesium ion present in water adversely affect the soil quality and crop yield, magnesium hazard (MH) was also evaluated for all the water samples. All the values of this study of pre monsoon and post-monsoon season are below 50 % and hence suitable for irrigation activities. Kelly's index indicates relative sodium quantity against calcium and magnesium and helps us to determine the suitability of the water for agricultural purposes and irrigation too. All the values are less than 1 and all sampling locations are suitable for irrigation and agricultural purposes and can be used for cultivation, land preparation in case of both pre and post-monsoon season. According to PI analysis, post monsoon water is better than pre monsoon water, possibly because of the addition of large amount of fresh rain water. But in this study, all the seasons are moderate for all sampling stations. Potential Salinity (PS) of the water samples varied from 0.09 to 0.30 in the pre-monsoon season and from 0.07 to 0.26 in post-monsoon season. All the values are considerably fair low. It is very must significant in the estuarine region because of the high salt content from sea water. In this case, all are within the prescribed limits.

To know the hydro geochemical characteristics of the study area and water, the analytical values were plotted on piper diagram (Piper 1944). All the samples of this study of both the seasons fall in the category of calcium-magnesium-bicarbonate representing a dominance of calcium, magnesium and carbonate ions in the water. The sources of this type of waters may be a typical shallow fresh water stations with rooted aquatic vegetation along the banks. Durov piper diagram for pre-monsoon and post-monsoon are being drawn for clear explanation of all the sampling locations and it's a typical method which will classify the law behind the trilinear piper diagram and also exhibit same results as that of piper diagram results. Hence, all the sampling locations are safe and suitable for irrigation and cultivation. The box-whisker plots do not vary significantly along the sampling stations. Some parameters fairly vary and the concentration is greater in pre-monsoon than post-monsoon because of heavy water of monsoon and flow of water during rainy season homogenize the water of the river.

The WQI values ranges from poor to excellent in pre-monsoon season and very poor to excellent in case of post-monsoon season. Quantitatively, all the stations exhibits good behavior in terms of WQI and it is due to the large pollutants is being diluted and washed away with heavy rain water in case of post-monsoon season. Hence, we can say post-monsoon is slightly better than pre-monsoon. Pearson's correlation analysis is an important statistical tool to exhibit the degree of dependency of one variable to the others (Belkhiri et al. 2011). In Pre-monsoon and Post-monsoon season (**Table 4, 5**), the values with red color were found to exist positively correlated or strongly correlated, values with green color signifies moderately correlated and ultimately, the values with blue color depicts weakly correlated. This signifies that the parameters change with direct proportionality. Some parameters were found to be in fair negative correlation signifying that these parameters change with inverse proportionality. The first three principal components (PCs)/ Factor loading analysis were considered for both the seasons to explain 76.906 % of the total variance of pre-monsoon and 74.906 % of the post-monsoon season. Scree plots of two different seasons have also been plotted and a conclusion may be drawn that factor 1 of pre-monsoon season dominantly contains TDS, TSS, EC, BOD, TH, $HCO^{3-}$, $SO_4^{2-}$, $NO_3^-$, $Cl^-$, $Ca^{2+}$, $Na^+$, TC, FC, Fe and Cr and PC1 of post-monsoon contains turbidity, TDS, TSS, EC, TH, Sulphate, Nitrate and Chloride as dominant variables. In both the seasons, the variables are purely hydro chemical and are supposed to originate from the geological process, indicating geo-genic sources. In factor 2 for both the seasons includes DO, nitrate and potassium are dominant factors which are generally contributed by fertilizers (both agricultural and industrial), indicating anthropogenic influences (Helena et al. 2000).

Overall, the River is good with some exception at places of municipal proximity and places of poor mobility. A few indices that determine the agricultural suitability do not permit the water to be used in irrigation. The water should be used in industry after proper treatment. The water which may be used for drinking and agricultural purposes may not be used in industry. Thus it can be concluded that overall quality of water with respect to drinking standards is better during the post-monsoon season in comparison with pre-monsoon The river needs protection and precautionary management plans.

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