

**Development of a Water Quality Index (WQI) and Application of
Multivariate Statistical Methods to Assess the Water Quality of
Lower Hooghly River, India : A Case Study**

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This is to certify that the thesis entitled “**Development of a Water Quality Index (WQI) and Application of Multivariate Statistical Methods to Assess the Water Quality of Lower Hooghly River, India : A Case Study**” is a bonafide work carried out by SAUMYADEEP BARUA under our supervision and guidance for partial fulfilment of the requirement of Master of Engineering (water Resources and Hydraulic Engineering) in School of Water Resources Engineering during the academic session 2021-24.

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ABSTRACT

Water Quality Index (WQI) is a valuable tool and gives single numeric expression to evaluate water quality and statistical analysis states the relationship between different parameters of water. To understand the changes in Physio-Chemical characteristics as per tidal variation were collected both in high tide and low tide from lower Hooghly River. After analysis it has been understood that due to high Salinity, TDS and EC water is not fit for uses in household and agricultural purposes and required proper treatment before using. In this study Hooghly River water quality studied thoroughly taken 10 (ten) sampling points in high tide and low tide starting from Geonkhali to Haldia dock under Purba Medinipur district at four (04) different season to assess the WQI. The main objective of this study is to know the Water Quality using WQI models and analysis of major cations and anions to understand there contribution in TDS and uses of river water in Agricultural, industrial and household purposes. From the value of Sodium absorption ratio (SAR), Sodium percentage (Na %), Kelly ratio (KR), Permeability Index (PI) value, Magnesium absorption ratio (MAR), and Potential salinity (PS) it can be stated that water is not fit for agricultural use. The value of Langelier Saturation Index (LSI) values indicates that unsuitable due to scale formation problems and Ryznar Stability Index (RSI) indicates that water is highly corrosive. Gibbs's diagram indicated that carbonate and silicate weathering significantly influence the lower Hooghly River ion chemistry and Piper trilinear diagrams indicated that Ca^{2+} and Mg^{2+} exceeded the Na^{+} and K^{+} . The value of WQI analysis comes in the range of 400~ 2500 and it depicts that the lower Hooghly River is unsuitable for drinking purposes.

KeyWords: Water quality index (WQI), Water quality parameters, ion chemistry, Hooghly River.

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Chapter 1

Introduction

1.1. Background of the study

Water is important and essential to life. Water is life because plants and animals cannot live without water. Water is needed to ensure food security, feed livestock, take up industrial production and to conserve the biodiversity and environment. Although, India is not a water poor country, due to growing human population, severe neglect and over-exploitation of this resource, water is becoming a scarce commodity. While this is a growing concern all over the world, India is most vulnerable because of the growing demand and in-disciplined lifestyle. The available water is generally used for agriculture, industrial production and domestic purposes. Water is also needed for fishery, hydro-power generation, transportation and maintaining biodiversity and ecological balance. The proportion of water used for agriculture and industries varies from country to country depending on the lifestyle, extent of industrial development and water use efficiency. The amount of water contained on earth is finite with about 333 million cubic miles of water, of which only 2.4% is fresh and 97.5% saline; its occurrence is controlled by the hydrologic cycle. 70% of the earth surface is covered with water, which amounts to 1400 million cubic kilometers ($M\ km^3$). However, 97.5% of this water being sea water, it is salty. Freshwater availability is only $35\ m\ km^3$. Out of the total fresh water, 68.7% is frozen in ice caps, 30% is stored underground and only 0.3% water is available on the surface of the earth. Out of the surface water, 87% is stored in lakes, 11% in swamp and 2% in rivers. As all the sweet water is not extractable, only 1% of the total water can be used by human beings. Central Pollution Control Board (CPCB) in 2015, identified 302 stretches along 275 rivers in the country that are polluted in 28 States and 6 Union Territories (UTs), considering the biochemical oxygen demand (BOD) values – a critical parameter of water quality. In 2018, the number of such stretches has now been found to be 351 (BOD level more than 3 mg/l), 117 of them are in the States of Assam, Gujarat and Maharashtra. Wastewater needs to be treated properly before it is discharged into the river systems. Government should strictly enforce the 'Polluter Pays Principle'. The fines need to be so high that industries would find it economically cheaper to install waste water treatment plant. To evaluate water quality data a range of tools have been developed and the Water Quality Index (WQI) model is one such tool. WQI models are based on an aggregation functions which allow analysis of large temporally and spatially-varying water quality datasets to produce a single value, i.e. the water quality index, that indicates the quality of the waterbody. Water quality can be assessed by continuously measuring and monitoring physical, chemical, and biological parameters, accumulating a large amount of data. Horton (1965) first described WQI for water quality assessment by considering multiple variables and summarizes these data in a single numeric expression and finally concluding into a single value (Jahin et al. 2020). The final value obtained helps determine the quality and suitability of water, making it a valuable tool for evaluating water quality. A WQI typically comprises four processes or components (Chidiac et al. 2023). First, the water quality parameters of interest are selected. Second, the water quality data are read and for each water quality parameter the concentrations are converted to a single-value dimensionless sub-index. Third, the weighting factor for each water quality parameter is determined and fourth, a final single value water quality index is calculated by an aggregation function using the sub-indices and weighting factors for all water quality parameters. Thus, water quality is significant in estimating

water suitability for various purposes. Therefore, to understand the changes in physio-chemical parameters with tidal variation both in high tide and low tide and to determine the WQI so many studies have been undertaken both in ground water and river water. Indices generally used to determine suitability of water in agricultural are SAR, Na%, PI, MAR, and KR (He et al.). The LSI and RSI are widely used indexes for industrial use as they define the scale forming and corrosive properties of source water (Shil et al.).

In this growing concern of water scarcity if Hooghly river water can be used for the people of east Medinipur and also for agricultural and industrial use. Therefore, a stretch of river Hooghly has been considered from the mixing point of Rupnarayan river in to Hooghly river upto Haldia Dock where so many industry and agricultural land dependent upon this river. Now, to know the water quality an assessment of WQI index considering parameters like TDS, Salinity, Cl, Mg, SO₄, EC etc. has been considered to determine the WQI of river. After analysis of WQI another study has also been made upon suitability of river water for agricultural and industrial use by determining SAR, %Na, KR, LSI, RSI etc. and it has been observed that river water is not suitable for household, agricultural and industrial use and required proper treatment before using. However, this study will be helpful to design treatment plant and future use by household, industry, agriculture etc.

1.2. Description of the Study Area

Samples were collected from 10 different location starting near Geonkhali having Latitude : N 22 deg 12' 28" and Longitude : E 88 deg 10' 29" (S10) near upto Haldia Dock having Latitude : N 22 deg 1' 13.82" and Longitude : E 88 deg 3' 41.85" (S1) from upstream to downstream in high tide and low tide in Hooghly river. Total 20 Samples were collected from 10 different stations both in high tide and low tide in four different month starting from August, 2023 (during monsoon) followed by September, 2023 (Post monsoon) and January, 2024 (Winter) and March, 2024 (Pre monsoon).



Fig. 1.1 : Map of study area

1.3. Research Gap

There is a substantial study of literature on Water Quality Index (WQI) upon river water, ground water etc. Also few researchers have studied the validation of different model of WQI. However, there exist a research gap of restricting the parameters for determination of WQI. Researchers have discussed about tidal variation along with river flow and also the changes in physiochemical parameters but the consideration of river depth has not been mentioned in their study. Collection of data from different depth of river plays an important role in the study of WQI because change in physiochemical parameters with depth played an important role in determination of WQI. As the parameters change with tidal variation and also it varies with depth, therefore WQI is also highly dependable upto depth of water collection from river or estuaries during high tide and low tide. Therefore, in this study depth of water collection in Hooghly river at different tide along with seasonal variation has been considered, to see the changes in physiochemical parameters. Also this study consists of correlation between different parameters using Pearson's correlation matrix which will help to understand the relation between different parameters. Such knowledge would contribute to know the exact scenario of water quality of river and in future the development of effective water treatment methodology to reduce the concentration of different parameters for uses in household, agriculture etc. and also sustainable water treatment strategies, ultimately contributing to improved water quality and public health in such areas.

1.4 Research Objective

Set on the banks of the Haldi River, the industrial town of Haldia at Purba Medinipur is a major port for trade and industry. Along the bank of the river major Port of India which is Haldia Dock has been developed. Due to this dock huge industrialisation, township area, agricultural land have been grown from decade ago and it is expanding in a rapid manner. Considering the above fact and in the world

of water scarcity to check the water quality a stretch of Hooghly river has been considered starting from Geonkhali (confluence point of Rupnarayan river and Hooghly river) upto Haldia Dock (confluence point of Hooghly and Haldi river) to know the water quality by determining WQI as per BIS guideline.

Collection of data: Water samples were collected from 10 different location of Hooghly river during four season (monsoon, post monsoon, winter and pre monsoon) in high tide and low tide.

Preservation technology: After collection of raw water sample from river same were stored in conical flasks adding different chemicals.

Analysis of samples: Thereafter, samples were carried out upto laboratory and different type of test were performed lot know the water quality like Titration method, UV Spectrum method, Azitometric method etc.

Correlation matrix : After getting the test results correlation matrix has been determined to know how the different parameters are related in water quality indexing process.

Use in agricultural field: SAR, % Na, KI etc. has been determined to know the water quality is fit for agricultural use or not.

Industrial use: Ryznar Stability index and to detrain the fitness of water for industrial use.

Overall, this research mainly aims to determine the WQI of Hooghly river so that water can be used as different purposes. After determination of WQI it has been seen that water is unsuitable having high salinity, TDS refers that water is not fit for agricultural and industrial use. Therefore, to use the water at different purposes desalination plant has to be installed. This data will be helpful for designing proper treatment plant to use river water at different purposes.

1.5 Methodology Adopted for research

The overall research methodology is mainly divided into five components: Literature Review for Identification of goal and objective, Collection of the information of the present situation by primary survey and secondary survey, Data Presentation and Organisation of data analysis, Development of a method to assess the water quality vulnerability zones in the study area and lastly output and result in analysis for Identifying strategies for scientific and sustainable management of water resources. The area considered here firstly plotted with the help of Arc GIS model from upstream to downstream. Then WQI was determined using Weighted average WQI method and CCME method. After determination of WQI in four different season at high tide and low tide method statistical analysis was made plotting different physiochemical parameters like Gibb's plot, Piper's plot to identify the position of major cations and anions with different parameters and it will help to understand the water quality for agricultural and industrial use. Pearson's correlation matrix also been determined to know the relation between different parameters. However, the overall water quality is unsuitable to use by public, irrigation and industry. This is the main source of water in Haldia region and great concern should be given so that water quality not to reduce further and discharge of water from different industry should be treated before mixing into river.

1.6 Outline of the Thesis

River water facility, condition, pollution status, economical background of district, cause of water pollution etc. assessment done in this project and analysis of WQI has been performed. This research work consists of six (06) chapters. Chapter 2 contains literature review of different similar nature of national and international scenarios of WQI and change of salinity due to tidal variation. Chapter 3 presents the description of study area. Chapter 4 discuss about methodology adopted to determine different parameters as per IS guideline. Chapter 5 consist of results and discussion after statistical analysis of experimental data. Chapter 6 contains mainly conclusion after detail analysis and Chapter 7 contains limitation and future scope in this study.

Chapter 2

Literature Review

2. LITERATURE REVIEW

The term refers to an overview of the previously published works on a topic. The term can refer to a full scholarly paper or a section of a scholarly work such as a book, or an article. Either way, a literature review is supposed to provide the researcher/author and the audiences with a general image of the existing knowledge on the topic under question. To be precise, a literature review serves to situate the current study within the body of the relevant literature and to provide context for the reader. In such case, the review usually precedes the methodology and results sections of the work.

The literature review section of our thesis on Water Quality Index (WQI) of Hooghly river at Purba Medinipur District near Haldia Dock at Haldia, West Bengal and it's a vital part of our research. In this section, it is providing an overview of the existing knowledge, research gaps, and relevant studies related to our topic. WQI has been determined using Weighted average WQI and CCME water quality index and also statistical analysis been made. Considering this thesis paper mostly review has been made on WQI of different river waters, estuaries, ground water and also use of different software to analyze the WQI and statistical analysis.

2.1. Research Review of International and National scale on water quality index (WQI) and statistical analysis

Nisha Gaur et al. (2022) studied water quality index (WQI) and geochemical characteristics on surface water of Tawang river, Arunachal Pradesh at Eastern Himalayan region has been made. In this study, 31 locations at an altitude of 2347 mtrs to 4077 mtrs has been considered to analyze the physio-chemical parameters during winter season using WQI to understand the suitability of water for drinking and irrigation purposes. After analysing, it has been observed that more than 60% area of the river is congruous with drinking purposes. However, 40% of the area of river can be used for drinking after ensuring proper treatment to make it potable. From Hiller Piper plot and Gibb's diagram, it may be inferred that the water is also suitable for irrigation purpose.

M. Farhad Howladar et al. (2017) studied WQI and multi variable statistics to evaluate the water quality around Maddhapara Granite Mining Industrial Area, Dinajpur, Bangladesh at a latitude 25°33'15" N to 25°34'13"N longitude 89°3'30" E to 89°4'53" E was made. Maddhapara Granite mine area is 330 Km away from capital city. After analysing the physio-chemical parameter of 12 numbers of selected points, the Water Quality Index (WQI) was determined. After determining the value of WQI, it has been inferred that the water quality as per IS 10500 and WHO guidelines, water of 80% area is very good and can be used as potable water. In this study, authors have analysed the objective by Cluster Analysis (CA) after dividing the entire area into three (03) clusters viz. Cluster I, Cluster II and Cluster III respectively. Cluster Analysis is the unsupervised classification pattern and the same was plotted on map to depict the water quality. Additionally, Principal Component Analysis (PCA) was made to identify the pattern of recorded data and extrapolate the data to highlight the similarities and differences between them. In

the analysis of WQI, PCA is a significant tool to identify the aspects of pollutants on environmental system.

Tahera Akter *et al.* (2016) studied WQI for assessing the drinking water quality in rural Bangladesh was conducted at 24 upazilas and water from 960 households was collected to determine the physio-chemical parameters and arsenic test was undertaken on the site. Accordingly, it was found that water of most of the places is contaminated with arsenic beyond the permissible limit, especially when samples were collected from tubewells.

After analysis of the water samples by weighted arithmetic WQI method, it was observed that the value of WQI is significantly low indicating poor quality of water. Consequently, in a substantial number of places within the study area, the percentage of iron, arsenic content and salinity is considerably high. Besides, it was evident that especially children are consuming such water on daily basis. However, authors have not stated any variation of parameters as per seasonal changes. The parameters should be catered to in order to disburse awareness among the mass pertaining to health surveillance and establishment of water treatment plants can be proposed after making a detailed study.

Hend Samir Atta *et al.* (2022) studied assessment of WQI of drinking ground water purpose case study area surrounding Ismailia Canal, Egypt. The main purpose of the study is sustainability of ground water as this is the second important source of potable water. The study includes flow direction in ground water conducted in the year 2019. After calculating the WQI by weighted average method, authors stated that abundance of Iron, Manganese and Zinc in the ground water is due to geogenic aspects and not due to pollution sources. Authors have also stated that the ground water is rich with cations and anions which is a clear indication that it is significantly affected by excess irrigation water. Here WQI is compared with the standard of WHO (2008) & Egyptian Standard (2007) and it was found that more than 60% of water is good quality and can be used as drinking, domestic irrigation purposes etc. but the remaining 40% water is required to be treated prior to its usage for domestic purposes, irrigation etc. as Ismailia Canal is instrumental in groundwater recharge.

Mahareen Ahmed *et al.* (2021) analysed Water quality indices and machine learning techniques for rating Water pollution: a case study of Rawal dam, Pakistan located at Islamabad; data collected from 012 to 2018 and June to December 2019. Six (06) numbers of samples were collected from Rawal dam lake. The GIS based grab sampling was carried out with the help of IOT (Internet of Things), placing at inlet and outlet of dam. However, the author delineated that the test for more number of parameters should be conducted to obtain precise and accurate result of water quality. Using the machine learning technique, author Ahmed *et al.* would like to determine the class of water quality instead of Water quality index (WQI). In this study, the author has also used five (05) machine learning algorithms which are K- Nearest Neighbors, Logistic Regression, Naïve Bayes, Multilayer Preceptron, Decision Tree (DT) respectively. These five algorithms were selected as these are user friendly and give more accurate result and these are widely used. During the case study, author found that the WQI ranges from poor to very poor condition, therefore, author has suggested to use machine learning techniques to improve the result of water quality with the aid of more parameters like topography, hydrological parameters, lineament density, rainfall, land use etc. for all regions or area.

Nirdesh Kumar Ravi *et al.* (2023) Water samples were collected from eighteen (18) sites of Ghaghara River for three (03) seasons viz. Pre-monsoon, Monsoon and Post-

monsoon respectively to study the WQI as well as to assess the cations and anions vital for agriculture. One way Analysis of Variance (ANOVA) determines the significance of variation of physio-chemical parameters seasonally and spatial scales. Author also used the Pearson's Correlation Matrix method to get the idea regarding relation between different parameters. WQI has been determined to understand the quality of water for use as potable purpose. Gibb's diagram and Piper's plot were adopted to know the position of cations and anions. SAR (Sodium Absorption Ratio) Na%, KI, PI, PS, NH & RSBC have also been determined to comprehend the suitability of water for irrigation purpose. Author also requested not to discharge untreated effluents into rivers.

MD. Galaluddin et al. (2021) reviewed 110 published manuscripts out of which 21 WQI models have been globally used and same are assessed. Consequently, it has been found that WQI models are not able to deal with the eclipsing problem which are caused by inappropriate sub-indexing rules, parameter weightings that do not reflect the influence of parameters. Researchers have also used huge range of aggregation techniques as additive or multiplicative function has already been established and using these functions, uncertainty of WQI models have been found out. Here authors tried to compare different WQI models and proposed to include more parameters that are newly contributing in water quality in the modern study (like microbiological water quality etc.). Besides, authors also suggested to consider Cluster approach and not Pearson's Co-relation Matrix approach to yield better results and simultaneously suggested use of fuzzy interface systems, artificial neural network which are computer based techniques to minimize uncertainty resulting from final aggregation process.

Rajesh Prajapati et al. (2018) studied the determination of WQI of drinking water in Varanasi District, Uttar Pradesh, India to recognize the causes and sources of water deterioration. Sixteen (16) locations have been identified to determine the WQI. From the result of WQI obtained, it has been observed that more than 50% of water can be used as potable water and the remaining 50% water is required to be treated before using. Author has also indicated that in some villages, due to poor sanitation facilities, water is being contaminated and therefore awareness programme is necessary to be undertaken.

Arjun Ram et al. (2021) studied Geographic Information System (GIS) to monitor groundwater quality regularly. GIS technique is also being used for spatial evaluation of various groundwater quality parameters. Author in his study would like to calculate WQI of groundwater using GIS interpolation technique and statistical approach. Consequent upon evaluation, the WQI map has been prepared using ArcGIS and it has been seen that major portion of water is excellent and around 25% of water comes in the zone of poor as per weighted average WQI method. During this study and hydro-chemical analysis, it has detected that major portion of groundwater is alkaline in nature in the form of dissolved carbonates and predominantly in the form of bicarbonates. From spatial distribution, it may be inferred that concentration of heavy metals is not detected in noticeable form or within limit.

D. Patel et al. (2023) studied from 2018-2022 in Navsari district located at the Arabian sea coast on southern edge of Gujarat. Author used 23rd APHA method for

collection and testing of Water Quality parameters to assess groundwater quality at above mentioned region. After analysis, it has been observed that total hardness, TDS and accordingly Turbidity are much higher as compared to BIS permissible limit. However, pH, Turbidity, nitrate are within the permissible limit. Therefore, it can be concluded that water quality in most of the places is considerable poor and require treatment before using and these values have also been used to monitor annual fluctuations of concentration of nutrients in groundwater for future study which will be instrumental to comprehend the ecological characteristics of groundwater.

Sandra Chidiac *et al.* (2023) studied history of water quality written by different authors like Horton, Dinius, Brown *et al.* etc. considering different water quality parameters in their studies. The mostly used equation National Sanitation Foundation (NSFWQI) has some restrictions like inadequate value for faecal coliforms and pH. Therefore, WQI model should be such that overall effect of WQI can be identified. Later on, to consider more parameters, Principal Component Analysis (PCA) model was developed. Water Quality is also apt for irrigation purposes (WSI-IPs). Later on, CCME Water Quality Index has also been studied to compare and understand various threshold values, different factors etc. Water Quality also demonstrate relationship between cations and anions, thereby giving an overview regarding uses in irrigation sector, fisheries, wildlife propagation etc. Water Quality Index results showed that water quality deteriorated from U/S to D/S and water quality is poor in wet season due to contamination of surface run-off river water. Author stated that WQI gives a possibility to assess geographical changes in ecological environment and subsequently, protection of wetlands by management. WQI is independent of parameters. Therefore, many statistical analyses have been made viz. PCA, Pearson's Correlation, Cluster Analysis, etc. Lastly, scientific technologies like, GIS technique, Fuzzy Logic technology to assess the WQI which are sensor based water quality monitoring system.

Abhijit Mitra *et al.* (2014) studied Sundarban area of West Bengal on April, 2008 during pre-monsoon period. Author Abhijit *et al.* analysed the 16 parameters of river water to understand the physiochemical parameters in high tide and low tide at 12 (twelve) sampling stations in Hooghly estuary flowing through lower stretch of the gangetic delta. Sundarban is majorly famous for its rich biodiversity due to presence of mangrove species. After analysis it has been seen that concentrations of different nutrients like sulphate, chlorine, nitrate etc. are quite high. Also due to intrusion of sea water from Bay of Bengal, salinity is also high which is around 2100 mg/ltr. Therefore, EC & TDS are also high. Sometimes due to application of pesticides, fertilizers etc., potassium, nitrate concentration is high. Eventually, it was inferred that entire stretch of water is not fit for usage in household and agricultural purposes. It is also an erosion prone area due to effect of extinction coefficient and nutrient load.

Wan Ahmed Nor Fawzul Hakiimie Wrozali *et al.* (2022) made a study at river near to Sungai Pengkalam Datu, Kelantan to know the water quality mainly on salinity and ammoniacal nitrogen to establish location of desalinisation plant. During the study it has been observed that salinity is high during the dry season and low during wet season and low tide. The objective of this study is mainly to establish the relationship between water quality in tidal variation and desalinisation treatment plant. Based on the analysis, it can be stated that both salinity and ammoniacal nitrogen fluctuated due to seasonal variation and due to these variations, performance and quality of RO membrane will reduce. Therefore, Wan Ahmed *et al.* suggested that desalinisation plant should be equipped with an equalizing tank in order to regulate salinity and ammoniacal nitrogen. The author also determined the correlation using Pearson's Correlation matrix between water quality parameter and precipitation and observed that salinity is negatively related with precipitation. However, ammoniacal nitrogen is positively related with precipitation. Therefore, it is suggested to install a temporary reservoir prior to desalinisation treatment and also placement of intake point should be made correctly to maintain sustainability of treatment plant.

Agwapuye *et al.* (2020) studied variation of nutrient concentration, suspended particulate matter and physiochemical parameters like pH, TDS, salinity, turbidity, conductivity etc. The variation in nutrient is mainly attributed to tidal mixing, river discharge, sea water intrusion at Great Kwa river, Nigeria. Accordingly, samples were collected both in high tide and low tide during 2019 to assess the physiochemical parameters. Ammonia, Nitrate, Nitrite, Phosphorus, etc. mainly taken in the monsoon season and observed that ammonia concentration is high significantly due to sewage effluents and agricultural run-offs. Phosphate, Nitrite, salinity increases with tide i.e. during high tide their concentration is high due to sea water intrusion. Increased nitrate concentration is mainly attributed to bacterial decomposition and oxidation of organic matter in the river. Conductivity is also high during high tide majorly due to intrusion of seawater. However, seasonal variation in EC is mainly due to fresh water discharge and dilution from surface run-off due to rainfall. TDS and TSS are also high during high tide due to intrusion of sea water and fresh water respectively and it will help to understand the changes in various parameters due to tidal influence, sewage & industrial disposal, bacterial activities etc.

Angela Nascimento *et al.* (2021) studied changes in water quality parameters of Sado estuary, Portugal that varied in fortnight and semidiurnal tidal variation. Sado estuary is a meso-tidal estuary located in the west coast of Portugal and samples were collected from May 2018 to June 2019. Angeal *et al.* stated that area of estuary most affected by river outflow and spatio-temporal distributions of the parameters directly dependent on fluvial variation. Now, to assess the temporal and spatial variability in estuary of different water quality parameters. Angela *et al.* has performed PERMANOVA using PRIMER 6 + PERMANOVA software. As per the station location, inner and outermost regions of the estuary showed opposite behaviour in PCA in ST. All the parameters have been analysed during high tide and nape tide. As per fortnight tidal variability in nape tide and spring tide, high value

of temperature and suspended particulate matter (SPM) is obtained whereas low value of NO_x concentration is obtained under NT and it has great influence on the total estuary. During semidiurnal tidal variability in high tide and low tide, PERMANOVA analysis inferred that salinity and pH seemed to vary along with tidal cycle to higher value during high tide and lower value during ebb tide and SPM value is also low during high tide. However, change in NO_x value was difficult to identify through the small variation obtained in NT & ST that indicates a possible limitation of phytoplankton biomass by nitrogen concentration in estuary. Author Angela et al. after analysis stated that fortnight tidal cycle reflects the most significant role than semidiurnal cycle in the estuary. The results obtained showed smaller variation (decrease) in water quality status during low tide than high tide. In addition to that, the water of the estuary can be used as one of the sources of nutrients during meteorological drought condition. However, author wished to make further study of estuary to understand the tidal effect through water column.

Sayanti Kar et al. (2022) during 2014 selected 05 major outfalls in river to determine distance and direction wise changes of concentration of pollutants in waste water considering DO, BOD, heavy metals etc. to understand the characteristics of river, the quality of river water was assessed in three seasons [Pre-monsoon, Monsoon & Post-monsoon]. During analysis, it has been observed that Sodium (Na) and TDS concentration is high in river at Haridwar region during rainy season and make the water unfit for drinking purpose. During rainy season, high amount of bacterial pollution was evident and high concentration of nitrate at the end of winter and summer season at Varanasi was noticed. To understand the discharge by Hydrographic survey of river, an instrument called ADCP (Acoustic Doppler Current Profiler) was used. This instrument measure the velocity at different points both horizontally and vertically during high and low tides. After analysis of different outfall, high concentration of dissolved solids mainly due to accumulation of animal wastes and chemical fertilizer with waste water discharge and agricultural runoff has been observed. DO level at few sampling site is low and reason for oxygen consumption is mainly microbial degradation. The value of EC at all locations is well within permissible limit and therefore, good for marine culture, irrigation, industry etc. However, river rich with the concentration of heavy metals may cause bioaccumulation and thereby severely influence aquatic life. However, no spatial and seasonal impact is found on pH to establish relationship between different parameters. Regression equation was generated and it was detected that total coliform and faecal coliform had strong relation. A model-based validation of parameters using Plug-Flow Model analysis done by using strip-wise depth average discharge at different sampling points (i.e. discharge points) considering tidal condition. GIS based mapping has been used to depict the scenario showcasing distance from outfalls of different parameters and it reflected a prominent influence of waste water along the banks of river from outfalls. Strong relationship between heavy metals and faecal coliform and total coliform has also been established. Therefore, author has pleaded to restrict the discharge from different industries, household etc. to maintain the river water quality.

Nisheeth C. Desai et al. (2020) selected four estuaries from south Gujarat region to understand the impact of industrial pollution in estuary. After analysis and establishment of correlation matrix using Pearson's Correlation Matrix, it has been observed that EC is negatively correlated with nutrients both in low tide and high tide. An increase in the level of turbidity will be detrimental to aquatic life and estuarine environment. DIO value is within permissible limit and changes in DO value during high tide and low tide occur due to aerobic and anaerobic phenomena in river water and DO is positively correlated with salinity. Result of BOD concentration indicates that water is contaminated by organic and nutrient substances carried in estuaries especially during low tide when estuarine water intrudes into sea water. An increasing level of total Nitrogen (TN) [including NO₃, NO₂ etc.] shows change in eutrophication in estuary, therefore, impact aquatic life and microorganisms. Concentration of phosphate and silicate is also high due to use of fertilizers, pesticides etc. in the agricultural field. PCA & correlation matrix showed a small amount of freshwater input during non-monsoon season and high nutrient input from sewage and industrial waste.

Md. Galaluddin et al. (2022) presented an improved water quality index (WQI) model to assess the coastal water quality at Cork Harbour, Ireland. 36 stations were located to monitor water quality during October 2019 to September 2020. During this material period, physio-chemical parameters were studied by depth average and seasonal average method. In this study, author et al. assessed the water quality using four machine learning algorithms such as (a) Decision tree (b) Random forest (c) Boruta (d) XG Boost. XG-Boost is one of the most famous techniques used as gradient boosting framework. WQI was also assessed using CCME WQI method. Author also identified a deviation in WQI using XG-Boost model and it has been found that maximum standard deviation was evident in few parameters like chlorophyll, Dissolved Oxygen, total organic nitrogen etc. After comparing the result with the standard value, it was noticed that XG-Boost does not give the result with complete accuracy of water quality. A novel technique which is Sub-indexing (SI) method is one of the major methods to uncertainty in WQI models. After analysing water quality using SI method, it can be elucidated that there is a noticeable difference between different WQI model outcomes for similar water quality inputs and this is due to different aggregation functions and use of weighted vs unweighted aggregation functions. However, these type of model like XG-Boost, SI which are popularly used to assess different WQI models would require further investigation formulating more database to get more accuracy in WQI modelling.

Ghassan et al. (2020) evaluated water quality of East Hammar marsh using Principal Component Analysis (PCA) and WQI using CCME method establishing three different stations from January 2018 to December 2018 to analyse the physio-chemical parameters. One station was located before the salt tide and another after the salt tide and it has been seen that WQI is poor during the entire study. After PCA analysis it has been found that temperature was highly correlated with salinity, calcium ions, sodium bicarbonate and negatively correlated with BOD, TP, TN. This model helps researchers to determine and compare the parameters with standard limits and it demonstrates degradation in water quality due to intrusion of water

from the Arabian sea which resulted in increase in concentration of salts and biological oxygen demand and subsequent decrease in Dissolved oxygen due to increased concentration of organic waste and high temperature. Summer season is the most influencing month deteriorating the WQI and sodium, salinity, chlorine, magnesium, total hardness are the most instrumental parameters in determining WQI in this study. Therefore, it can be stated that the river water is unfit for drinking as well as agricultural use as it contains higher percentage of salinity.

Duong Van Ni *et al.* (2022) studied the surface water quality of Hau river in HauGanga province, Vietnam and data was collected from 06 locations during high tide and low tide. One way analysis of variance i.e. ANOVA, Cluster Analysis (CA) and Discriminant Analysis (DA) were applied to determine the influence of tides and seasonal variation on water quality. After analysis it has been found that river water is organically polluted and has a high risk of eutrophication. There is no noticeable variation in value of different parameters have been shown between high tide and low tide, However, value of physio-chemical parameters is high in low tide than high tide. Entire area (12 points) was divided into three clusters for CA (CA I, CA II, CA III) and after analysis it has been found that water quality is mainly influenced and classified by BOD, COD, TSS, phosphate and FC. Therefore the study shows that water quality is not unfit for drinking purposes and proper treatment is required before usage in different purposes.

Ismail Mondal *et al.* (2016) determined the physio-chemical parameters to check the water quality and pollution scenario of Ichamati river and to comprehend that, author selected nine points from starting to end point of river. The upper stretch of the river depends mainly on rain water from rainy season whereas the lower stretch of the river is mostly influenced by tidal fluctuation. This river is now a major contributor and breeding ground of weed species therefore humongous growth of water hyacinths is noticeable. This excess bloom of hyacinths will contribute to reduced Dissolved Oxygen concentrations, thereby significantly impacting survival of aquatic flora and fauna and eventually decreasing the riverine biodiversity. Temperature of Ichamati river is also pivotal due to metabolic rates and generation of photosynthesis, conductivity, salinity, water density etc. Salinity of river increases from U/S to D/S and mainly in the D/S, it is considerably higher due to intrusion of sea water from Bay of Bengal, therefore, EC is also high. In this study, knowledge regarding distribution of chlorophyll is disseminated and maximum concentration is observed during the pre-monsoon time. Therefore, author has suggested further study regarding difference in R.L bed in upper and lower stretch of river with tidal flow as even in low tide, the river is unable to clean flood water, thus long-lasting inundation prevails in the area.

Alichabuk *et al.* (2020) assessed the WQI using weighted average arithmetic method along the Tigris river in Iraq, locating 14 stations on the river thereby analysing physio-chemical parameters. Arc GIS mapping used to plot the water quality in this study and using Arc GIS, WQI of the entire river was calculated. The Inverse Distance weighted (IDW) method was used to generate interpolation map for

each parameter during dry and wet season for river. After analysing the data, a prediction map was drawn to understand the river quality and situation from U/S to D/S. After the assessment, it was observed that the river water is not fit for domestic use, irrigation, drinking and industrial purpose etc. WQI value increases in D/S due to increase in pollutants due to surface run-off, rainfall etc. From the GIS map and depiction in the distribution map it has been seen that water quality is worst during wet season from U/S to D/S and gets better during wet season. Therefore, for further use of the river water, proper treatment of the water is inevitable.

HareKrishna Jana *et al.* (2020) studied some physio-chemical parameters of Haldia Industrial site and Green belt canal in the year 2020. This study was made at seven (07) different locations around Haldia at Hooghly river. After analysis it has been found that the pH is within permissible limit, TDS is quite high due to unused high coke into the water. TSS concentration is also considerably more than desirable limit and this is due to organic and inorganic matter generating from industries. Green belt canal has higher concentration of DO level therefore considered unhealthy for aquatic life. As BOD level is increasing, therefore it is an indicator of increasing pollution and hazard for aquatic flora and fauna. Coliform bacteria have also been studied and it can be inferred that average coliform load is not suitable for aquatic life. Thus, water quality is very poor and requires proper monitoring and treatment before use.

Yi Liu *et al.* (2017) studied the dynamics of ground water physio-chemical parameters in coastal groundwater mining zone (CGMZ) of Tolo Harbour, Hong Kong. After sampling at 15 different sites, the data of physio-chemical parameters were depicted making spatial distribution. According to groundwater salinity dynamics, it can be stated that source of salinity is the infiltrated seawater from beach. DO is the vital microorganism activity and has significant impact on redox reactions in CGMZ. pH value shows that there is no relation between pH and tidal fluctuation and this is due to no external high pH but seawater entering the aquifer to increase groundwater pH. Author has tried to find out the relationship between temperature and salinity and it also depicts that salinity highly changes with temperature especially in seawater rather than groundwater. After detailed study of physio-chemical parameters, it can be inferred that intermixing process of seawater and groundwater is the main contributor of salinity dynamics. However, salinity dynamics with tidal cycle should be evaluated to get more accurate result. In addition to that, correlation matrix may be determined to get knowledge regarding relation between different parameters.

Goabaone J. Ramatlapeng *et al.* (2021) conducted a study in Wouri estuary located at Douala, Cameroon along the Atlantic coast and Wouri consisting of three major riverine estuaries.

Now, it may be considered that changes in salinity during mixing in an estuary depends upon the following factors: (i) tidal forces (ii) initial salinity of the end member water being mixed (i.e. seawater and freshwater) (iii) relative volume of water from different sources. Here author has made a comparison between

normalized water level and mixing of seawater intrusion. From the study it has been observed that near normalized tidal peak, increased salinity varies between sequential tides. However, the hydrological mixing behaviour (where river is mixing with estuary) shows a temporal change in salinity due to change in source of water or mixing of waters and sometimes temporal riverine and tidal force also causes of changing hydrologic regime. After studying biogeochemical process, author would like to establish tide-salinity pattern for different tidal cycle (ebb tide, high tide, neap tide etc.) with seasonal variation along the seawater-freshwater mixing zone. Author has plotted salinity variation during tidal flooding and tidal ebbing by Hysteresis curve. Consideration of conductivity, temperature and depth to construct tidal salinity pattern will be helpful to determine spatial and temporal variability of estuarine hydrologic mixing.

Somdeep Ghosh *et al.* (2021) studied river Hooghly during monsoon, winter and summer seasons locating 18 different stations to study the physio-chemical parameters and abundance of few potentially toxic elements (PTEs). To understand this, WQI has been determined and also geospatial analysis was made by Inverse Distance Weighted (IDW) process and using Arc GIS model. The river exhibited comparatively high salinity and TDS in monsoon and winter due to high evaporation rate, water temperature and lower precipitation. During study it was observed that sewage from adjoining cities, industrial discharge, agricultural run-off which contains dissolved organic carbon admixture with PTEs. The value of DO also refers that river water can be used for drinking, irrigation etc. only after proper treatment. Here, author has also made statistical analysis to determine correlation between different parameters using Pearson's Correlation matrix and establish PCA between PTEs using SPSS software. Positive correlation between PTEs indicate that same origin point for their source, however, higher concentration of PTEs may affect anthropogenic activities, water temperature etc. ANOVA used to establish statistical relation between toxic elements. WQI has also been determined for drinking purposes as per BIS & WHO guidelines. WQI is very severe in Hooghly river and found not suitable for drinking purposes mainly due to natural erosion, anthropogenic activities etc. From the value of PTEs, it can be stated that U/S water is non-carcinogenic but due to contamination mainly in D/S, it may turn out carcinogenic. In years to come it may give rise to cardiovascular disorders. Therefore, protecting the river is the need of the hour as Hooghly river supports life along its banks and is used by public regularly for different purposes. Though PTEs like Cd, CO, Zn etc. allow temporal increment in concentration but awareness program should be conducted to change the WQI for usage in these times of water crisis.

S Revina Istiarto *et al.* (2022) studied rate of change in pH and salinity in Anjir Serapat lowland irrigation area. We know that in tidal irrigation, there is a strong relationship between elevation of ground level and height of tide. Rate of change of pH in correspondence to change of water level has been determined. However, there is no significant change in pH value due to change in water level but it changes due to anthropogenic eutrophication. In water environment, pH is inversely proportional to salinity i.e. with increased salinity, pH reduces and vice-versa. Therefore, it has

been suggested to uplift water quality in high tide such that water quality can meet irrigation requirement. However, determination of SAR, Na% etc. will help obtain accurate result towards use of river water for irrigation purposes.

Review of Thesis Papers:

After detailed study of different literature on Water Quality Index (WQI) upon river water, ground water, estuary and also intrusion of sea water. Also few researchers have studied the validation of different model of WQI. However, there exist a research gap of restricting the parameters for determination of WQI. Researchers have discussed about tidal variation along with river flow and also the changes in physiochemical parameters but the consideration of river depth has not been mentioned in their study. Collection of data from different depth of river plays an important role in the study of WQI because change in physiochemical parameters with depth played an important role in determination of WQI. As the parameters change with tidal variation and also it varies with depth, therefore WQI is also highly dependable upto depth of water collection from river or estuaries during high tide and low tide. Therefore, in this study depth of water collection in Hooghly river at different tide along with seasonal variation has been considered, to see the changes in physiochemical parameters. Also this study consists of correlation between different parameters using Pearson's correlation matrix which will help to understand the relation between different parameters. Such knowledge would contribute to know the exact scenario of water quality of river and in future the development of effective water treatment methodology to reduce the concentration of different parameters for uses in household, agriculture etc. and also sustainable water treatment strategies, ultimately contributing to improved water quality and public health in such areas.

CHAPTER – 3

DESCRIPTION OF THE STUDY AREA

Water quality parameters analysis are important process for regular monitoring and to understand the Environmental conditions. Salinity is a common phenomenon in rivers that generally deal directly with the sea through estuaries. Water circulation in the estuary area is strongly influenced by the flow of fresh water sourced from the River body and saltwater from the sea. The process of seawater entering estuary is known as seawater Intrusion. This interaction will affect the distribution of salinity. At high tide, seawater will intrude on the river at a Considerable distance. Seawater intrusion in rivers can cause rivers to have high salinity. The effect of Salinity in the waters can cause a decrease in oxygen concentrations, including those found on river bodies that have been influenced by estuary waters. The stretch of Hooghly river has been considered is very close to sagar island. I.e. very near to Bay of Bengal. Therefore, river water is highly influenced by sea water and followed by increase of salinity, TDS, EC and Na. Despite of that huge amount of starting population, Industry, agriculture are vastly dependent on the river. Therefore, it is very much essential to know the water quality which will cadre the future scarcity of water to some extent locally. At Geonkhali, Rupnarayan river connect with Hoogly river & at Haldia Haldi river is connected with the Hoogly river. Hence there is a need for studying the quality of the river water to assess its uses for drinking and other purposes. In this region Salinity is a major problem. Salinity is the principal cause of water quality degradation in the area. Inverse distance weighting (IDW) is commonly used and is easy to automate. The port is situated about 130 kilometres (81 mi) north of the deep sea (Sandhead) and 30 kilometres (19 mi) inland from the Bay of Bengal by river.

In this study, the area considered is Purba Medinipur district in West Bengal, starting from the location Geonkhali bearing latitude N 22° 12' 28" and longitude E 88° 10' 29" upto Haldia dock bearing latitude N 22° 1' 52" and longitude E 88° 6' 7" in Hooghly river. The location point along with latitude and longitude given in table 3.1. The entire stretch considered in this study mainly comes in the region of Haldia city under Purba Medinipur district in West Bengal. Haldia dock is mainly a river based port & industrial city located approximately 125 km southwest of Kolkata near the mouth of the Hoogly river. This study basically under Hooghly river upon which so many industry, huge population, agriculture etc. are highly dependent.

Table No. 3.1: Study area location

Sr No	Water sampling stations	Sample code	Location	
			Latitude	Longitude
1	Near Geonkhali -river surface (0.5 m) High tide water	S10 (H)	N 22 °12' 28"	E 88 ° 10' 29"
2	Near Geonkhali -river surface (0.5 m) Low tide water	S10 (L)		
3	Near Natpatia -river surface (0.5 m) High tide water	S9 (H)	N 22 °11' 38"	E 88 °4' 12
4	Near Natpatia -river surface (0.5 m) Low tide water	S9 (L)		
5	Near Kukrahati -river surface (0.5 m) High tide water	S8 (H)	N 22 °11' 18"	E 88 °7' 14"
6	Near Kukrahati -river surface (0.5 m) Low tide water	S8 (L)		
7	Near Erekhali-river surface (0.5 m) High tide water	S7 (H)	N 22 °10' 51"	E 88 °8' 22"
8	Near Erekhali -river surface (0.5 m) Low tide water	S7 (L)		
9	Near Begunbera-river surface (0.5 m) High tide water	S6 (H)	N 22 °08' 35"	E 88 ° 10' 27"
10	Near Begunbera -river surface (0.5 m) Low tide water	S6 (L)		
11	Near Shalukkhali -river surface (0.5 m) High tide water	S5 (H)	N 22 °7' 31"	E 88 ° 11' 31"
12	Near Shalukkhali -river surface (0.5 m) Low tide water	S5 (L)		
13	Near Baneswar Chak-river surface (0.5 m) High tide water	S4 (H)	N 22 °5' 35"	E 88 °11' 10"
14	Near Baneswar Chak-river surface (0.5 m) Low tide water	S4 (L)		
15	Near Brindaban Chak-river surface (0.5 m) High tide water	S3 (H)	N 22 °3' 27"	E 88 °11' 10"
16	Near Brindaban Chak-river surface (0.5 m) Low tide water	S3 (H)		

17	Near Old Pump house-river surface (0.5 m) High tide water	S2 (L)	N 22 °2' 35"	E 88 °7' 12"
18	Near Old Pump house-river surface (0.5 m) Low tide water	S2 (L)		
19	Near Haldia Dock-river surface (0.5 m) High tide water	S1 (H)	N 22 °1' 52"	E 88 °6' 7"
20	Near Haldia Dock-river surface (0.5 m) Low tide water	S1 (L)		

Firstly, the position of the study area was identified on the Google Earth. After selecting the entire study area each location was physically visited and Latitude and Longitude of each station was noted through GPS machine. Then through the path and Measure menu, draw the river profile of “Hooghly” river and add the station point with proper station identifier by measuring the distance approximately. Then considering the Latitude and Longitude of each station study map has been prepared applying Arc GIS software and same is shown in Fig 3.1 in study area map. In this study map starting from Geonkhali bearing station code S-10 upto Haldia dock bearing station code S-1 from upstream to downstream in Hooghly river have been plotted.

The latitudes and longitudes of each station considered in the study (S-10 to S-1) have been tabulated in Table no. 3.1.

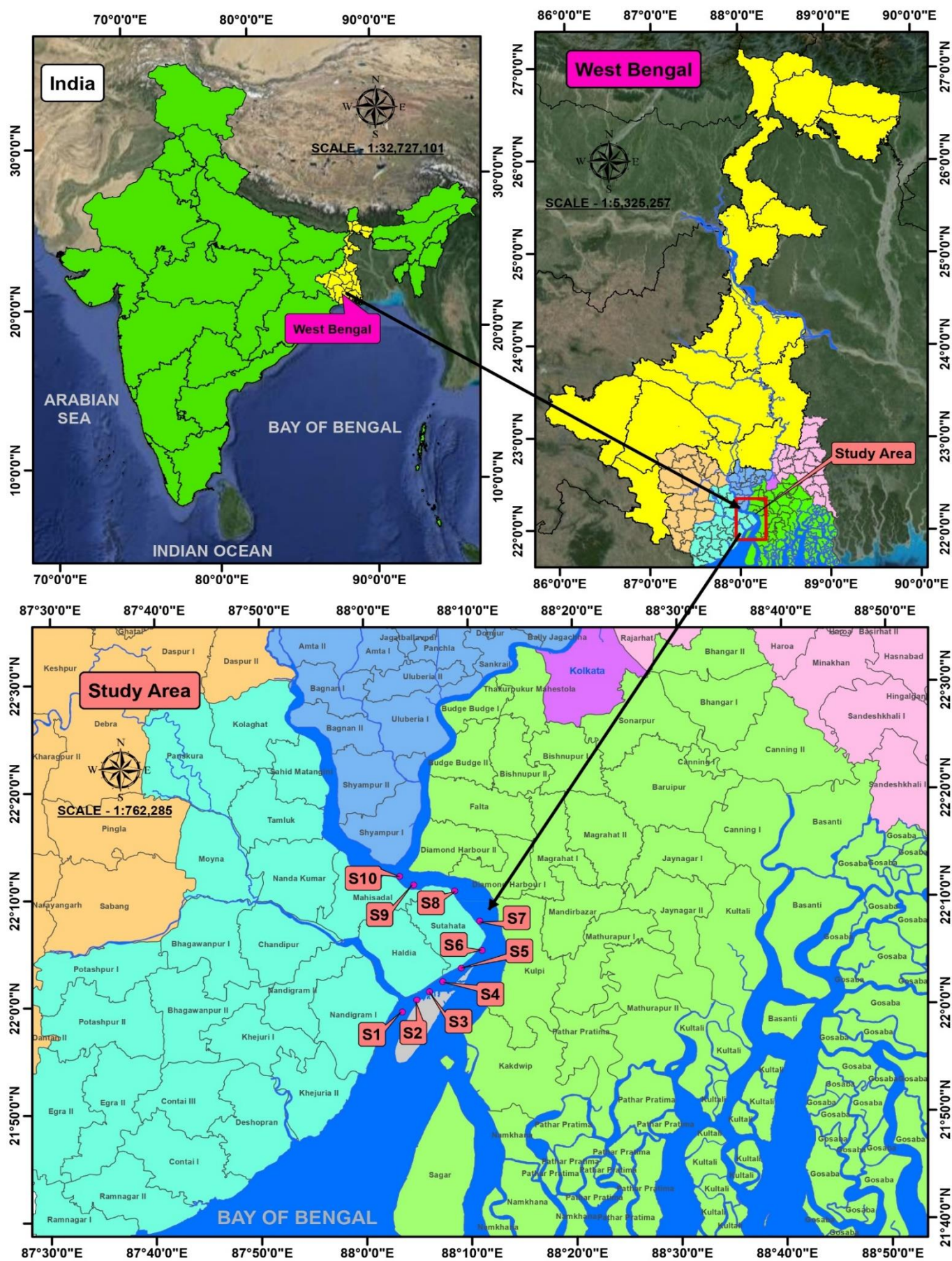


Fig 3.1 : Study area map

3.1 Profile of the study area

3.1.1 Community

Current estimated population of Haldia Municipality in 2024 is approximately 284,000. 2024 and same was 200827 in the year 2011 [source : Haldia Municipality]. The last census was conducted in the year 2011 and according to the census total literates in Haldia city are 158,380 of which 87,334 are males while 71,046 are females. Average literacy rate of Haldia city is 88.54 percent of which male and female literacy was 93.26 and 83.35 percent. The sex ratio of Haldia city is 916 per 1000 males. Child sex ratio of girls is 960 per 1000 boys. Total no. of Slums in Haldia city numbers 9,652 in which population of 44,873 resides. This is around 22.34% of total population of Haldia city. Hinduism is majority religion in Haldia city with 83.72 % followers. Islam is second most popular religion in city of Haldia with approximately 15.74 % following it. In Haldia city, Christianity is followed by 0.17 %, Jainism by 0.03 %, Sikhism by 0.09 % and Buddhism by 0.04 %. Around 0.05 % stated 'Other Religion', approximately 0.16 % stated 'No Particular Religion'.

3.1.2 Lifestyle and life pattern :

Being a port based industrial town, in Haldia, the status of people are relatively high. They lead extremely busy lives and do most of the work, jobs and business. There are lots of colleges i.e. engineering college, medical college, Law College etc. because of that many number of student are also there. The people do jobs i.e. teaching or many other government sectors. There are so many people doing their engineering jobs in the industry. Due to having lots of industry, there are many labours, migrant labours are also lived in Haldia.

3.1.3 Culture :

Set on the banks of the Haldi River, the industrial town of Haldia is a major port for trade and industry. But it also has great cultural significance. While traditional Hindu festivals such as Durga Puja, Kali puja , Ganesh chaturthi, Saraswati puja, Onam , Holi , Ratha Yatra , Vasa Utsav and many more are celebrated in a unique fashion. Being an industrial town Vishwakarma puja is widely celebrated in Haldia. Few thousands of Vishwakarma idols are worshiped in proper Haldia city itself. Seeing the pandal-hopping enthusiasm of local people till midnight, an outsider can easily get confused whether it's preterm Durga Puja. A vast majority of pandal hoppers comprises villagers gathered from various parts of the Medinipur district and other surrounding regions of Haldia & they commence their Vishwakarma Puja parikrama right from the Haldia Dock Complex which is made accessible to commoners once in a year only in this auspicious day of Vishwakarma Puja. People of Haldia preserve high expectations in terms of puja celebration from well-known companies/industries like- Indian Oil Corporation, Haldia Petrochemicals, Haldia Dock Complex, Tata Chemicals, Exide Industries, Hindustan Unilever, Bharat Petroleum, Hindustan Petroleum, Dhunseri Petrochem etc to mention a few who happen to be the giant organizers of Vishwakarma Puja in Haldia. Apart from them, in every fifty meter interval you'll find a Vishwakarma idol being worshiped. Apart from that haldia's biggest fair, Haldia Mela is organised by Haldia Development Authority and Haldia Municipality every year.

3.1.4 Health:

Health levels and attainment in the community is much better. A good healthcare infrastructure improves the quality of life of citizens. Hospitals are the lifeline of any city or place. There are Haldia Sub-divisional Hospital, Dr BC Roy Hospital – Haldia Medical College in Haldia. Private medical services, Primary Health Centers (PHCs) and sub-centers are present also in haldia.

3.1.5 Transportation:

Haldia is fast emerging as a very important industrial destination in the industrial map of the West Bengal as well as Eastern Region, and also a very good tourism destination due to world class infrastructure facilities as well as world class connectivity. Accessibility is a very crucial factor as it is the means by which a tourist can reach the area where attractions are located. Tourist attraction of whatever type would be of little importance if the locations are inaccessible by normal means of transport. Haldia is connected in three – ways Rail, Road and Water. Haldia is connected with the Kolkata – Mumbai National Highways (NH-6) by the National Highway (NH-41) at Kolaghat. Haldia is connected to Kolkata by bus. Haldia is also connected to Kharagpur by bus.

Haldia railway station is the major railway station connecting the city to Kolkata, Chennai and Delhi. For long-distance trains except one or two weekly for Delhi and - 25 -indhya you have to go to either Mecheda or Kolkata or Kharagpur. Haldia Port is well connected with the Railways and huge bulk & container cargo is exported and imported through Indian Railways. Haldia is also connected via the 1620 km long inland waterway, National Waterway 1 that runs from Prayagraj across Ganges, Bhagirathi and Hooghly river system to Haldia (Sagar). Waterway connectivity plays a vital role to connect Haldia & Kolkata as Haldia is essentially a Port Town. Various channels of connectivity via waterways are available such as:

- Raichak – Kukrahati Ferry Service.
- Haldia Township to Nandigram ferry Service.
- Haldia to Sagardeep Boat Service.
- Kukrahati- Diamond Harbour Launch (Boat) Service.

3.2 Natural Profile of study area

3.2.1 Pedology (soil texture):

The entire district is underlain by unconsolidated bedded sedimentary rocks. The important rivers are Rupnarayan, Haldi, Kansabati, Hugli and Keleghai. The district is characterized by sub tropical humid type of climate. The maximum temperature varies between 37°C and 43°C and minimum temperature varies between 7°C and 7.8°C. The humidity here ranges from 60% to 90% due to the existence of the Bay of Bengal in the south. Average annual rainfall is 1752.6 mm. The occurrence of cyclone with heavy shower is a common feature especially in the coastal parts of the district. Two types of soil are predominant i.e. - 25 -indhyan alluvium comprising 122921 ha. And coastal alluvium comprising 181,879 ha. of land. The district is dominated by clayey soils and clay loam soils. In Nandigram-I & II, Mahishadal-I, Patashpur-I & II, Khejuri- I & II, Bhagwanpur-I, Egra-II and Deshpur blocks more than 70% soils are clayey in texture.

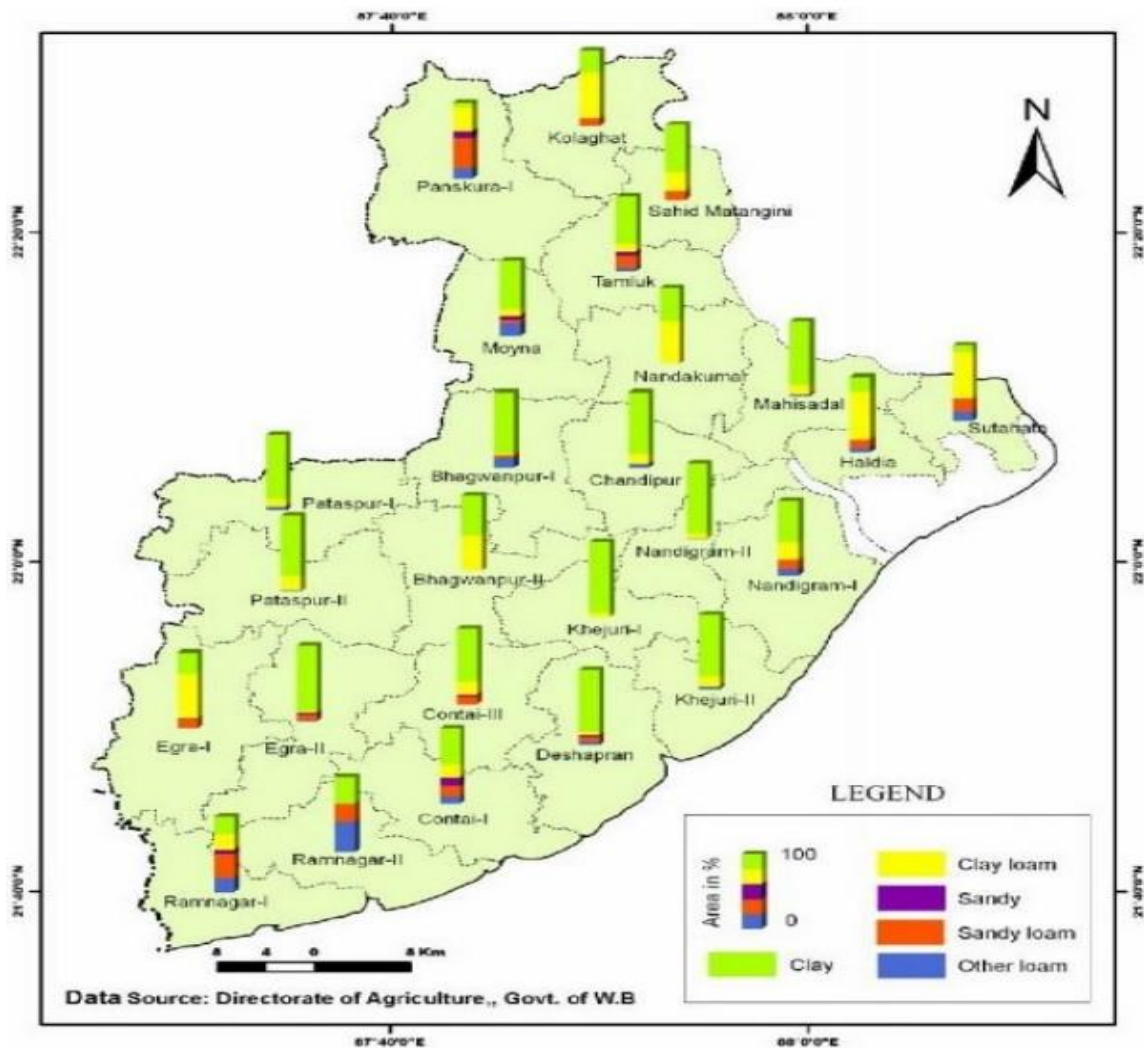


Fig 3.2: Soil Texture [Source : IRS-1D, LISS-III, 2002, 4th February]

3.2.2 Geology and Hydrology:

Haldia region is made up of estuarine floodplain alluviums during the Late Holocene to Late Pleistocene period. Recent to sub-recent deposits of tidal flats, beaches and bars, sand dunes and swampy tracts are found on the emerged and submerged surfaces of the region. Channel fringe tidal flats and backwater wetlands are deposited and filled with mud and finer sand or silt in places of tidal influences. Ground water in the district occurs under semi-consolidated to confined condition in both the litho systems. In general the area is underlain by a single aquifer in each litho system, which splits up into multiple aquifers with the intervening clay/sandy clay layers. In Quaternary sediments this single aquifer has been spilled up into two regionally extensive aquifers whereas in Tertiary sediments four such regionally extensive aquifers has come out from the single aquifer.

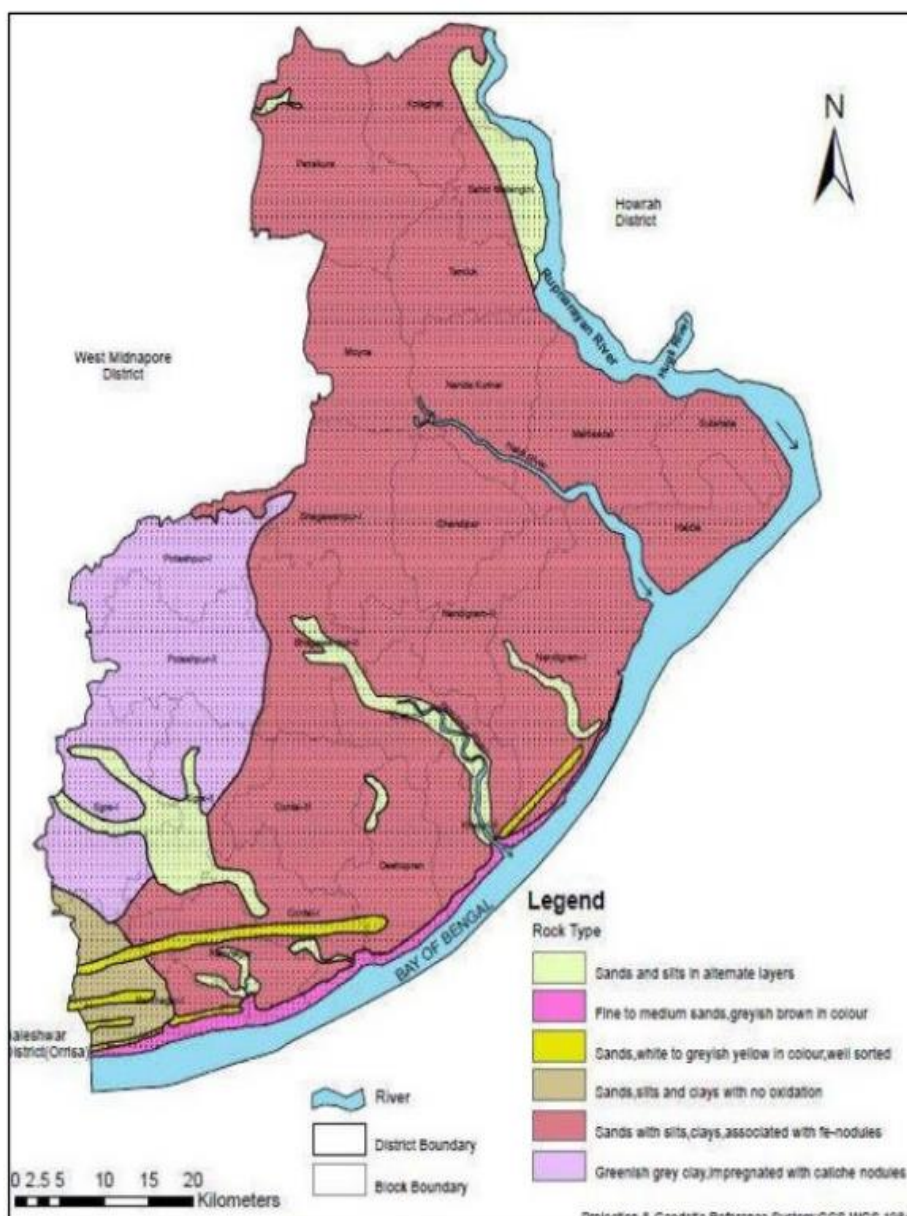


Fig 3.3 : Hydrogeological map of Purba Medinipur District
[Source : IRS-1D, LISS-III, 2002, 4th February]

3.2.3 Climate:

The district of Purba Medinipur experiences an extreme climate with high range of temperature. The climate of the district is characterized by oppressive heat and high humidity in summer with average daily maximum temperature varies between 25°C and 39°C. Winter is generally dry and cold with average winter temperature around 18° C. The average annual rainfall in the district is 1712mm. The variations in the annual rainfall within the district and from year to year are not large. The rainfall during the monsoon season – June to September – constitutes 74 percent of the annual rainfall; July and August are the rainiest months. The district receives a mean annual rainfall varying from 1531 mm to 1929 mm.

3.2.4 Drainage Pattern:

In Hoogly, Rupnarayan and Haldi catchment drainage pattern is funnel/palmate shaped sub watershed with dendritic drainage pattern. In the Village drainage is imperfect to moderately well. The rivers of district Purba Medinipur, owing to the typical physiographical condition of the district, emerge from the Chhotanagpur Plateau to the West, flows East or South-East ward direction according to the slope of the land and meets Bay of Bengal. All the rivers in this region are rain-fed and flow to the fullest during monsoon.

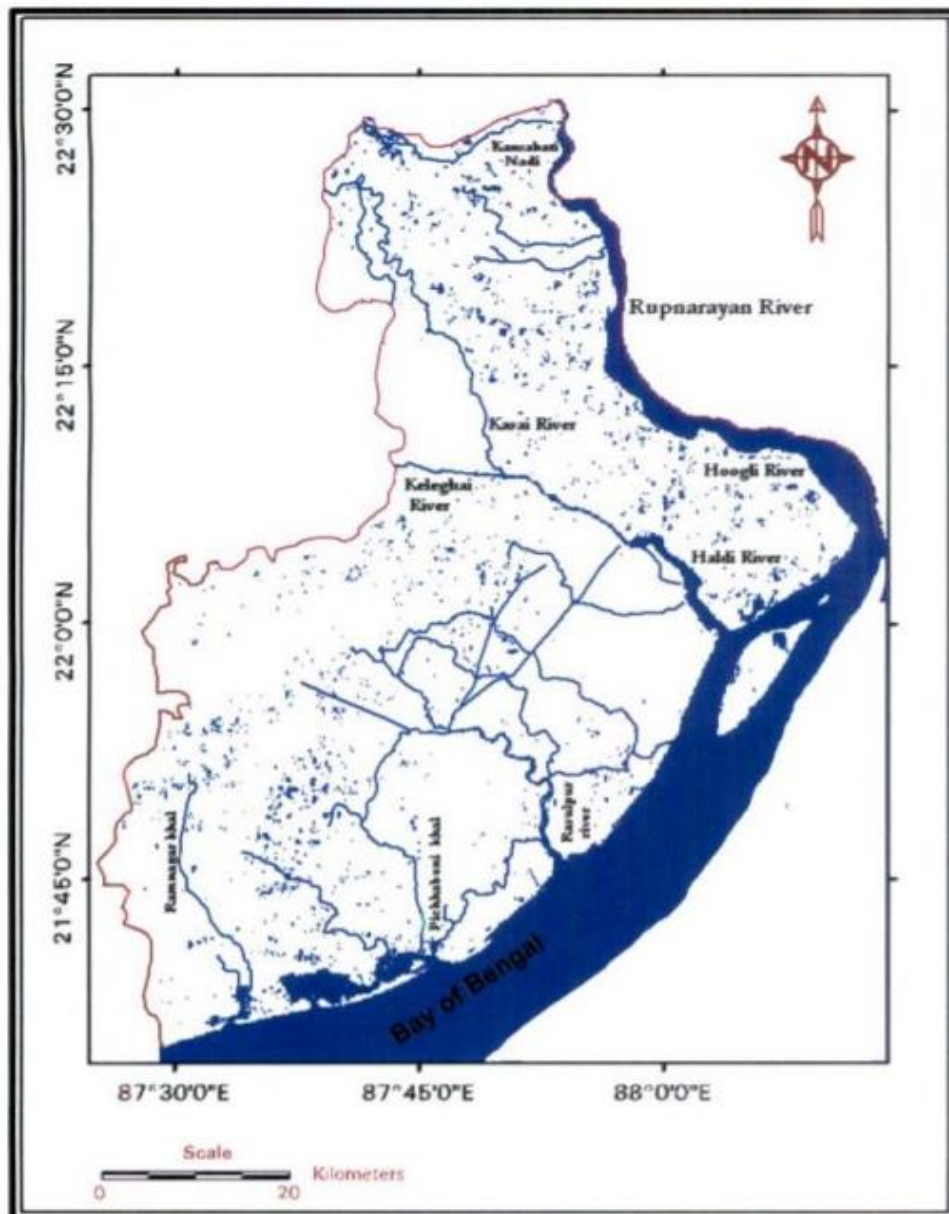


Fig 3.4 : Drainage map and surface water map of Purba Medinipur District [Source : IRS-1D, LISS-III, 2002, 4th February]

3.2.5 Land Use Pattern:

Purba Medinipur district is one of the most important agricultural districts of West Bengal. The Land Use and Land Cover classification of the Purba Medinipur district shows the six main classes. Most of the area (46.41%) to the total land is used for the agricultural practices. About 33.06% area remain under the vegetation cover, along with the other land uses of wetlands (12.27%), water bodies (3%), built-up area (5.05%) and sandy tract (0.20%). Census (2011), shows that the total forest land of the district is 900 ha. Total land for agricultural use was 289150 ha in 2013-14.

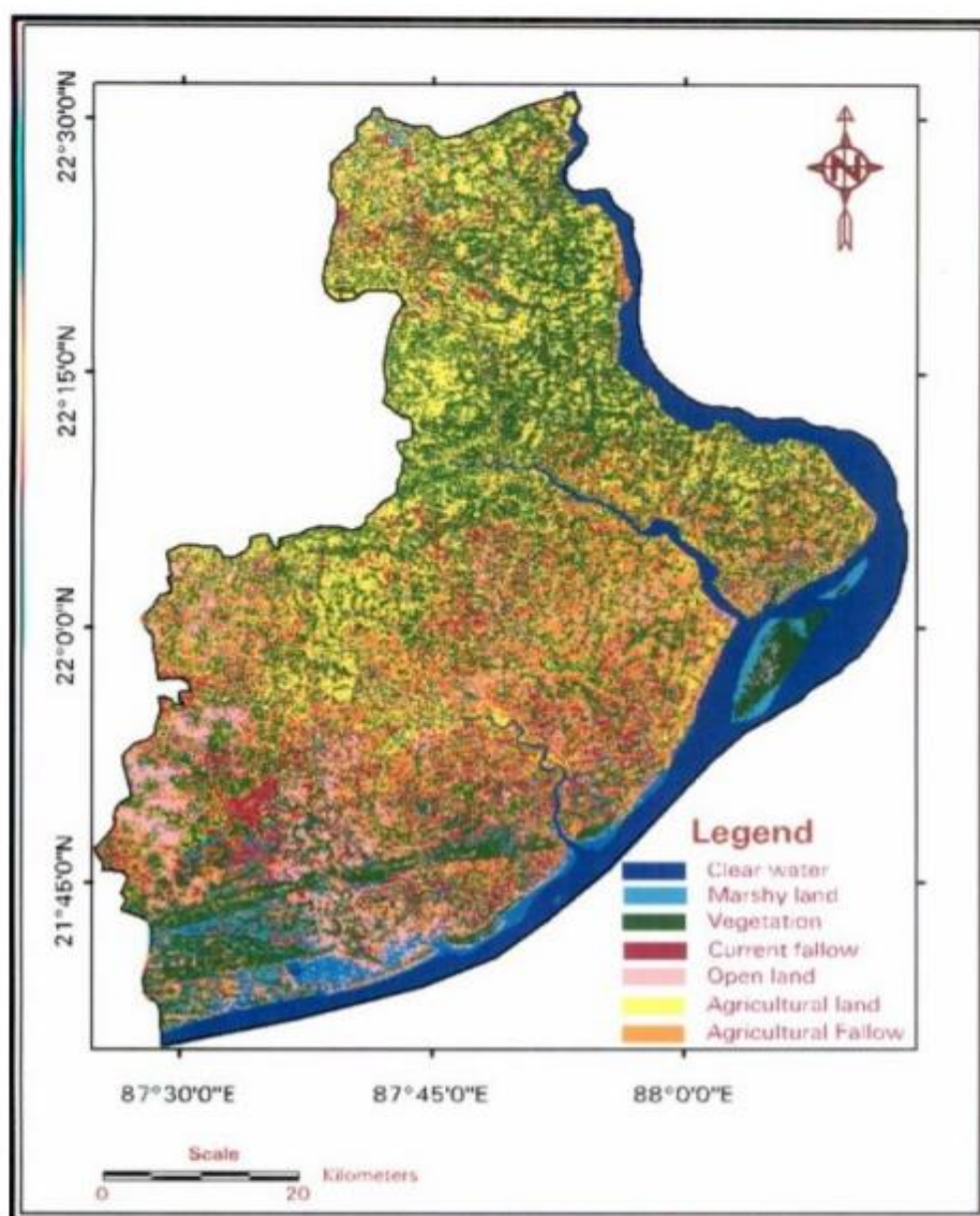


Fig 3.5: Land use pattern map of Purba Medinipur district
[Source : IRS-1D, LISS-III, 2002, 4th February]

In order to promote public health, safety and the general social welfare of the community, it is necessary to apply reasonable limitation on the use of land and buildings. This is to ensure that the most appropriate economical and healthy development of the city takes place in accordance with the land use

plan. For this purpose, 10 different primary land use categories have been proposed. Further they are sub-divided into another level. The proposed land use list are Residential, Commercial, Public & Semi Public, Industrial, Transportation, Utilities and Services, Agricultural , Water bodies , Open Space and Special Use Zone-1 (Heritage, Tourism) etc.

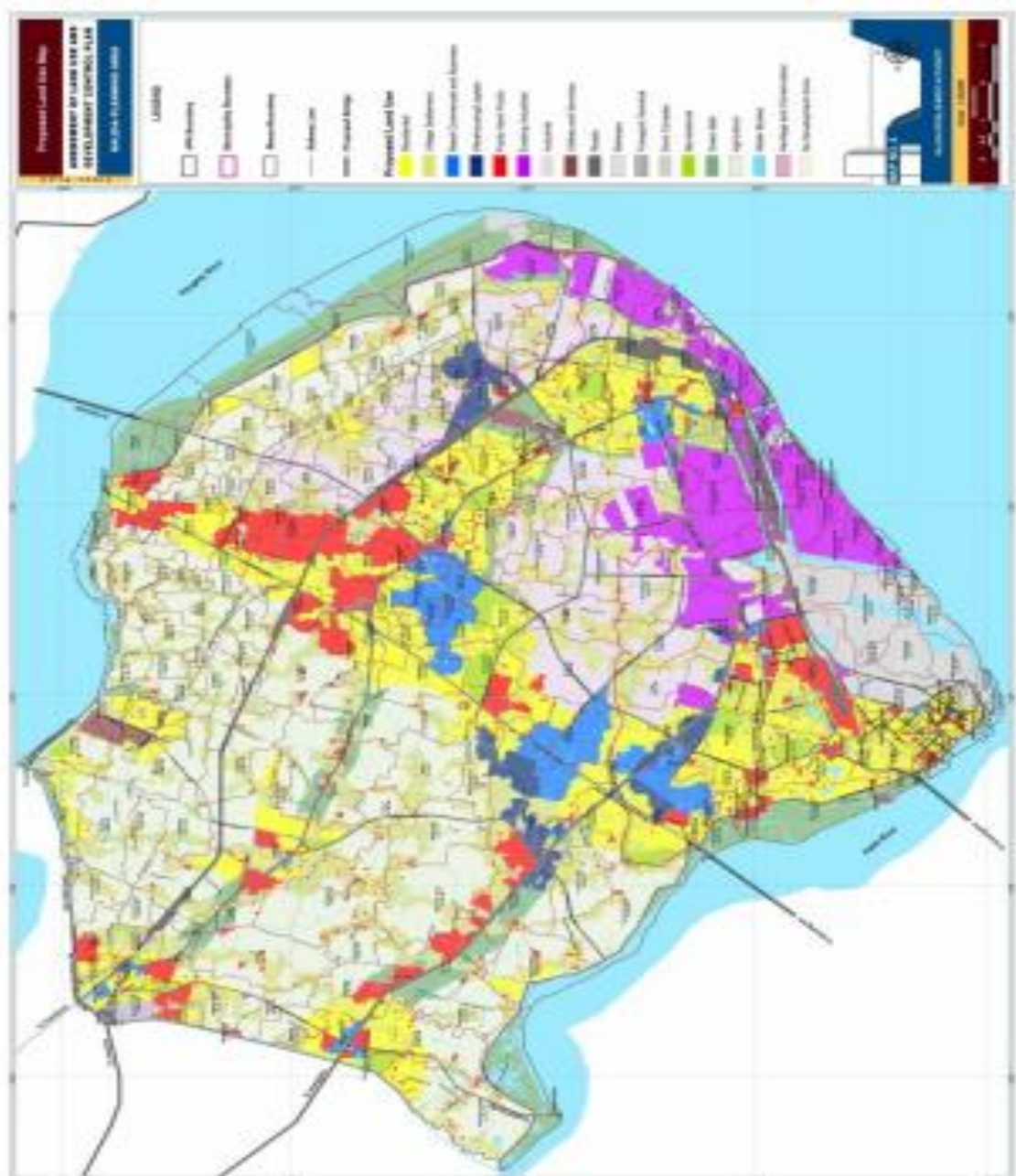


Fig 3.6 : Proposed land use map by Haldia Development Authority
[Source: Haldia Development Authority]

3.2.6 Industry:

The industrial town of Haldia is a major port for trade and industry. Haldia has several major factories, including South Asian Petrochemicals Ltd, Indian Oil Corporation Limited (IOCL), Haldia Energy Limited, Exide, Shaw Wallace, Tata Chemicals, Haldia Petrochemicals, India Power Corporation Ltd., Hindustan Lever, LTC&Co., S.J.Constructions and other major logistics companies are jay road carriers which provides affordable logistics across all channels in India. The port has attracted major international petrochemicals companies, like

Mitsubishi Chemical Corporation (MCC). A large number of companies are also being set up now, Dredging Corporation of India Limited (DCI), primarily being ancillary industries to the Haldia Petrochemicals. The Haldia Petrochemicals is the second largest project of such kind in India. All the companies have been flourished in the vicinity of Hooghly river and due to development of Haldia Dock, Haldia has become industrial hub.

Chapter-4

Methodology

In this chapter, methodologies to achieve various activities of the study objectives are discussed. The various activities carried out in the study is shown through the flow chart in Figure 4.1. The detailed description of methodology is as below:

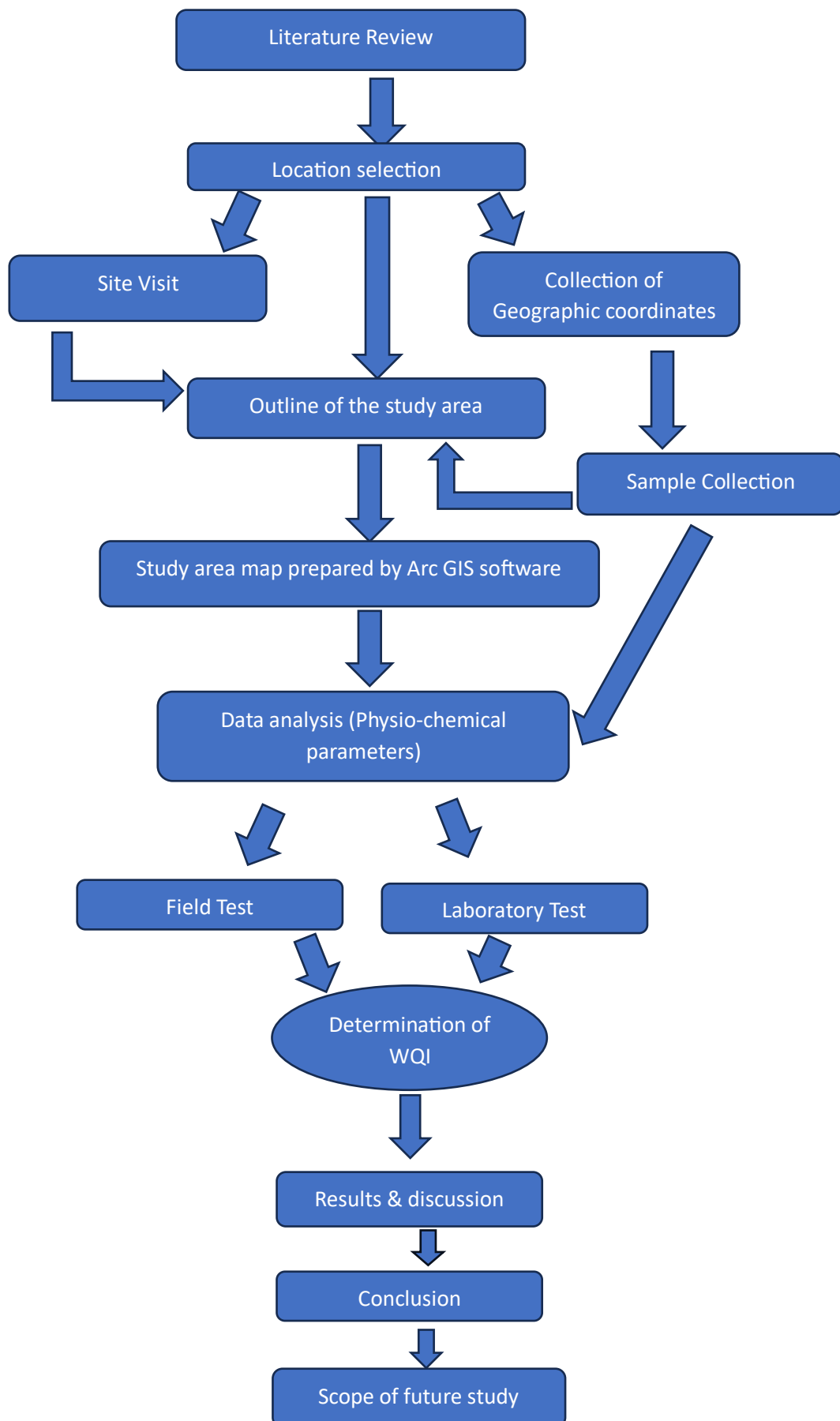


Fig. 4.1 : Flow Chart of Methodology

4.1 Data Collection

The first site visit in the study area for the sample collection was started during monsoon season on 24th August, 2023. The sample collection was started from Geonkhali from the river bank of the Hoogly river and then heading towards Haldia throughout the hooghly river bank upto Haldia Dock, Haldia. Each location was visited twice in a single season to collect data during high tide and low tide. Therefore, total 10 nos of location were selected throughout the river at a certain distance and total 20 nos sample collected considering high tide and low tide. Thereafter, samples are collected in the month of October (i.e. Post monsoon), January (I.e. Winter) and April (i.e. pre monsoon). The water samples are collected in a 2L clean water bottle during the first field visit.



Fig 4.2 : Sample collection at Geonkhali from Hooghly river bank



Fig 4.3 : Sample collection at Kukrahati from Hooghly river bank



Fig 4.4 : Collected sample to be poured at conical flasks before testing

4.2 Monitoring Methodology

Water samples were collected and analyzed as per the procedures outlined in IS: 3025/ APHA. 2 litre sample volume were collected for physico-chemical analysis of the water quality. After collected the water sample immediately preserve as per mentioned standard guideline. Paramerts which considered here are pH, Temperature,DO, Cl, Salinity, TDS,SO₄,NO₃,BOD,TH,Ca,Mg,EC. The parameters are measured in the field after collecting the samples to analyze the WQI. From the above list of parameters, few are analyzed at laboratory as per IS code and few parameter are analyzed during collection of sample. The monitoring methodology (laboratory & onsite) are described below.However, IS 2296 has used to determine the water quality standards.

Table 4.1: Analytical Procedure

S.No.	Parameters	Analytical Methods	Reference
1	pH (at 25 °C)	By pH meter	IS 3025 (Part - 11):1983
2	Chloride as Cl	Argentometric Titration	IS 3025 (Part - 32):1988
3	Salinity	Argentometric Titration	2520AAPHA22ndEdn.2 012
4	Total Dissolved Solids	By Gravimetric	IS3025(Part-16):1984(Reaff:2014)
5	Sulphate as SO ₄	By UV- Spec	IS 3025(Part - 24):1986
6	Nitrate as NO ₃	By UV- Spec	ASTM(Part - 31)1978
7	BOD, 5 days @ 20°C as O ₂	BOD Incubator	IS 3025 (Part - 44):1993
8	Dissolved Oxygen	Titrimetric Method	IS 3025 (Part - 38):1989
9	Total Hardness as CaCO ₃	Titrometric Method	IS 3025 (Part - 21):1983
10	Calcium as Ca	Titrometric Method	IS 3025 (Part - 40):1991
11	Magnesium as Mg	EDTA Method	IS 3025 (Part - 46) 1994
12	Electrical Conductivity	Conductivity meter	IS 3025(Part-14):2013

Table 4.2: Onsite parameters for analysis

S.N o.	Parameters	Analytical Methods	Reference
1	pH (at 25 °C)	By Hand pH Meter	IS 3025 (Part - 11):1983
2	Dissolved oxygen	Iodimetry (Fixing & Titration)	IS 3025 (Part - 38):1989
3	Total Dissolved Solids	By Hand TDS Meter	IS3025 (Part- 16):1984(Reaff:2014)
4	Conductivity	By Hand Conductivity Meter	IS 3025(Part-14):2013
5	Temperature	Thermometer	

4.3 Laboratory Test:

4.3.1. Hydrogen ion concentration (pH)

Principal:

pH value denotes the concentration of hydrogen ions in the water and it is a measure of acidity or alkalinity of a substance.

Procedure :

pH value of water was determined directly using pH meter as shown in Fig 4.5. The determination of pH may be made electrometrically using pH meter provided with a pH electrode pH vary with temperature, note the temperature at which is determined and set the pH meter to the appropriate temperature The pH meter is pre-calibrated by using standard solution of known pH value of a given sample of water.



Fig 4.5 : pH meter

4.3.2. Chloride (Cl):

Principal :

Chloride (Cl⁻) is one of the major inorganic anions, or negative ions, in saltwater and freshwater. It originates from the dissociation of salts, such as sodium chloride or calcium chloride, in water. Chlorides are binary compounds of chlorine.

Test Procedure :

Argentometric Method

Principal: In a neutral or slightly alkaline solution, potassium chromate can indicate the end point of the silver nitrate titration of chloride. Silver chloride is precipitated before red silver chromate is formed.

Reagents

- (i) Potassium chromate indicator solution - Dissolve 50 g of potassium chromate in a little distilled water. Add silver nitrate solution until a definite red precipitate is formed. Let it stand for 12 h, filter and dilute to 1 litre with distilled water.
- (ii) Standard silver nitrate titrant - 0.014 1 N. Dissolve 2.395 g of silver nitrate in distilled water and dilute to 1 litre. Standardize against 0.014 1 N sodium chloride solution. 1 ml = 500 µg of chloride, store in a brown bottle.
- (iii) Standard sodium chloride solution - 0.014 1 N. Dissolve 824.0 mg of sodium chloride: dried at 140°C) in distilled water and dilute to 1 litre. 1 ml = 500 µg of chloride.
- (iv) Procedure
Use 100 ml diluted sample to 100 ml. If the sample is highly coloured, add 3 ml of aluminium hydroxide suspension, mix, let settle and filter. If sulphide, sulphite or thiosulphate is present, add 1 ml of hydrogen peroxide and stir for 1 minute. Directly titrate the samples in the pH range 7 to 10. Adjust sample pH to 7-10 with sulphuric acid or sodium hydroxide if it is not in the range. Add 1.0 ml of potassium chromate indicator solution. Titrate with standard silver nitrate solution to a pinkish yellow end point. Standardize silver nitrate solution and establish reagent blank value by titration method.

Calculation :

$$\text{Chloride, mg/l} = [(V_1 - V_2) \times N \times 35450] / V_3 \dots\dots\dots(I)$$

Where

V₁ = volume in ml of silver nitrate used by the sample,

V₂, = volume in ml of silver nitrate used in the blank titration,

V₃ = volume in ml of sample taken for titration, and

N = normality of silver nitrate solution.

4.3.3. Total Dissolved Solids :

Principal : Total dissolved solids (TDS) is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized, or micro-granular (colloidal sol) suspended form.

Test Procedure :

There are two methods to calculate the Total Dissolved Solids (TDS). Those are (a) Gravimetric Method (b) Electrical Conductivity Method.

Gravimetric Method :

Principle : Total dissolved solids means the portion that passes through the filter after removing total suspended solids. The factors that affect the separation of suspended solids and dissolved solids are pore size, porosity, area and thickness of the filter. A well mixed sample is filtered through a standard glass fiber or suitable filter, and the filtrate is evaporated to dryness in pre-weighed dish and dried to constant weight at 103°C to 105°C. The increase in weight of dish represents total dissolved solids.

Procedure : Heat clean dish to 103°C to 105°C in an oven for one hour, store in dessicator for 30 minutes and weigh immediately. Filter well-mixed sample through glass fiber filter or grade 42 filters. Pour 50 ml or a suitable volume of filtered sample to a pre weighed evaporating dish and evaporates to dryness on a steam bath. After evaporation dry for at least one hour in an oven at 103°C to 105°C cool in a dessicator for 30 min and weigh. Repeat cycles of drying, cooling, desiccating and weighing until a constant weight is obtained.

Calculation :

Total dissolved solids, mg/l = $(A-B) \times 1000 / \text{Sample volume(ml)}$(II)

Where A= Weight of dried sample + dish, mg and B = Weight of dish, mg

Electrical Conductivity Method :

Principle: Electrical conductivity of the sample is the reflection of TDS content and empirically could be determined.

Calculation:

TDS mg/l = conductivity in micro mho cm⁻¹ x 0.59(III)

In this study TDS meter have been used at site to get the value of TDS as shown in Fig 4.6.



Fig 4.6 : TDS meter

4.3.4 Sulphate : Natural sources of dissolved SO_4^{2-} in freshwater ecosystems include mineral weathering, volcanic activity, decomposition and combustion of organic matter, oxidation of sulphides, and sea spray aerosols.

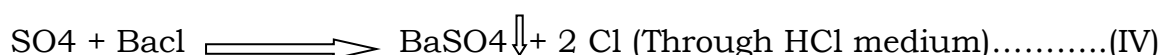
Procedure : Three methods as given below are prescribed:

- i) Gravimetric method,
- ii) Thorin method, -and
- iii) Turbidity method.

- (i) Gravimetric method: This method is applicable for all the waters having sulphate concentrations above 10 mg/l.

Principle and Theory - Sulphate is precipitated in hydrochloric acid medium as barium sulphate by the addition of barium chloride solution. The precipitation is carried out near boiling temperature and after a period of digestion, the precipitate is filtered, washed with water until free of chlorides, ignited or dried and weighed as barium sulphate (BaSO_4).

The reaction in its simplest form is :



Procedure: Adjust the clarified sample, necessary to remove interfering agents to contain approximately 100 mg of sulphate ion in 500 ml volume. Add 2 to 3 drops of methyl red indicator solution. Add hydrochloric acid drop by drop till an orange red colour appears. Lower concentrations of sulphate ion may be tolerated if it is impracticable to concentrate the sample to the optimum level, but in such cases it is better to fix the total volume at 150 ml after concentration on hot plate. Heat the solution to boiling, while stirring gently, add warm barium chloride solution slowly until precipitation appears to be complete, then add about 2 ml in excess. Digest the precipitate at 80-90°C for at least 2 hours.

Filtration -Filter the precipitate through filter paper and wash the precipitate with small portion of warm distilled water until the washings are free of chloride ions as indicated by testing with silver nitrate-nitric acid reagent. Dry the precipitate in crucible and ignite at 800°C for 1 hour and make it cool in a desiccator and weigh.

Sulphate concentration as mg/l BaSO₄ = [BaSO₄ mg/l X 411.5]/ ml of sample.....(V)

4.3.5 Total Hardness:

Principal : Hardness in water is that characteristics which prevents the formation of sufficient lather or foam , when such hard waters are mixed with soap. It is usually caused by the presence of Calcium and Magnesium salts present in water, which form scum by reaction with soap. Dissolved calcium (Ca⁺⁺) and magnesium (Mg⁺⁺) are the only two divalent cations found at appreciable levels in most waters.

Test Procedure :

There are two methods for determination of total hardness, namely (a) Ethylenediamine tetraacetic acid (EDTA) method, and (b) Method based on analytical data to determine carbonate and non-carbonate hardness.

The EDTA method is based on the reaction of calcium and magnesium salts with ethylenediamine tetraacetic acid or its disodium salt and is applicable to all types of water but not applicable to wastewater. The analytical data method is based on computation from analytical results of the sample and is applicable to both water and waste water.

Reagents :

- (i) Buffer Solution : Dissolve 16.9 g ammonium chloride (NH₄Cl) in 143 ml concentrated ammonium hydroxide (NH₄OH), add 1.25 g of magnesium salt of EDTA and dilute to 250 ml with distilled water. Store the solution in a polyethylene bottle tightly stoppered to prevent loss of ammonia or pick-up of carbon dioxide for no longer than 1 month. Dilute 10 ml of the solution to 100 ml with distilled water and check that the pH value is 10.0 ± 0.1.

In the absence of magnesium salt of EDTA, dissolve 1.179 g disodium salt of EDTA (AR quality) and 780 mg magnesium sulphate (MgSO₄.7H₂O) or 644 mg magnesium chloride (MgCl₂.6H₂O) in 50 ml of distilled water. Add this solution to 16.9g ammonium chloride and 143 ml concentrated ammonium hydroxide with mixing and dilute to 250 ml with distilled water. To attain the highest

accuracy, adjust to exact equivalence through appropriate addition of a small amount of EDTA or magnesium sulphate or chloride. The exact amount can be determined by taking an appropriate aliquot of buffer and titrate it with disodium salt of EDTA.

- (ii) Eriochrome Black T Indicator Solution:
Dissolve 0.40 g eriochrome black T and 4.5g hydroxylamine hydrochloride (NH₂OH HCl) in 100 ml 95 percent ethanol. This indicator is stable for more than 2 months. Alternatively, dissolve 0.5g eriochrome black T in 100 ml triethanolamine or 2-methoxyethanol or mixed 0.5 g EBT dye and 100g sodium chloride in a pestle and mortar. Store in a tightly stoppered bottle. All indicator formulations tend to deteriorate especially when exposed to moisture. If the end point colour change is not sharp enough it is either due to the presence of some interfering ions or due to deterioration of the indicator. In the latter case, addition of inhibitor sodium cyanide or sodium sulphide (NaCN or Na₂S) does not sharpen the end point colour change.

(iii) Standard Calcium Solution:

1ml = 1.00 mg calcium carbonate (CaCO_3). Dry analytical grade calcium carbonate (CaCO_3) in an oven at 180°C for 1 h. Weigh 1.000 g, suspend it in distilled water and add 1 : 1 hydrochloric acid AR quality, dropwise slowly to dissolve the solid. Use minimum amount of acid. Boil for a few minutes, cool, add a few drops of methyl red indicator and adjust to orange colour with 3 N ammonium hydroxide or 1 : 1 hydrochloric acid. Dilute to 1 000 ml with distilled water.

(iv) Standard EDTA Solution:

Dissolve 3.723 g EDTA ($\text{Na}_2\text{H}_2\text{C}_{10}\text{H}_{12}\text{O}_8 \cdot 2\text{H}_2\text{O}$) which has been dried overnight in a sulphuric acid desiccator, in demineralized water and dilute to 1 000 ml. The reagent is stable for several weeks and large volume is usually prepared. Check the reagent by titrating 25 ml of standard calcium solution stored in polyethylene bottles.

Procedure :

Pipette an aliquot of water sample, maximum 50 ml in a porcelain dish or 150-ml beaker and adjust the volume to approximately 50 ml. Add 1 ml hydroxylamine hydrochloride ($\text{NH}_2\text{OH} \cdot \text{HCl}$) solution. Add 1 to 2 ml buffer solution so as to achieve pH of 10.0 to 10.1. If the end point is not sharp and add 2 ml sodium cyanide or sodium sulphide inhibitor solution. The addition of sodium cyanide or sodium sulphide may be omitted if copper, zinc, lead, cobalt and nickel are absent and if the sample contains less than 0.25 mg of iron and 0.025 mg of manganese. If manganese is present, add 1 or 2 small crystals of potassium ferri cyanide [$\text{K}_4\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O}$]. Stir and wait for at least 5 min until sodium ferri cyanide precipitates. Add 2 ml eriochrome black T indicator solution, titrate with standard EDTA solution stirring rapidly in the beginning and slowly towards the end till end point is reached when all the traces of red and purple colour disappear and solution is clear sky blue in colour. Blank titration, carried out in a similar way as that for sample, may be used for comparison.

4.3.6 Dissolved Oxygen (D.O.)

Principal : All the gases of atmosphere are soluble in water to some degree. Both Nitrogen and Oxygen are closed soluble, as they do not react with water chemically. Hence, Henry's law may be used to calculate their amounts present at saturation at any given temperature. The amount of Oxygen found dissolved in a given water at a given temperature and pressure is known as the Dissolved Oxygen (D.O.).

Test Procedure :

In this study to determine DO Iodometry Titration process has been obtained and it is a method of volumetric chemical analysis. It is a Redox titration process using sodium thiosulphate solution ($\text{Na}_2\text{S}_2\text{O}_3$) which acts as a reducing agent.

Sodium Thiosulphate stock solution:

Dissolve approximately 25 g of sodium thiosulphate in boiled distilled water and make up to 1000 ml. Add 1 g of sodium hydroxide to preserve it.

Standard sodium thiosulphate solution:

Dissolve 250 ml of stock solution in boiled distilled water and make up to 1 litre and standardize sodium thiosulphate against known standard before use.

To the sample collected in 300 ml bottle, add 2 ml of manganese sulphate solution followed by 2 ml of alkaline iodide solution. Use separate pipettes of 2 ml capacity for each reagent and take care that tip of the pipette in each case is dipped well below the liquid surfaces carefully.

Replace the stopper without the inclusion of any air bubble and thoroughly mix the content by shaking the bottle several times and allow the precipitate formed to settle. After 2-3 minutes of settling, carefully remove the stopper and immediately add 2 ml of concentrated sulphuric acid by running the acid down the neck of the bottle and mix thoroughly to dissolve the liberated iodine. Take 200 ml of the solution and titrate immediately against standard sodium thiosulphate solution, adding 3-4 drops of starch indicator solution. The end point is pale blue to colourless.

Calculation : The dissolved oxygen in mg per litre is equal to the volume in ml of 0.025 N thiosulphate solution used for titration.

4.3.7. Bio-Chemical Oxygen Demand (BOD)

Biochemical oxygen demand may be defined as the amount of oxygen required by microorganisms for stabilizing bio-degradable dissolved organic matter under aerobic condition at a standard time and temperature. It is widely used to determine the pollution strength of domestic and industrial wastes in terms of oxygen that they will require if discharged into natural watercourses in which aerobic condition exists. The test is one of the most important in stream pollution control activities where organic loading must be restricted to maintain desired DO level. The determination is used in studies to measure the purification capacity of streams and serves regularly authorities as a means of checking on the quality of effluents discharged to such waters. Information concerning the BOD of wastes is an important consideration in the design of treatment activities. It is a factor in the choice of treatment method and is used to determine the size of certain units, particularly trickling filter actuated sludge units.

Principal:

BOD is the most commonly used parameter to determine relative oxygen requirements i.e. the strength of different types of waste water. In the standard test a 300 ml bottle is used and the sample is incubated at 20°C for 5 days. This 5 day - 20°C BOD or BOD₅ at 20°C is the most common and widely used parameter to organic pollution. BOD at 20°C may be defined as first stage BOD exerted in 5 days at a test temperature of 20°C. First stage BOD means only carbonaceous oxygen demand and it does not include the nitrogenous oxygen demand. The biochemical oxygen demand (BOD) test is based on mainly bio-assay procedure which measures the dissolved oxygen consumed by micro-organisms while assimilating and oxidizing the organic matter under aerobic conditions. The standard test condition

includes incubating the sample in an air tight bottle, in dark at a specified temperature for specific time.

The oxygen required for the nitrification process that is conversion of NH_3 - nitrogen into NO_2 - nitrogen and NO_2 - nitrogen into NH_3 nitrogen. So we can write: Total Biochemical Oxygen Demand, (2nd stage BOD) = CBOD + NBOD When we have first stage and second stage at same time we can call it combined BOD. The sketch for exertion of carbonaceous and nitrogenous biochemical oxygen demand for a waste water sample is drawn below.

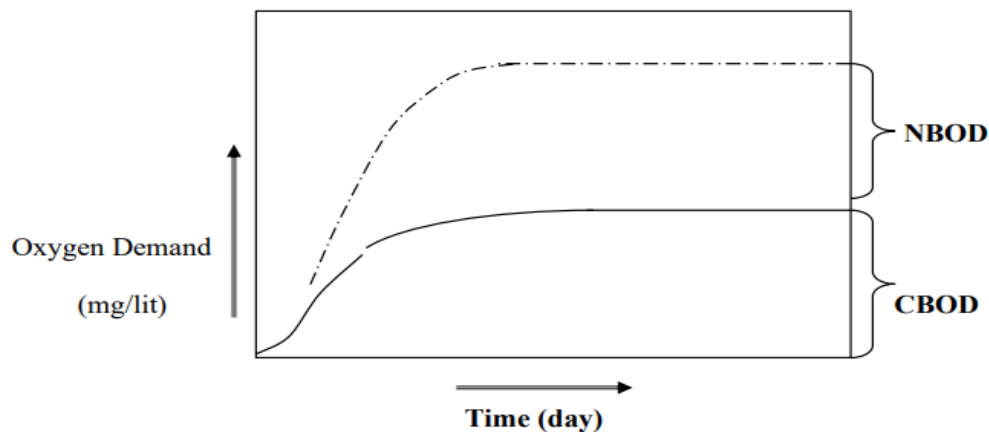


Fig 4.7 : Oxygen demand vs Time (day)

When sufficient number of nitrifying organic matter is present nitrification can occur as shown in the dotted line. Nitrification usually occurs from 5 to 8 days after the start of the incubation period.

Available Methods:

Basically BOD determination involves determination of D.O at a particular interval and at a specific temperature (20°C). BOD measurement is done usually by any one of the following two methods depending upon dissolved oxygen depletion.

- I) Direct Method : This method is suitable for those BOD₅ that does not exceed 7mg/lit, provided that they are aerated to bring the dissolved oxygen level nearly to the saturation at the start of the test. This method does not involve any modification of the sample.
- II) Dilution Method : This method is suitable for those wastes which pass high BOD₅ value involving high DO depletion if measured directly. Here the sample is diluted to desired degree to have safe DO depletion value. This method can be performed in two ways:
 - a) With seed – Which is performed when the wastewater sample does not contain sufficient amount of microorganism. Seed sample containing necessary microorganism are to be added to the original sample.
 - b) Without seed – This test is usually performed when the waste water contains sufficient amount of microorganism to biodegrade dissolved oxygen matter.

Procedure :

Preparation of Dilution Water :

Aerate the required volume of distilled water in a container by bubbling compressed air for 8 to 12 hours to attain dissolved oxygen saturation. Let it stabilize for 4 h at room temperature (around 27°C).

At the time of use, add 1 ml each of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride for each liter of dilution water. Add 2 to 5 ml of treated sewage per liter of dilution water for seeding purpose.

Dilution of Sample and Incubation

Neutralize the sample to pH around 7.0 using alkali or acid of such strength that the quantity of reagent does not dilute the sample by more than 0.5 percent. On the basis of chemical oxygen demand (COD), determine expected BOD.

Use the following formula for calculating sample volume:

Sample volume in ml, per litre dilution = $(X/\text{Expected BOD}) \times 1000$

For keeping 2 dilutions take $X = 2.5$ and 4.0

For single dilution take $X = 3.0$ or 3.5 .

In case of high BOD samples, prepare primary dilutions with distilled water and then make the final dilution.

Determination of Initial Dissolved Oxygen (DO)

Determine initial DO for one bottle and keep two bottles for incubation at $27^{\circ}\text{C} \pm 1^{\circ}\text{C}$ for 3 days. Prepare six blanks by siphoning out dilution water directly into the bottles. Determine initial DO in two bottles and incubate remaining four bottles at $27^{\circ}\text{C} \pm 1^{\circ}\text{C}$ for 3 days.

Determination of Final DO

After 3 days incubation at $27^{\circ}\text{C} \pm 1^{\circ}\text{C}$, determine final DO in incubated bottles.

CALCULATION :

When Sample is Undiluted

BOD, mg/l = DO before incubation - DO after incubation(VI)

When Dilution Water is Seeded:

BOD, mg/ l = $[(D1-D2)/P] \times 1000$ (VII)

Dilution Water is Seeded:

BOD, mg/l = $[D1-D2-(B1-B2)*f/P] \times 1000$ (VIII)

Where

D1 = Initial DO of sample in mg/l,

D2 = DO of sample after incubation in mg/l,

B1 = DO of seed control before incubation in mg/l,

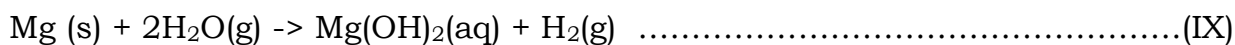
B2 = DO of seed control after incubation in mg/l,

f = ratio of seed in diluted sample to seed in control; [i.e. (percent seed in diluted sample) : (percent seed in seed control)]

P = percentage dilution of sample (sample volume in ml/10)

4.3.8. Magnesium (Mg)

Magnesium metals are not affected by water at room temperature. Magnesium generally is a slow-reacting element, but reactivity increases with oxygen levels. Furthermore, magnesium reacts with water vapor to magnesium hydroxide and hydrogen gas:



Principal : This standard prescribes three methods for the determination of magnesium: a) Gravimetric method as magnesium pyrophosphate; b) Volumetric method using EDTA; and c) Atomic absorption spectrophotometric method. Here, we have obtained EDTA method to determine the concentration of Mg.

When water sample containing both calcium and magnesium is titrated with EDTA at pH 10, Using Eriochrome black-T as indicator, which estimates values of calcium and magnesium. In a separate titration against EDTA at pH 12 to 13 range using murexide or Patton and Reeder's indicator, calcium is selectively estimated. From these two values, magnesium content may be calculated.

Procedure :

Take a suitable aliquot of the solution, expected to contain approximately 10 to 30 mg of calcium and magnesium in a 500 ml conical flask. Add 10 ml of hydroxylamine hydrochloride solution, 2 ml of potassium cyanide solution and 25 ml of triethanolamine solution. Dilute to 150 to 200 ml and add sufficient quantity of buffer solution to bring the pH to 10 ± 0.1 . Add 3 to 4 drops of EBT indicator solution and titrate with 0.01 M EDTA solution till the red colour changes to pure blue end point free from violet tinge.

Calculation :

$$\text{Magnesium as mg (in mg/l percent by mass)} = [0.02435 * 1000 * (V_2 - V_1)] / V \dots\dots\text{(X)}$$

where V = volume in ml of the sample taken for the test;

V₁ = volume in ml of BDAT consumed in titration for calcium determination in the same aliquot of solution of sample

V₂ = volume in ml of EDTA solution consumed in titration.

4.4 Determination of Water Quality Index

4.4.1 Determination of Water Quality Index (WQI) through different process

- (i) Canadian Council of Ministers of the Environment (CCME) Water Quality Index

The index is based on a combination of three factors:

1. the number of variables whose objectives are not met, (Scope)
2. the frequency with which the objectives are not met, (Frequency) and
3. the amount by which the objectives are not met, (Amplitude).

These are combined to produce a single value (between 0 and 100) that describes water quality.

The CCME WQI relies on measures of the scope, frequency and amplitude of excursions from objectives (see next section). However, the methods by which these

measures are calculated differ somewhat in each index and will thus provide different results when applied to each data set.

CCME WQI value has been determined, water quality is ranked by relating it to one of the following categories:

Excellent: (CCME WQI Value 95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.

Good: (CCME WQI Value 80-94) – water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Fair: (CCME WQI Value 65-79) – water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Marginal: (CCME WQI Value 45-64) – water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

Poor: (CCME WQI Value 0-44) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

Calculation of the Index:

After the body of water, the period of time, and the variables and objectives have been defined, each of the three factors that make up the index must be calculated. The calculation of F1 and F2 is relatively straight forward; F3 requires some additional steps.

F1 (Scope) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration (“failed variables”), relative to the total number of variables measured:

$$F1 = (\text{Total number of failed variables} / \text{total number of variables}) * 100 \dots\dots\dots (XI)$$

F2 (Frequency) represents the percentage of individual tests that do not meet objectives (“failed tests”):

$$F2 = (\text{Total number of failed test} / \text{Total number of tests}) * 100 \dots\dots\dots (XII)$$

F3 (Amplitude) represents the amount by which failed test values do not meet their objectives. F3 is calculated in three steps.

The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an “excursion” and is expressed as follows. When the test value must not exceed the objective:

$$\text{Excursion} = (\text{failed test value} / \text{objective}) - 1$$

For the cases in which the test value must not fall below the objective

$$\text{Excursion} = (\text{objective} / \text{field test value}) - 1$$

The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or nse, is calculated as:

$$nse = (\sum \text{Excursion}) / \text{Number of tests}$$

F3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100.

$$F3 = (nse) / (0.01nse + 0.01) \dots\dots\dots (XIII)$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors.

Now, The CCME Water Quality Index (CCME WQI) is calculated

$$= 100 - (\sqrt{F1^2 + F2^2 + F3^2}) / 1.732 \dots\dots\dots (XIV)$$

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the “worst” water quality and 100 represents the “best” water quality.

(ii) Weighted Average WQI method

The WAWQI method was used in this study, consisting of 4 steps, which are as follows :

1. Select parameters to measure the quality of the groundwater;
2. Quality ratings are scaled for each parameter;
3. The unit weight (W_i) is calculated, and W_i is inversely dependent upon the standard value (S_i) of the parameters recommended;
4. Calculating the overall WQI by summing the subindex value.

The following equations were used to calculate the WQI. Each water quality parameter's unit weight (W_i) was computed using Equation (1) as follows:

$$W_i = K/S_i \quad \dots\dots\dots(XV)$$

where W_i stands for the unit weight of i th parameters. K is a proportionality constant. S_i is the standard value of each parameter.

$$K = 1 / \sum (1 / S_i) \quad \dots\dots\dots(XVI)$$

Each parameter's quality rating scale (Q_i) was calculated

$$Q_i = (V_i - V_0) / (S_i - V_0) \quad \dots\dots\dots(XVII)$$

For the pH, the quality rating scale was determined

$$Q_i = (V_i - 7) / (S_i - 7) \quad \dots\dots\dots(XVIII)$$

where V_i is the concentration value for the i th analysed parameter and V_0 is the ideal value of the parameter. Whereas, except for pH (ideal value 7, all other parameter's ideal value is zero.

The final equation can be presented as

$$S_{Li} = (\sum W_i * Q_i / \sum W_i) \quad \dots\dots\dots(XIX)$$

$$WQI = \sum S_{Li} \quad \dots\dots\dots(XX)$$

S_{Li} is the subindex of the i th parameter and i represents the number of parameters taken into consideration.

CHAPTER 5

RESULTS AND DISCUSSIONS

The study has been made on selected parameters on Hooghly river as per details shown in Map in study area (Fig. 3.1). In the following lines , the Physiochemical parameters which have considered in the study are being discussed as per Bureau of Indian Standard (BIS 2012, 2015) and World Health Organization (WHO 2017) of drinking water standards as a reference in this study. The main concern of lower Hooghly river is Salinity and accordingly high TDS and EC. Fig is showing change in salinity at different season from upstream to downstream.

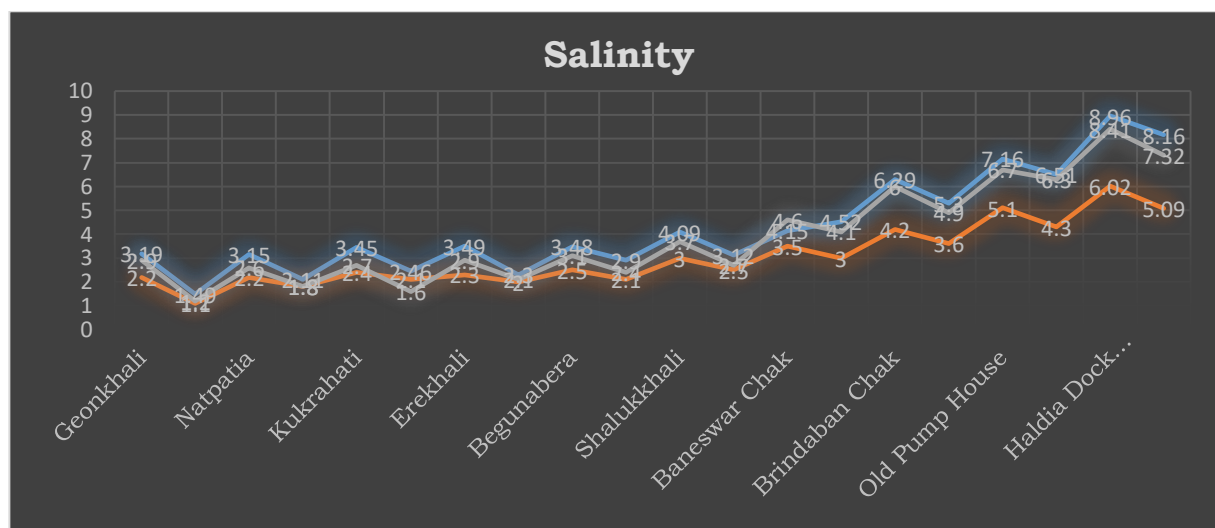


Fig 5.1 : Seasonal variation of salinity from u/s to d/s

Details of Physiochemical parameters for different season from upstream to downstream and mean and standard deviation are appended below in Table 5.1 to 5.12.

Table 5.1 : Results of pH with seasonal variation & location

Parameter	pH					
places	pH(pre-monsoon)	(monsoon)	pH (post-monsoon)	pH (winter)	Mean	Std deviation
S10 (HT)	7.25	7.3	7	7.1	7.1625	0.137689
S10 (LT)	7.01	7.12	7.06	7.09	7.07	0.046904
S9 (HT)	6.92	6.99	7.01	6.95	6.9675	0.040311
S9 (LT)	6.86	6.53	6.99	6.92	6.825	0.203715
S8 (HT)	6.98	6.63	6.93	6.97	6.8775	0.166408
S8 (LT)	6.8	6.72	6.83	6.83	6.795	0.051962
S7 (HT)	7.1	6.9	6.9	6.92	6.955	0.097125
S7 (LT)	6.92	6.9	6.9	6.91	6.9075	0.009574
S6 (HT)	7.23	6.8	7.01	7.12	7.04	0.183485
S6 (LT)	7.8	7.6	7.6	7.4	7.6	0.163299

S5 (HT)	7.41	7.1	7.2	7.42	7.2825	0.158403
S5 (LT)	7.59	7.3	7.5	7.52	7.4775	0.124466
S4 (HT)	7.43	7.4	7.4	7.43	7.415	0.017321
S4 (LT)	7.59	7.42	7.52	7.49	7.505	0.070475
S3 (HT)	7.62	7.53	7.51	7.48	7.535	0.060277
S3 (LT)	7.72	7.59	7.63	7.61	7.6375	0.057373
S2 (HT)	7.63	7.58	7.5	7.5	7.5525	0.063966
S2 (LT)	7.69	7.51	7.5	7.51	7.5525	0.091788
S1 (HT)	7.73	7.61	7.72	7.53	7.6475	0.09535
S1 (LT)	7.8	7.6	7.65	7.55	7.65	0.108012

Table 5.2 : Results of Chloride (Cl) with seasonal variation & location

Parameter	Chloride (mg/l)					
places	Chloride (pre-monsoon)	Chloride (monsoon)	Chloride (post-monsoon)	Chloride (winter)	Mean	Std deviation
S10 (HT)	802	800	768	720	772.5	38.31014
S10 (LT)	398	352	502	448	425	64.59102
S9 (HT)	759	621	791	760	732.75	75.96655
S9 (LT)	358	305	408	365	359	42.24532
S8 (HT)	1132	1035	1350	1252	1192.25	137.6139
S8 (LT)	530	723	816	705	693.5	119.3608
S7 (HT)	1101	888	1395	1202	1146.5	211.1279
S7 (LT)	792	751	846	811	800	39.58956
S6 (HT)	1336	1093	1483	1415	1331.75	170.1242
S6 (LT)	1081	969	12.6	1179	810.4	538.7421
S5 (HT)	1626	1330	1780	1729	1616.25	201.2964
S5 (LT)	1216	1138	1373	1283	1252.5	99.82151
S4 (HT)	1996	1653	1800	2073	1880.5	190.2919
S4 (LT)	1783	1299	1983	1853	1729.5	298.7234
S3 (HT)	2518	1762	2666	2583	2382.25	417.9126
S3 (LT)	2086	1549	2300	2161	2024	328.8434

S2 (HT)	2810	2150	2976	2860	2699	372.5462
S2 (LT)	2658	1859	2770	2719	2501.5	430.7733
S1 (HT)	3516	2511	3729	3644	3350	566.1431
S1 (LT)	3001	2099	3321	3080	2875.25	535.099

Table 5.3 : Results of Salinity with seasonal variation & location

Parameter	Salinity (ppt)					
places	Salinity (pre-monsoon)	Salinity (monsoon)	Salinity (post-monsoon)	Salinity (winter)	Mean	Std deviation
S10 (HT)	2.9	2.2	3.19	3	2.8225	0.432078
S10 (LT)	1.2	1.1	1.49	1.3	1.2725	0.166408
S9 (HT)	2.6	2.2	3.15	3	2.7375	0.426956
S9 (LT)	1.8	1.8	2.11	1.88	1.8975	0.1466
S8 (HT)	2.7	2.4	3.45	3.19	2.935	0.473181
S8 (LT)	1.6	2.1	2.46	2.13	2.0725	0.354718
S7 (HT)	2.9	2.3	3.49	3.21	2.975	0.510457
S7 (LT)	2.1	2	2.3	2.16	2.14	0.125433
S6 (HT)	3.1	2.5	3.48	3.3	3.095	0.42595
S6 (LT)	2.4	2.1	2.9	2.8	2.55	0.369685
S5 (HT)	3.7	3	4.09	3.9	3.6725	0.475771
S5 (LT)	2.7	2.5	3.12	2.8	2.78	0.258715
S4 (HT)	4.6	3.5	4.15	4.79	4.26	0.573353
S4 (LT)	4.1	3	4.52	4.29	3.9775	0.673913
S3 (HT)	6	4.2	6.29	6.13	5.655	0.977224
S3 (LT)	4.9	3.6	5.3	5.08	4.72	0.764373
S2 (HT)	6.7	5.1	7.16	6.86	6.455	0.923237
S2 (LT)	6.3	4.3	6.51	6.41	5.88	1.056819
S1 (HT)	8.41	6.02	8.96	8.75	8.035	1.362314
S1 (LT)	7.32	5.09	8.16	7.55	7.03	1.34102

Table 5.4 : Results of TDS with seasonal variation & location

Parameter	TDS (mg/l)					
places	TDS (pre-monsoon)	TDS (monsoon)	TDS (post-monsoon)	TDS (winter)	Mean	Std deviation
S10 (HT)	2877	2133	3509	3288	2951.75	605.4009
S10 (LT)	1510	1283	1896	1625	1578.5	254.9386
S9 (HT)	2739	2289	3569	3439	3009	602.7161
S9 (LT)	1763	1503	2000	1820	1771.5	205.531
S8 (HT)	2780	2491	3821	3550	3160.5	627.4236
S8 (LT)	1426	1902	2190	1898	1854	316.3964
S7 (HT)	3501	2810	4190	3823	3581	586.0279
S7 (LT)	2436	2333	2638	2511	2479.5	128.4121
S6 (HT)	4068	3312	4531	4300	4052.75	528.7718
S6 (LT)	3251	2893	3802	3523	3367.25	388.0261
S5 (HT)	4850	3939	5323	5102	4803.5	607.8665
S5 (LT)	3620	3331	4045	3819	3703.75	303.145
S4 (HT)	6001	4562	5402	6216	5545.25	740.4761
S4 (LT)	5355	3876	4861	5553	4911.25	749.0048
S3 (HT)	7565	5253	7909	7729	7114	1248.595
S3 (LT)	6303	4663	6949	6531	6111.5	1002.033
S2 (HT)	8389	6389	8911	8569	8064.5	1137.788
S2 (LT)	7936	5501	8281	8105	7455.75	1310.757
S1 (HT)	10550	7553	11201	10935	10059.75	1692.4
S1 (LT)	9102	6328	10103	9355	8722	1651.614

Table 5.5 : Results of Sulphate (SO₄) with seasonal variation & location

Parameter	Sulphate (mg/l)					
places	Sulphate (pre-monsoon)	Sulphate (monsoon)	Sulphate (post-monsoon)	Sulphate (winter)	Mean	Std deviation
S10 (HT)	102.1	80.9	121	115.2	104.8	17.7867
S10 (LT)	96.38	79.6	118	102.6	99.145	15.88606
S9 (HT)	111.5	94	116	111.5	108.25	9.733961
S9 (LT)	98.3	88	105.81	101.48	98.3975	7.584292

S8 (HT)	145.8	131	204.5	190	167.825	35.01413
S8 (LT)	99.5	125	155	136.5	129	23.22714
S7 (HT)	192	150	220	209	192.75	30.7395
S7 (LT)	139	135	143	136.3	138.325	3.534002
S6 (HT)	243	201	272	260.3	244.075	31.08948
S6 (LT)	183	173	205	200	190.25	14.86327
S5 (HT)	289	250	311	306	289	27.65261
S5 (LT)	206	199	235	217	214.25	15.69235
S4 (HT)	353	275	310	353	322.75	37.73924
S4 (LT)	315	236	345	326	305.5	47.96179
S3 (HT)	466	325	488	479	439.5	76.86568
S3 (LT)	373	291	410	386	365	51.65914
S2 (HT)	495	389	531	510	481.25	63.24753
S2 (LT)	451	311	476	462	425	76.6855
S1 (HT)	612	439	649	635	583.75	97.69809
S1 (LT)	543	369	601	561	518.5	102.5719

Table 5.6 : Results of Nitrate (NO₃) with seasonal variation & location

Parameter	Nitrate (mg/l)					
places	Nitrate (pre-monsoon)	Nitrate (monsoon)	Nitrate (post-monsoon)	Nitrate (winter)	Mean	Std deviation
S10 (HT)	0.25	0.23	0.3	0.28	0.265	0.031091
S10 (LT)	0.18	0.23	0.25	0.19	0.2125	0.03304
S9 (HT)	0.29	0.25	0.29	0.28	0.2775	0.01893
S9 (LT)	0.25	0.24	0.29	0.27	0.2625	0.022174
S8 (HT)	0.28	0.25	0.3	0.31	0.285	0.026458
S8 (LT)	0.23	0.23	0.3	0.3	0.265	0.040415
S7 (HT)	0.31	0.25	0.28	0.31	0.2875	0.028723
S7 (LT)	0.26	0.24	0.28	0.31	0.2725	0.029861
S6 (HT)	0.29	0.28	0.31	0.31	0.2975	0.015
S6 (LT)	0.26	0.25	0.29	0.29	0.2725	0.020616

S5 (HT)	0.3	0.26	0.29	0.29	0.285	0.017321
S5 (LT)	0.35	0.3	0.38	0.35	0.345	0.033166
S4 (HT)	0.32	0.29	0.35	0.33	0.3225	0.025
S4 (LT)	0.29	0.28	0.31	0.31	0.2975	0.015
S3 (HT)	0.29	0.3	0.31	0.31	0.3025	0.009574
S3 (LT)	0.3	0.31	0.3	0.31	0.305	0.005774
S2 (HT)	0.31	0.3	0.3	0.32	0.3075	0.009574
S2 (LT)	0.28	0.32	0.29	0.3	0.2975	0.017078
S1 (HT)	0.32	0.32	0.33	0.3	0.3175	0.012583
S1 (LT)	0.3	0.31	0.33	0.3	0.31	0.014142

Table 5.7 : Results of BOD with seasonal variation & location

Parameter	BOD (mg/l)					
places	BOD (pre- monsoon)	BOD (monsoon)	BOD (post- monsoon)	BOD (winter)	Mean	Std deviation
S10 (HT)	4.4	4.8	5	4.5	4.675	0.275379
S10 (LT)	4.8	4.9	4.9	4.6	4.8	0.141421
S9 (HT)	5.1	5.2	5.3	4.9	5.125	0.170783
S9 (LT)	4.8	5	5.3	5.1	5.05	0.208167
S8 (HT)	4.7	4.9	5.2	5.2	5	0.244949
S8 (LT)	4.8	4.9	5.8	5.6	5.275	0.499166
S7 (HT)	5.2	5.3	5.6	5.3	5.35	0.173205
S7 (LT)	3.9	4.6	5.6	5.5	4.9	0.804156
S6 (HT)	5.9	5.9	5.8	5.6	5.8	0.141421
S6 (LT)	4.8	5.1	5.6	5.1	5.15	0.331662
S5 (HT)	6.2	5.8	6.1	6	6.025	0.170783
S5 (LT)	5.7	5.6	5.8	5.8	5.725	0.095743
S4 (HT)	6.8	5.8	6.2	6.3	6.275	0.411299
S4 (LT)	5.6	5.6	6.1	5.9	5.8	0.244949
S3 (HT)	6.8	5.9	6.6	6.6	6.475	0.394757
S3 (LT)	5.1	5.1	5.8	5.3	5.325	0.330404

S2 (HT)	7.3	5.6	6.3	6.8	6.5	0.725718
S2 (LT)	6	5.8	6.1	6	5.975	0.125831
S1 (HT)	8	6.2	7.9	6.9	7.25	0.858293
S1 (LT)	7.1	5.9	7.8	6.9	6.925	0.78475

Table 5.8 : Results of DO with seasonal variation & location

Parameter	Dissolved Oxygen (DO) (mg/l)					
places	Dissolved Oxygen (pre-monsoon)	Dissolved Oxygen (monsoon)	Dissolved Oxygen (post-monsoon)	Dissolved Oxygen (winter)	Mean	Std deviation
S10 (HT)	5.9	5.9	6	5.9	5.925	0.05
S10 (LT)	6.1	6	5.9	5.8	5.95	0.129099
S9 (HT)	6	6	5.9	5.6	5.875	0.189297
S9 (LT)	6.1	5.9	6	6	6	0.08165
S8 (HT)	4	5.1	5.9	6	5.25	0.925563
S8 (LT)	5.8	5.6	6.5	6.1	6	0.391578
S7 (HT)	5.7	5.8	6.2	5.9	5.9	0.216025
S7 (LT)	6.2	5.9	6.1	6	6.05	0.129099
S6 (HT)	5.8	6.2	5.8	6.1	5.975	0.206155
S6 (LT)	6.2	6	5.9	6.1	6.05	0.129099
S5 (HT)	6.1	5.9	6.2	6.5	6.175	0.25
S5 (LT)	6.5	6.1	6.3	6.6	6.375	0.221736
S4 (HT)	6.1	6.2	6.5	6.2	6.25	0.173205
S4 (LT)	6.2	6.1	6.3	6.3	6.225	0.095743
S3 (HT)	6.2	6.3	6.1	6	6.15	0.129099
S3 (LT)	6.6	6.6	6.2	6.6	6.5	0.2
S2 (HT)	6	6.2	6.5	6.3	6.25	0.208167
S2 (LT)	6.3	6.3	6.5	6.2	6.325	0.125831
S1 (HT)	6.2	6.5	6.3	6.3	6.325	0.125831
S1 (LT)	6.5	6.6	6.4	6.1	6.4	0.216025

Table 5.9 : Results of Hardness with seasonal variation & location

Parameter	Hardness (mg/l)					
places	Hardness (pre-monsoon)	Hardness (monsoon)	Hardness (post-monsoon)	Hardness (winter)	Mean	Std deviation
S10 (HT)	219	183	280	249	232.75	41.4759
S10 (LT)	156	139	199	168	165.5	25.30481
S9 (HT)	208	176	221	210	203.75	19.36276
S9 (LT)	177	155	206	183	180.25	20.96624
S8 (HT)	238	223	335	305	275.25	53.45637
S8 (LT)	199	221	301	265	246.5	45.53021
S7 (HT)	268	215	302	298	270.75	40.14453
S7 (LT)	185	182	202	192	190.25	8.883505
S6 (HT)	270	221	301	288	270	35.05234
S6 (LT)	220	198	251	238	226.75	22.99819
S5 (HT)	338	279	371	351	334.75	39.56745
S5 (LT)	245	230	276	261	253	19.88299
S4 (HT)	411	321	359	419	377.5	46.11218
S4 (LT)	385	268	432	401	371.5	71.70542
S3 (HT)	499	341	521	505	466.5	84.18036
S3 (LT)	418	300	463	433	403.5	71.49126
S2 (HT)	590	459	632	603	571	76.70289
S2 (LT)	521	361	549	536	491.75	87.91426
S1 (HT)	720	525	751	746	685.5	107.8595
S1 (LT)	602	409	668	615	573.5	113.3211

Table 5.10 : Results of Calcium (Ca) with seasonal variation & location

Parameter	Calcium (mg/l)					
places	Calcium (pre-monsoon)	Calcium (monsoon)	Calcium (post-monsoon)	Calcium (winter)	Mean	Std deviation
S10 (HT)	85	63	101	92	85.25	16.21471
S10 (LT)	73	69	87	75	76	7.745967
S9 (HT)	73	61	75	71	70	6.218253

S9 (LT)	68	58	75	69	67.5	7.047458
S8 (HT)	109	101	81	132	105.75	21.09305
S8 (LT)	77.6	98	81	101.8	89.6	12.07421
S7 (HT)	112	89	79	125	101.25	21.01388
S7 (LT)	103	98	75	103	94.75	13.37597
S6 (HT)	55	48	61	58	55.5	5.567764
S6 (LT)	45	36	55	49	46.25	7.973916
S5 (HT)	70	63	76	73	70.5	5.567764
S5 (LT)	45	45	50	45	46.25	2.5
S4 (HT)	89	69	73	97	82	13.21615
S4 (LT)	73	51	76	71	67.75	11.35415
S3 (HT)	101	69	102	101	93.25	16.17354
S3 (LT)	76	58	86	78	74.5	11.81807
S2 (HT)	125	101	128	128	120.5	13.0767
S2 (LT)	108	75	111	113	101.75	17.95132
S1 (HT)	144	103	153	143	135.75	22.29163
S1 (LT)	135	90	145	138	127	25.01999

Table 5.11 : Results of Magnesium (Mg) with seasonal variation & location

Parameter	Magnesium (mg/l)					
places	Magnesium (pre-monsoon)	Magnesium (monsoon)	Magnesium (post-monsoon)	Magnesium (winter)	Mean	Std deviation
S10 (HT)	33	25	35	35	32	4.760952
S10 (LT)	30	25	36	31	30.5	4.50925
S9 (HT)	30	23	31	31	28.75	3.86221
S9 (LT)	27	23	24	23	24.25	1.892969
S8 (HT)	58.9	49	73	73	63.475	11.71761
S8 (LT)	30.6	42	41	39.7	38.325	5.235376
S7 (HT)	55.9	45	33	66.8	50.175	14.50204
S7 (LT)	36.8	35	35	37.9	36.175	1.429161
S6 (HT)	32	29	33	35	32.25	2.5
S6 (LT)	25	28	30	26	27.25	2.217356

S5 (HT)	41	39	46	41	41.75	2.986079
S5 (LT)	29	29	31	32	30.25	1.5
S4 (HT)	45	31	36	41	38.25	6.075909
S4 (LT)	43	32	45	43	40.75	5.909033
S3 (HT)	65	41	63	61	57.5	11.12055
S3 (LT)	49	32	52	51	46	9.416298
S2 (HT)	76	51	81	75	70.75	13.42572
S2 (LT)	62	43	69	63	59.25	11.26573
S1 (HT)	87	63	92	90	83	13.49074
S1 (LT)	79	51	85	79	73.5	15.26434

Table 5.12 : Results of Electrical Conductivity(EC) with seasonal variation & location

Parameter	EC ($\mu\text{S/cm}$)					
places	Conductivity (pre-monsoon)	Conductivity (monsoon)	Conductivity (post-monsoon)	Conductivity (winter)	Mean	Std deviation
S10 (HT)	3896	3900	4705	4405	4226.5	398.6046
S10 (LT)	3180	2701	3995	3421	3324.25	538.0566
S9 (HT)	3909	3279	3300	3180	3417	332.1476
S9 (LT)	2518	2149	2863	2599	2532.25	294.9208
S8 (HT)	3953	3552	5445	5051	4500.25	893.409
S8 (LT)	2098	2801	3231	2800	2732.5	469.1627
S7 (HT)	4863	3903	3050	5319	4283.75	1012.321
S7 (LT)	3523	3374	3814	3631	3585.5	185.2215
S6 (HT)	5812	4731	6473	6139	5788.75	755.0384

S6 (LT)	4623	4183	5408	5005	4804.75	523.964 6
S5 (HT)	6928	5656	7603	7288	6868.75	854.237 8
S5 (LT)	5172	4759	5780	5466	5294.25	434.698 7
S4 (HT)	8618	6601	7765	8929	7978.25	1041.71 3
S4 (LT)	7648	5565	9438	7931	7645.5	1594.05 7
S3 (HT)	10836	7539	11330	11071	10194	1781.46 1
S3 (LT)	8999	6651	9930	9325	8726.25	1436.26 5
S2 (HT)	12001	9139	12755	12259	11538.5	1629.97 9
S2 (LT)	11309	7839	11801	11550	10624.75	1867.99 8
S1 (HT)	14867	10623	15794	15398	14170.5	2395.29 9
S1 (LT)	13060	9081	14495	13423	12514.75	2368.84 3

5.1 The statistical analysis

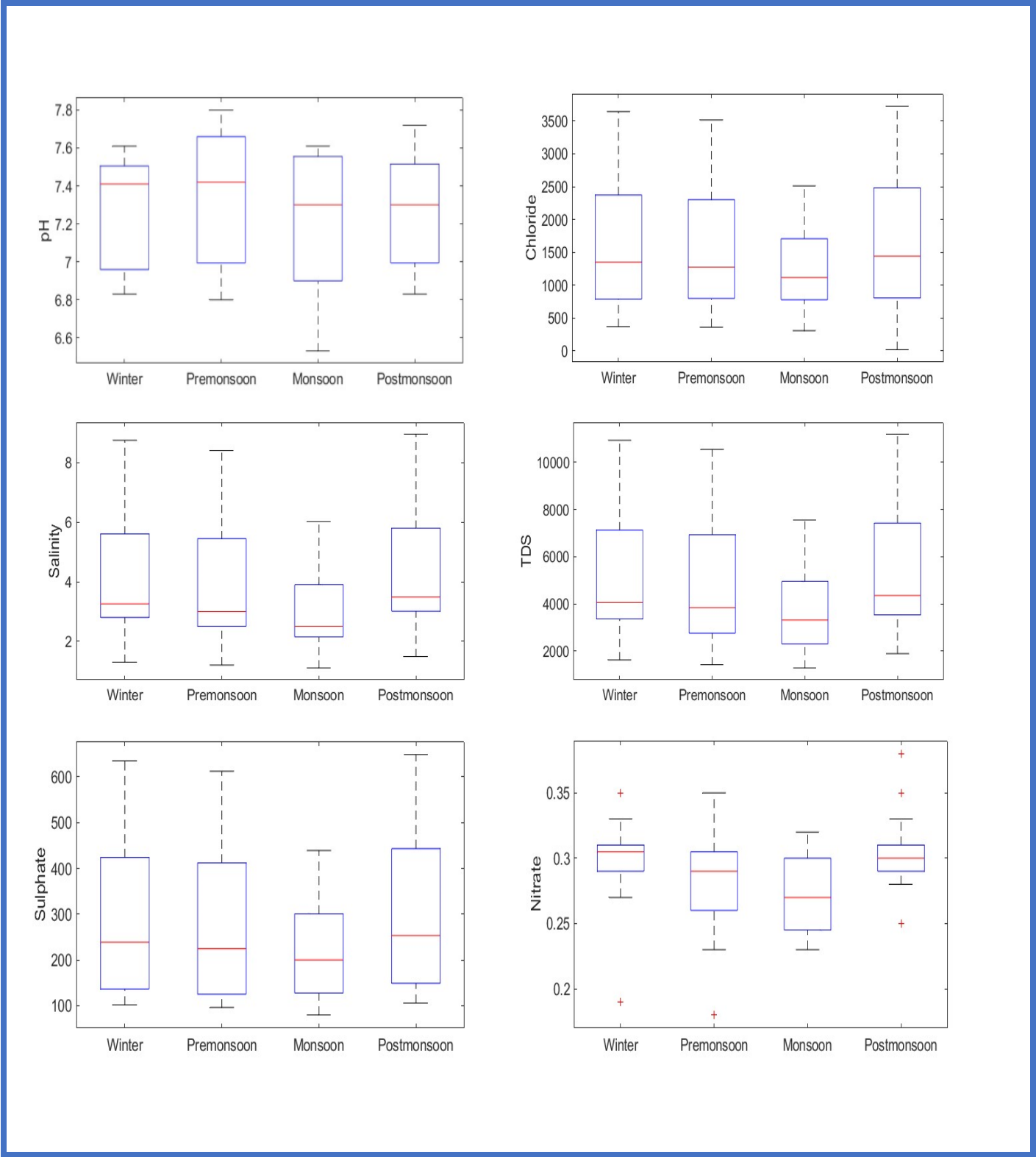
The statistical analysis of water sample, range, mean of different physio-chemical parameters have been shown in table 5.1 to 5.12. From the analysis it has been found that temperature of water is within a range of about 22 deg ~ 27 deg for a period of August,2023 to April,2024. A box plot in Fig 5.1 showing seasonal variation of different physio-chemical parameters. Now, as per pH value it is seen that river water is mostly alkaline nature and it comes in the range of 6.5~7.9. In the study area specially in the upstream at few places pH value is less than 7 i.e. acidic in nature, however, in the downstream towards Haldia Dock water is mostly alkaline in nature. The hydrolysis of natural water mostly affected by carbonate and bicarbonate salts.sometimes, change in temperature also changes the value of TDS and subsequently Electrical Conductivity (EC) [International Journal of Research and Analytical Reviews (IJRAR), E-ISSN: 2348-1269, P-ISSN : 2349-5138].The hydrolysis of pH is also affected by different salts like fluoride, phosphate, silicate etc.Salinity in Hooghly river is very high and it comes in the range of 1.1~8.9 ppt.There are many different salt that contribute in the water salinity.The major ions in seawater or river water are: chloride, sodium, magnesium, sulfate, calcium, potassium, bicarbonate etc.Freshwater usually has a higher bicarbonate ratio while seawater has greater sodium and chloride concentrations.Due to this high salinity,

river water also contains huge amounts of dissolved solids and Total Dissolved Solids (TDS) comes in the range of 1283~10103 mg/l. It has been found that TDS is comparatively low in monsoon season and maximum at Post monsoon time. Therefore, the value much beyond the permissible limit. Dissolved Solids comes mainly due to contact of water with soils, rocks, and other natural materials. Due to high concentration of dissolved solids, water is unsuitable for drinking, irrigation, or other uses and in water distribution systems high TDS contribute to corrosion of plumbing fixtures and reduce the lifespan of equipment. When these type of water is used for irrigation, high dissolved solids can reduce crop yield because the dissolved salts make it more difficult for plants to extract water from the soil. [Leslie A. et al., Water Resource Science Area, Colorado Water Science Centre].

Chloride is a major component of dissolved solids. Sodium chloride-table salt, source of chloride to river water and value of chloride is also high and the value is in the range of 305 mg/l (during monsoon)~3729 mg/l (during post monsoon). As the value of chloride content is very high it contributes in the Dissolved solids and Salinity. Therefore, Hardness is also quite high in Hooghly river and comes in range of 135~750 mg/l. Hardness mainly caused by compounds of calcium and magnesium, and by a variety of other metals. General guidelines for classification of waters are: 0 to 60 mg/L (milligrams per liter) as calcium carbonate is classified as soft; 61 to 120 mg/L as moderately hard; 121 to 180 mg/L as hard; and more than 180 mg/L as very hard. Therefore, the water is very hard and not suitable for use. The concentration Calcium and Magnesium is also high and the range of these divalent water cations are 58~153 mg/l and 23~92 mg/l respectively. Two-thirds of Ca^{2+} in the river water originated from the weathering of carbonate rocks (Berner & Berner, 1996). The Mg^{2+} ions in the river water are contributed by weathering of silicate and carbonate rocks. The sequence of major cations contributing to water chemistry are $\text{Na}^{+} > \text{Ca}^{2+} > \text{Mg}^{2+}$ and here Na^{+} is abundant in nature and range of Na is 238~1418 mg/l. Sodium compounds serve many different industrial purposes, and may also end up in water from industries. The main reason for high concentration of Na is Industrial waste. They are applied in metallurgy, and as a cooling agent in nuclear reactors. About 60% of sodium is utilized in chemical industries, where it is converted to chlorine gas, sodium hydroxide or sodium carbonate, and about 20% of sodium is utilized in food industries as a preservative or a flavouring agent. Therefore, Electrical Conductivity (EC) is far beyond the desirable limit. The maximum and minimum value of EC lies between 2098~15800 $\mu\text{mho}/\text{cm}$. The conductivity of water due to water level fluctuations is often directly connected to water flow. Conductivity and salinity fluctuations due to water level changes are most noticeable in estuaries. As tides rise, saltwater from the ocean ingress into the river, resulting increasing salinity and conductivity values. When the tide falls, the saltwater is pulled back toward the ocean, lowering conductivity and salinity. Tidal variation of Hooghly river is also very high and therefore huge fluctuation of TDS, EC has been observed in between high tide and low tide. Sometimes, surface runoff from different area contributes towards TDS and EC as surface runoff contains substantial amount of salt.

Now, in case of anion, concentration of anions comes as $\text{Cl}^{-} > \text{SO}_4^{2-} > \text{HCO}_3^{-} > \text{NO}_3^{-}$, therefore Cl^{-} is abundant in nature within the study area. Chlorides are binary compounds of chlorine. Chlorine chemically combines with a metal to form chloride. The natural waters near the mines and sea dissolve sodium chloride and also presence of chlorides may be due to mixing of saline water and sewage in the water and result comes in the range of SO_4^{2-} mainly originates from dissolved and

leached from rocks containing gypsum, iron sulfides, and other compounds containing SO₄.



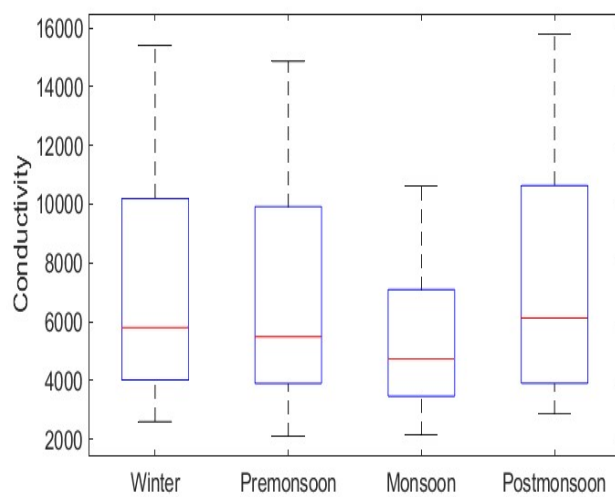
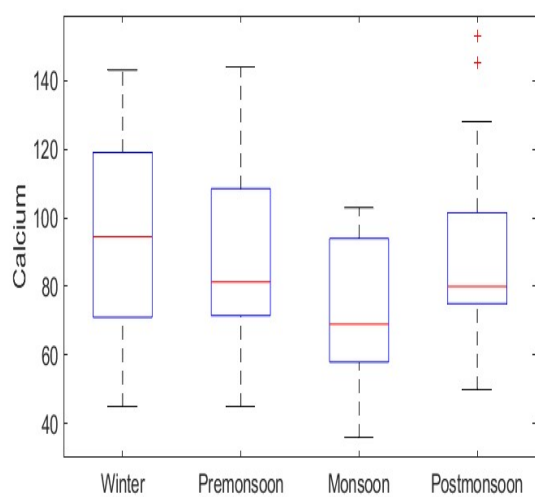
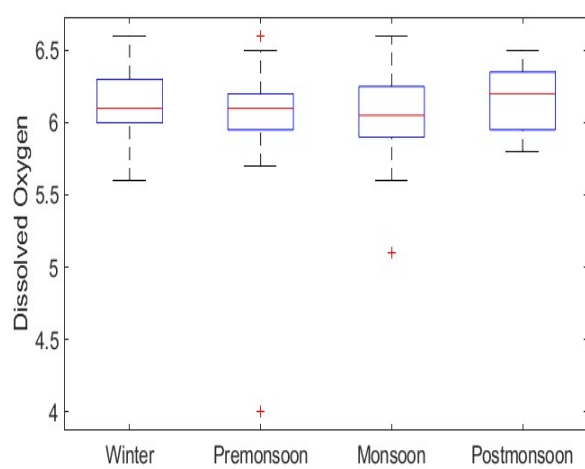
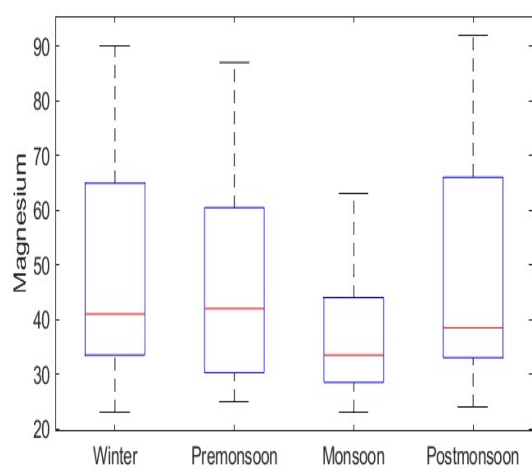
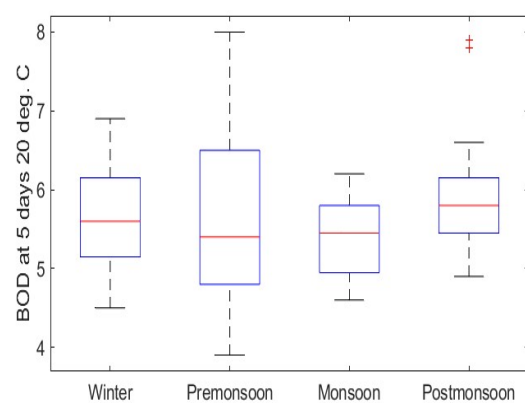
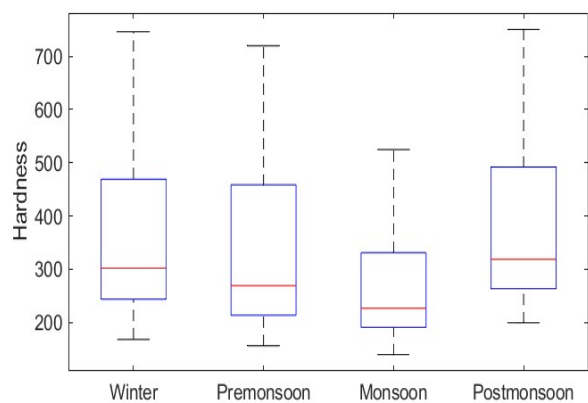


Fig. 5.2: Box plot showing seasonal variation in physiochemical parameters

5.2 Water Quality Index (WQI)

WQI of the Hooghly river from S10 to S1 from upstream to downstream has determined as per below mention procedure:

- (i) Weighted Average WQI method and
- (ii) Canadian Council of Ministers of the Environment (CCME) WQI method .

Table 5.13 : Classification of water quality as per Weighted Average WQI method

WQI value	Water Quality Status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unsuitable for drinking purpose

Table 5.14 : Classification of water quality as per CCME WQI method

WQI value	Water Quality Status
95-100	Excellent
80-94	Good
65-79	Fair
45-64	Marginal
0-44	Poor

In this study,the range of WQI obtained after analyzing the river water using two above mentioned methods for four different season (Aug, 2023 to April,2024) are given in tabular format :

Table 5.15 : Range of WQI

Seasons	WQI Range		
	Weighted Avg WQI	(CCME) WQI	The range of WQI in the study area depicts that the entire stretch of river is very poor and not suitable for drinking purpose.
Monsoon	400~1800	22~54	
Post Monsoon	500~2600	21~49	
Winter	450~2500	21.5~50	
Premonsoon	420~2500	22~51	

5.3 Correlation Matrix

It is the relation between the analyzed water quality parameters with help of Correlation Matrix and Regression Analysis. The various water quality parameters have a significant correlation. The results proved to be a useful mean for rapid monitoring of water quality with the help of systematic calculations of correlation coefficient between parameters and regression analysis. The statistical regression and correlation analysis has been found to be a time saving and cost effective technique. Finding linear correlation between various physicochemical water parameters can be treated as a unique step ahead towards the water quality management. It has been seen that there is a strong relation between pH, TDS, Salinity in all four season (Monsoon, Post Monsoon, Winter, Premonsoon). pH is not related with TDS, Salinity, Calcium, Magnesium etc. In Monsoon and Post Monsoon season Sulphate is related with TDS and salinity, but in winter season not so much changes has been observed with TDS and salinity. Chloride content is significantly related with TDS and Salinity in high tide and low tide as well as with seasonal variation. Na is also related with pH, TDS and salinity and changes in the Na is noticeable. EC and TDS is also related with Calcium therefore, indicating the input from the rock weathering. EC is highly related with Salinity and TDS in all seasons. The EC and TDS showed a positive correlation with cations and anions, indicating contribution from the mineral weathering as a source of solute in the river water. Mg^{2+} and Na^{+} significantly contributed to the Hooghly river and Nitrate and sulphate ions showed a positive correlation and may be attributed to atmospheric precipitation and anthropogenic sources.

Table 5.16 : Co-relation matrix of physiochemical parameters for winter season

	Winter:											
	pH	Chloride.	Salinity.	TDS.	Sulphate.	Nitrate.	BOD5.	DO	Hardness.	Calcium.	Magnesium.	Conductivity
pH Value	1.0000											
Chloride (as Cl)	0.7935	1.0000										
Salinity(ppt)	0.7295	0.9825	1.0000									
TDS (mg/L)	0.7811	0.9915	0.9948	1.0000								
Sulphate (as SO ₄)	0.7924	0.9949	0.9775	0.9861	1.0000							
Nitrate (as NO ₃)	0.3384	0.4034	0.3542	0.3676	0.3661	1.0000						
BOD at 5 days 20deg C	0.6415	0.8770	0.8407	0.8469	0.8892	0.5131	1.0000					
Dissolved Oxygen	0.7036	0.4728	0.3655	0.4135	0.4719	0.5344	0.4660	1.0000				
Hardness	0.7192	0.9823	0.9878	0.9812	0.9811	0.3471	0.8639	0.4157	1.0000			
Calcium	0.0248	0.5508	0.6087	0.5506	0.5368	0.1355	0.4993	-0.1220	0.6390	1.0000		
Magnesium	0.3663	0.7956	0.8138	0.7837	0.7804	0.2891	0.6710	0.1671	0.8388	0.8855	1.0000	
Conductivity	0.7994	0.9934	0.9838	0.9923	0.9939	0.3324	0.8556	0.4463	0.9827	0.5541	0.7866	1.0000

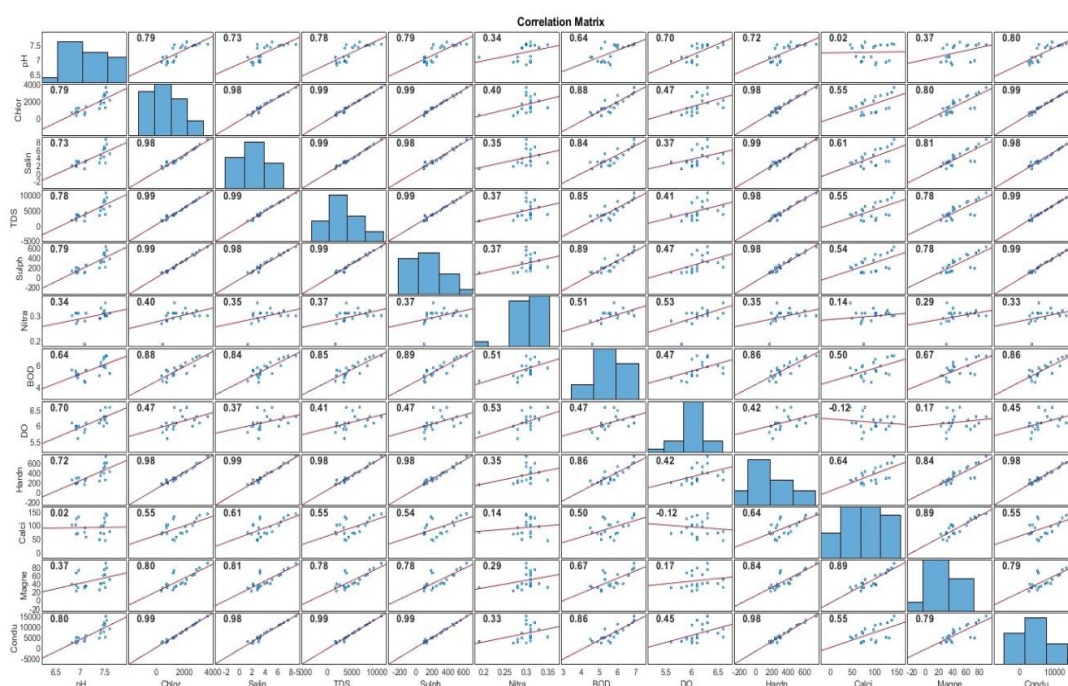


Fig. 5.3: Plot showing the correlation between variables in winter season

Table 5.17: Co-relation matrix of physiochemical parameters for pre-monsoon season

	Pre monsoon											
	pH	Chloride	Salinity	TDS	Sulphate	Nitrate	BOD5	DO	Hardness	Calcium	Magnesium	Conductivity
pH Value	1.0000											
Chloride (as Cl)	0.7989	1.0000										
Salinity(ppt)	0.7523	0.9881	1.0000									
TDS (mg/L)	0.7980	0.9957	0.9937	1.0000								
Sulphate (as SO ₄)	0.7942	0.9923	0.9798	0.9929	1.0000							
Nitrate (as NO ₃)	0.5315	0.5868	0.5518	0.5757	0.5557	1.0000						
BOD at 5 days 20deg C	0.6457	0.8785	0.8686	0.8836	0.8939	0.5926	1.0000					
Dissolved Oxygen	0.4922	0.2865	0.2933	0.3409	0.3543	0.1449	0.2697	1.0000				
Hardness	0.7443	0.9884	0.9923	0.9909	0.9871	0.5321	0.8922	0.2957	1.0000			
Calcium	0.1899	0.6530	0.7040	0.6497	0.6302	0.2107	0.5164	-0.1398	0.7003	1.0000		
Magnesium	0.5184	0.8802	0.8954	0.8689	0.8621	0.4434	0.7505	-0.0318	0.8980	0.9013	1.0000	
Conductivity	0.7965	0.9935	0.9896	0.9981	0.9943	0.5452	0.8875	0.3511	0.9899	0.6484	0.8679	1.0000

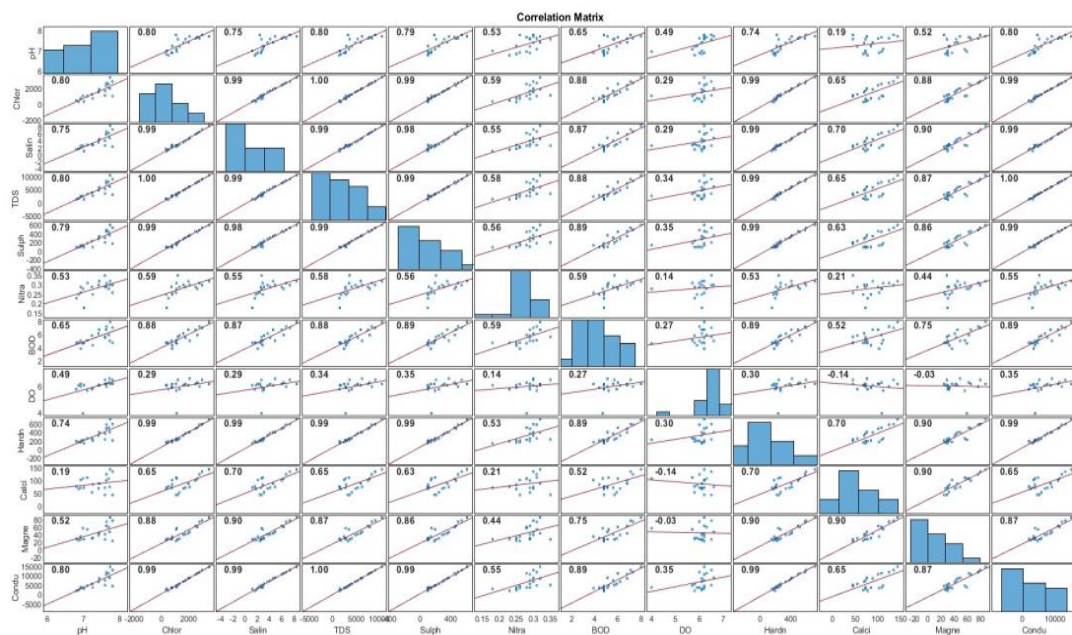


Fig 5.4 : Plot showing the correlation between variables in pre-monsoon season

Table 5.18 : Co-relation matrix of physiochemical parameters for monsoon season

	Monsoon :											
	pH	Chloride.	Salinity.	TDS.	Sulphate.	Nitrate.	BOD5.	DO	Hardness.	Calcium.	Magnesium.	Conductivity
pH Value	1.0000											
Chloride (as Cl)	0.7391	1.0000										
Salinity(ppt)	0.6848	0.9756	1.0000									
TDS (mg/L)	0.7451	0.9901	0.9852	1.0000								
Sulphate (as SO ₄)	0.7329	0.9793	0.9633	0.9886	1.0000							
Nitrate (as NO ₃)	0.7021	0.8877	0.8583	0.9016	0.9014	1.0000						
BOD at 5 days 20deg C	0.5120	0.7810	0.7526	0.8012	0.8049	0.7997	1.0000					
Dissolved Oxygen	0.7528	0.6324	0.6495	0.7002	0.7025	0.7547	0.6097	1.0000				
Hardness	0.6686	0.9749	0.9870	0.9772	0.9665	0.8300	0.7475	0.5996	1.0000			
Calcium	-0.1198	0.3210	0.3873	0.2927	0.2671	0.0389	-0.0397	-0.1895	0.4347	1.0000		
Magnesium	0.2640	0.7341	0.7519	0.7093	0.6955	0.4860	0.4570	0.1173	0.7913	0.7772	1.0000	
Conductivity	0.7769	0.9872	0.9811	0.9950	0.9807	0.8871	0.7873	0.7158	0.9741	0.2884	0.6906	1.0000

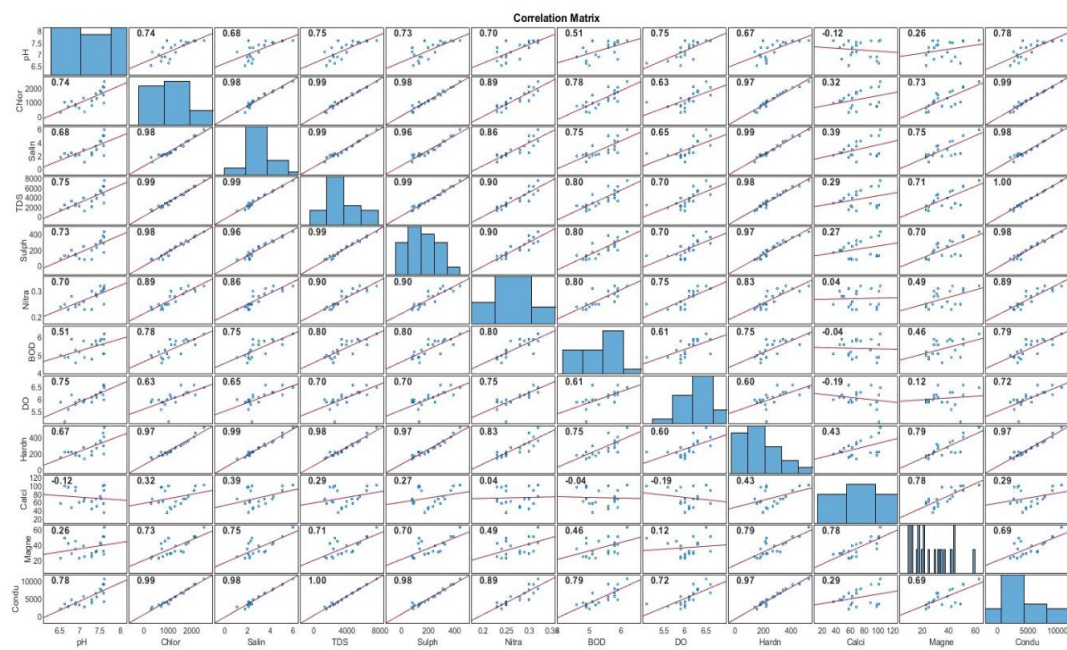


Fig 5.5 : Plot showing the correlation between variables in monsoon season

Table 5.19 : Co-relation matrix of physiochemical parameters for post-monsoon season

	Post Monsoon:											
	pH	Chloride.	Salinity.	TDS.	Sulphate.	Nitrate.	BOD5.	DO	Hardness.	Calcium.	Magnesium.	Conductivity
pH Value	1.0000											
Chloride (as Cl)	0.6694	1.0000										
Salinity(ppt)	0.7405	0.9583	1.0000									
TDS (mg/L)	0.7719	0.9541	0.9922	1.0000								
Sulphate (as SO ₄)	0.7934	0.9640	0.9758	0.9813	1.0000							
Nitrate (as NO ₃)	0.4836	0.3917	0.3567	0.3646	0.3724	1.0000						
BOD at 5 days 20deg C	0.6853	0.8533	0.8821	0.8728	0.8941	0.4889	1.0000					
Dissolved Oxygen	0.4274	0.5939	0.5314	0.5094	0.5581	0.4243	0.5523	1.0000				
Hardness	0.7250	0.9607	0.9853	0.9706	0.9771	0.3300	0.8725	0.5859	1.0000			
Calcium	0.4261	0.7762	0.8355	0.7995	0.7608	0.0381	0.7103	0.4279	0.8483	1.0000		
Magnesium	0.5342	0.8606	0.8819	0.8574	0.8542	0.1783	0.7331	0.4348	0.9111	0.8591	1.0000	
Conductivity	0.8252	0.9420	0.9645	0.9677	0.9817	0.3714	0.8642	0.5188	0.9680	0.7753	0.8591	1.0000

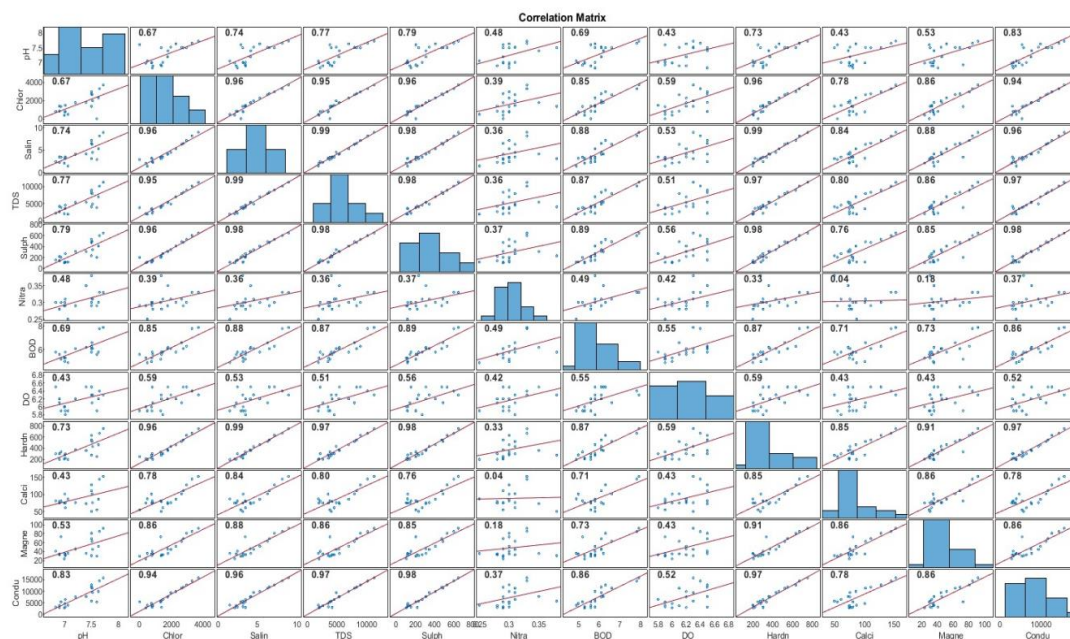


Fig 5.6 : Plot showing the correlation between variables in post-monsoon season

5.4 Water Quality Index of lower Hooghly River

The Water Quality Index (WQI) of water samples from the stretch of Hooghly River has been determined with the help of two (02) different procedure.

- (i) Weighted average Arithmetic method
- (ii) Canadian Council of Ministers of the Environment (CCME) WQI method

In this context, the parameters for ten different stations have been considered and value of WQI determined and same is given Table 5.21 to 5.25. As per Weighted average Arithmetic method Water quality can be defined as excellent (0-25), good (26-50), Poor (51-76), Very Poor (76-100) and Unsuitable for drinking purpose (> 100). According, as per analysis of Water quality Index it has been found that WQI varies from 400~1800 during monsoon season , 500~2600 during Post Monsoon season, 450~2500 during winter and 420~2500 during pre monsoon season [as per weighted average arithmetic method] and same analysis has also been made using Canadian Council of Ministers of the Environment (CCME) WQI method. As per CCME , water quality is classified as Excellent (95-100) , Good (80-94), Fair (65-79), Marginal (45-64), Poor (0-44).Accordingly, Hooghly river water has also been tested using above two method for four different season and results in both the cases are same. For different season WQIs are : Monsoon WQI 400~1800,Post Monsoon WQI 500~2600, Winter 450~2500, Pre Monsoon 420~2500 [As per Weighted Average WQI Method] and For Monsoon 22~54, Post Monsoon 21~49,Winter 21.5~50, Pre monsoon 22~51 [As per CCME WQI Method].The entire stretch of river water quality is very poor and not suitable for drinking purpose for for different season. The portion of Hooghly river is selected

highly polluted with industrial waste as the Haldia region and nearest places are industrial belt. Though all the discharge from industry been treated and then discharged in river. The main reasons behind these poor quality of water are high TDS and Salinity. Therefore, the water can not be used as household uses. River water is also rich with Cation and Anions and all are (Ca, Mg, HCO₃, SO₄ etc.) more than permissible limit. These high concentration of cations and anions are harmful for aquatic species and toxic to the environment. High Concentration of Calcium, Magnesium will cause the corrosion in high amount, therefore all the metallic things will be corroded very soon.

Table 5.20: Value of WQI for Monsoon season

Monsoon			
Sl No.	Location	CCME WQI	Weighted average WQI
1	S10 (HT)	38.57	703.135
2	S10 (LT)	53.76	400.693
3	S9 (HT)	52.06	709.625
4	S9 (LT)	53.97	595.207
5	S8 (HT)	41.27	763.665
6	S8 (LT)	42.25	679.535
7	S7 (HT)	40.51	742.305
8	S7 (LT)	41.062	646.082
9	S6 (HT)	39.82	805.910
10	S6 (LT)	43.99	681.231
11	S5 (HT)	43.55	943.953
12	S5 (LT)	39.61	800.769
13	S4 (HT)	33.08	1081.598
14	S4 (LT)	40.45	939.494
15	S3 (HT)	33.13	1277.957
16	S3 (LT)	32.73	1097.022
17	S2 (HT)	27.29	1523.449
18	S2 (LT)	33.84	1304.308
19	S1 (HT)	22.24	1789.824
20	S1 (LT)	27.79	1525.627

Table 5.21: Value of WQI for Post-Monsoon season

Post-Monsoon			
Sl No.	Location	CCME WQI	Weighted average WQI
1	S10 (HT)	42.94	981.730
2	S10 (LT)	41.87	510.167
3	S9 (HT)	46.4	975.113
4	S9 (LT)	49.112	686.508
5	S8 (HT)	34.72	1061.944
6	S8 (LT)	29.73	794.339
7	S7 (HT)	37.012	1075.305
8	S7 (LT)	39.35	746.055
9	S6 (HT)	39.83	1076.019
10	S6 (LT)	54.28	910.251
11	S5 (HT)	36.25	1251.774
12	S5 (LT)	40.82	976.072
13	S4 (HT)	35.13	1268.893

14	S4 (LT)	33.18	1370.446
15	S3 (HT)	22.74	1871.484
16	S3 (LT)	22.08	1582.362
17	S2 (HT)	21.41	2109.432
18	S2 (LT)	21.76	1924.585
19	S1 (HT)	22.18	2636.768
20	S1 (LT)	21.48	2412.598

Table 5.22: Value of WQI for Winter season

Winter			
SI No.	Location	CCME WQI	Weighted average WQI
1	S10 (HT)	40.09	920.451
2	S10 (LT)	45.995	451.688
3	S9 (HT)	47.37	926.709
4	S9 (LT)	49.82	619.306
5	S8 (HT)	35.95	1196.880
6	S8 (LT)	36.19	887.667
7	S7 (HT)	40.19	997.018
8	S7 (LT)	49.197	706.269
9	S6 (HT)	40.81	1022.960
10	S6 (LT)	42.53	874.707
11	S5 (HT)	34.45	990.554
12	S5 (LT)	41.95	699.683
13	S4 (HT)	28.69	1448.610
14	S4 (LT)	34.71	1303.273
15	S3 (HT)	29.42	1826.941
16	S3 (LT)	33.58	1512.544
17	S2 (HT)	21.525	2034.337
18	S2 (LT)	22.35	1894.473
19	S1 (HT)	21.502	2561.068
20	S1 (LT)	22.04	2227.481

Table 5.23: Value of WQI for Pre-Monsoon season

Pre- Monsoon			
SI No.	Location	CCME WQI	Weighted average WQI
1	S10 (HT)	38.57	890.773
2	S10 (LT)	42.66	427.309
3	S9 (HT)	43.75	819.516
4	S9 (LT)	42.82	592.487
5	S8 (HT)	47.11	844.434
6	S8 (LT)	51.4	537.946
7	S7 (HT)	39.297	908.125
8	S7 (LT)	36.256	661.945
9	S6 (HT)	44.56	972.398
10	S6 (LT)	41.947	758.813
11	S5 (HT)	36.86	1144.922
12	S5 (LT)	41.23	857.858
13	S4 (HT)	30.61	1405.044

14	S4 (LT)	35.44	1245.553
15	S3 (HT)	25.04	1794.862
16	S3 (LT)	36.147	1459.017
17	S2 (HT)	28.577	1998.779
18	S2 (LT)	23.724	1863.822
19	S1 (HT)	22.265	2485.621
20	S1 (LT)	22.8	2167.270

5.5 Evaluation of Hooghly river water quality for irrigation and industrial purposes

To assess the suitability of water quality of Hooghly river following indices have been calculated: 1) Sodium Absorption ratio (SAR), 2) Sodium percentage (%Na) , 3) Kelly's Ratio (KR), 4) Permeability Index (PI) , 5) Potential Salinity (PS), 6) Magnesium Absorption Ratio (MAR), 7) Residual sodium bicarbonate (RSBC) , 8) Langelier Saturation Index (LSI), 9) Ryznar stability index (RSI).

Table 5.24: Water suitability index details, including calculation formula and ranges :

Sl No.	Indices	Formula	Range	Reference
1	Sodium Absorption ratio (SAR)	$\text{Na} / \sqrt{(\text{Ca} + \text{Mg}) / 2}$ in meq/l	2-8=very sensitive 8-20=moderately sensitive 20-50=Moderately tolerant 50-100=tolerant	Sodium Absorption ratio ,irrigation, soil health published by Kate Wisialowski
2	Sodium percentage (%Na)	$[\text{Na} / (\text{Ca} + \text{Mg} + \text{Na} + \text{K})] * 100$ in meq/l	Excellent (<20), Good (20-40), Permissible (40-60),	Application of water quality index (WQI)

			Doubtful (60–80), and Unsuitable (>80)	and statistical techniques to assess water quality for drinking, irrigation, and industrial purposes of the Ghaghara River, India by Nidresh Kumar Ravu et al.
3	Kelly's Ratio (KR)	$\text{Na}/(\text{Ca}+\text{Mg})$ in meq/l	<1=suitable for irrigation >1 =unsuitable for irrigation	Assessment of groundwater quality for irrigation by A.Nagaraju et AL.
4	Permeability Index (PI)	$[(\text{Na}+\sqrt{\text{HCO}_3})/(\text{Ca}+\text{Mg}+\text{Na}+\text{K})]*100$ in meq/l	class I -(> 75%, suitable), class II - (25–75%, good) and classIII - (< 25%, unsuitable) for irrigation	Assessment of groundwater quality for irrigation use by Kishan S. Rawat et Al. Doneen (1964)
5	Potential Salinity (PS)	$\text{Cl}+(1/2)\text{SO}_4$ in meq/l	PS<3 suitability of water for irrigation	Assessment of groundwater quality for irrigation use by Kishan S. Rawat et Al. Doneen (1964)
6	Magnesium Absorption Ratio (MAR)	$[\text{Mg}/(\text{Ca}+\text{Mg})] * 100$ In meq/l	MAR>50% not recommended for irrigation purpose	Assessment of groundwater quality for irrigation use by Kishan S. Rawat et Al. Khodapanah et al. 2009
7	Residual sodium bicarbonate (RSBC)	(HCO_3-Ca) in meq/l	RSBC index values of <5 meq/L indicates water suitable for irrigation	Application of water quality index (WQI) and statistical techniques to assess water quality for drinking, irrigation, and industrial purposes of the Ghaghara River, India by Nidresh Kumar Ravu et al. Ravikumar et al. 2011
8	Langelier Saturation Index (LSI)	pH (measured)-pHs where $\text{pHs}=(9.3+\text{A}+\text{B})-(\text{C}+\text{D})$ $\text{A}= (\text{Log}_{10}[\text{TDS}] - 1)/10$ $\text{B}= -13.12 \times \text{Log}_{10}(\text{oC} + 273) + 34.55$ $\text{C}= \text{Log}_{10}[\text{Ca}^{2+} \text{ as } \text{CaCO}_3] - 0.4$ $\text{D}= \text{Log}_{10}[\text{alkalinity as } \text{CaCO}_3]$	The positive value of LSI indicates the saturation of calcium carbonate and its potential to form scale.	Langelier (1936)
9	Ryznar stability index (RSI)	2pHs-pH (measured) Where pHs denote the pH at	RI<5.5- Heavy scale will form 5.5<RI<6.2- scale will form 6.2<RI<6.8-No difficulties	References: [1] : Kevin Rafferty, Scaling in geothermal heat pump systems,

		saturation of calcium carbonate	6.2<RI<8.5-water aggressive RI>8.5 aggressive	is	U.S. Department of Energy (july 1999) [2] : Metcalf and Eddy, Wastewater Engineering Treatment and Reuse 2003 Explanation of Ryznar Stability Index formula.
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Results of different water suitability index for agriculture and industrial use i.e. SAR,%Na,KR,PS,PI etc. are given in Table 5.26 to 5.29. After analysis it has been found that SAR value lies mainly in the range of 50-100 and so many places it is >100. Therefore, Sodium content is very high and Electrical Conductivity (EC) and TDS is also very high. Excess salinity will reduce the osmotic activity of plants and create hindrance to assimilate water and nutrients from the soil. EC indicates the presence of sodium & chloride ions, which may appear due to the use of fertilizer. Continuous usage of water with high SAR may cause prolonged damage to soil and may reduce Permeability of soil and in turn crop yield is decreased. %Na is determined from the values of sodium, potassium, calcium and magnesium. Presence of sodium in water is represented by soluble sodium or percent sodium. %Na is classified into five types unsuitable, doubtful, permissible, good and excellent. Wilcox diagram is generally used to evaluate the appropriateness for irrigation using %Na and EC. It is categorized as very good to good, Good to permissible, Doubtful to unsuitable, unsuitable and permissible to doubtful.

Table 5.25: Calculation of Agricultural and Industrial suitability Index (Monsoon season)

places	SAR	Na%	Kelly's ratio	Permeability Index	Potential salinity	MAR	RSBC	LSI	RSI
S-10 HT	48.09	73.33	3.62	75.24	840.45	28.40	6	-1.10	9.2
S-10 LT	29.46	63.72	2.14	66.28	391.8	26.59	-3	-1.24	9.1
S-9 HT	51.38	74.33	3.96	76.20	668	27.38	9.5	-1.42	9.5
S-9 LT	43.84	71.53	3.44	73.63	349	28.39	9	-1.91	9.9
S-8 HT	42.49	66.06	2.45	67.60	1100.5	32.66	-28	-1.55	9.5
S-8 LT	31.07	60.88	1.85	62.84	785.5	30	-28	-1.48	9.3
S-7 HT	42.88	67.89	2.61	69.63	963	33.58	-8	-1.29	9.3
S-7 LT	39.48	66.25	2.42	68	818.5	26.31	-26	-1.30	9.2
S-6 HT	78.32	79.41	6.31	80.96	1193.5	37.66	42.9	-1.62	9.9
S-6 LT	70.35	80.24	6.21	82.03	1055.5	43.75	43	-1.00	9.4
S-5 HT	70.57	76.24	4.94	77.78	1455	38.23	40	-1.15	9.3
S-5 LT	67.56	77.84	5.55	79.61	1237.5	39.18	43	-1.16	9.5
S-4 HT	80.61	77.97	5.7	79.41	1790.5	31	42	-0.79	8.9
S-4 LT	81.03	79.81	6.28	81.27	1417	38.55	40	-0.98	9.3
S-3 HT	84.81	77.46	5.71	78.81	1924.5	37.27	52	-0.63	8.8
S-3 LT	81.24	78.30	6.05	79.66	1694.5	35.55	31.5	-0.77	9.1
S-2 HT	85.34	76.54	4.89	77.69	2344.5	33.55	25	-0.40	8.5

S-2 LT	62.62	72.33	4.07	73.79	2014.5	36.44	20	-0.72	9.0
S-1 HT	90.88	76.88	4.98	77.94	2730.5	37.95	28	-0.36	8.5
S-1 LT	73.48	74.33	4.37	75.55	2283.5	36.17	12	-0.52	8.7

Table 5.26: Calculation of Agricultural and Industrial suitability Index (Post-Monsoon season)

places	SAR	Na%	Kelly's ratio	Permeability Index	Potential salinity	MAR	RSBC	LSI	RSI
S-10 HT	61.48	73.37	3.72	74.66	828.5	25.73	-21	-1.14	9.1
S-10 LT	35.19	64.48	2.24	66.52	561	29.26	-11	-1.14	9.0
S-9 HT	68.54	76.88	4.70	78.30	849	29.24	10	-1.23	9.3
S-9 LT	47.33	71.45	3.36	73.34	460.90	24.24	2	-1.27	9.2
S-8 HT	59.37	71.96	3.38	73.28	1452.25	47.40	11	-1.24	9.3
S-8 LT	45.96	69.30	2.94	71.03	893.5	33.60	-1	-1.38	9.3
S-7 HT	71.62	76.24	4.78	77.72	1505	29.46	30	-1.22	9.2
S-7 LT	50.83	71.94	3.42	73.76	917.5	31.81	16	-1.30	9.2
S-6 HT	88.24	79.50	6.43	80.99	1619	35.10	69	-1.14	9.2
S-6 LT	79.76	79.02	6.11	80.60	115.1	35.29	53	-0.67	8.8
S-5 HT	90.00	78.45	5.76	79.81	1935.5	37.70	71	-0.81	8.8
S-5 LT	92.23	80.63	7.24	82.10	1490.5	38.27	65.5	-0.79	9.0
S-4 HT	118.93	81.90	8.05	83.08	1955	33.02	88	-0.59	8.6
S-4 LT	89.09	78.04	5.72	79.27	2155.5	37.19	44	-0.58	8.6
S-3 HT	110.75	79.21	6.09	80.23	2910	38.18	67.8	-0.33	8.3
S-3 LT	93.53	78.01	5.63	79.14	2505	37.68	42	-0.40	8.5
S-2 HT	118.36	78.93	5.78	79.78	3241.5	38.75	45	-0.24	8.2
S-2 LT	91.38	75.91	4.81	76.97	3008	38.33	33	-0.38	8.4
S-1 HT	128.11	78.66	5.78	79.43	4053.5	37.55	40	0.10	7.9
S-1 LT	96.32	75.73	4.49	76.63	3621.5	36.95	7	-0.10	8.1

Table 5.27: Calculation of Agricultural and Industrial suitability Index (Winter season)

places	SAR	Na%	Kelly's ratio	Permeability Index	Potential salinity	MAR	RSBC	LSI	RSI
S-10 HT	62.87	74.33	3.94	75.65	777.6	27.55	-12	-1.17	9.2
S-10 LT	35.16	65.64	2.41	67.84	499.3	29.24	-1	-1.24	9.2
S-9 HT	69.73	77.32	4.88	78.77	815.75	30.39	16	-1.37	9.5
S-9 LT	56.47	75.54	4.16	77.26	415.74	25	7	-1.42	9.4
S-8 HT	51.36	67.62	2.53	68.88	1347	35.60	-38	-1.13	8.9
S-8 LT	47.19	68.62	2.80	70.18	773.25	28.05	-20.8	-1.44	9.1
S-7 HT	51.67	67.50	2.63	68.86	1306.5	34.82	-21	-1.09	8.9
S-7 LT	46.34	68.92	2.76	70.66	879.15	26.89	-6	-1.22	9
S-6 HT	89.74	80.10	6.58	81.58	1545.15	37.63	70	-1.35	9.3
S-6 LT	70.54	79.16	5.76	81.02	1279	34.66	54	-1.02	9.2
S-5 HT	91.79	79.47	6.07	80.81	1882	35.96	63.5	-0.7	8.8
S-5 LT	72.36	77.68	5.83	79.52	1391.5	41.55	68	-0.72	9.2
S-4 HT	96.18	78.75	5.78	79.92	2249.5	29.71	46	-0.73	8.6
S-4 LT	74.96	77.32	4.96	78.82	2016	37.71	49.7	-0.42	8.9
S-3 HT	104.22	78.82	5.79	79.88	2822.5	37.65	58	-0.54	8.5
S-3 LT	96.49	78.68	6.0	79.82	2354	39.53	50	-0.32	8.7
S-2 HT	106.50	77.92	5.28	78.87	3115	36.94	43	-0.44	8.3

S-2 LT	93.59	76.61	4.98	77.62	2950	35.79	20.4	-0.22	8.6
S-1 HT	129.33	79.49	5.99	80.27	3961.5	38.62	41	-0.32	8.3
S-1 LT	106.56	77.35	5.11	78.17	3360.5	36.40	3	-0.37	8.4

Table 5.28: Calculation of Agricultural and Industrial suitability Index (Pre-Monsoon season)

Location	SAR	Na%	Kelly's ratio	Permeability Index	Potential salinity	MAR	RSBC	LSI	RSI
S-10 HT	64.44	75.68	4.19	77.03	853.05	27.96	-7.4	-0.93	8.9
S-10 LT	33.16	65.56	2.31	67.95	446.19	29.12	2	-1.22	9.0
S-9 HT	60.33	75.30	4.20	76.86	814.75	29.12	8	-1.30	9.3
S-9 LT	53.50	74.39	3.88	76.11	407.15	28.42	5	-1.42	9.3
S-8 HT	52.27	69.83	2.85	71.22	1204.9	35.08	-18.5	-1.02	8.8
S-8 LT	44.45	70.44	3.02	72.35	579.75	28.28	1.4	-1.38	9.2
S-7 HT	58.82	71.49	3.21	72.89	1197	33.29	-1	-0.81	8.6
S-7 LT	56.09	71.95	3.35	73.39	861.5	26.32	-15	-1.11	8.9
S-6 HT	90.66	80.05	6.87	81.58	1457.5	36.78	75.6	-0.92	9.0
S-6 LT	82.82	80.72	7	82.41	1172.5	35.71	60	-0.53	8.7
S-5 HT	100.0	80.54	6.71	81.82	1770.5	36.93	72	-0.61	8.6
S-5 LT	100.28	82.21	8.24	83.68	1319	39.18	74	-0.69	8.8
S-4 HT	107.75	80.62	6.58	81.79	2172.5	33.58	76	-0.43	8.3
S-4 LT	91.25	78.79	5.99	79.97	1940.5	37.06	35	-0.54	8.7
S-3 HT	108.22	79.26	5.93	80.27	2751	39.15	57	-0.22	8.2
S-3 LT	100.93	80.44	6.38	81.57	2272.5	39.2	49	-0.33	8.4
S-2 HT	110.72	78.89	5.52	79.81	3057.5	37.81	43	-0.09	8.0
S-2 LT	92.73	76.75	5.02	77.82	2883.5	36.47	35	-0.16	8.2
S-1 HT	126.45	79.61	5.88	80.38	3822	37.66	30	0.08	7.9
S-1 LT	101.21	77.04	4.89	77.90	3272.5	36.91	3	0.02	8.0

Kelley's Ratio (KR) > 1 indicates an abundance level of sodium in waters and unacceptable for irrigation. Here, KR is much more than desirable limit i.e. 1 and not fit for irrigation and therefore, highest value of sodium in the water. Permeability index (PI) of water is calculated using sodium, carbonates, calcium and magnesium. PI is classified under class I, class II and class III as per limiting values, less than 25 % it is classified as class I, 25% to 75 % it is classified as class II and greater than 75 % it is classified as Class III. Here almost all the location in all 04 seasons comes under category Class-III which is not fit for irrigation due to very less permeability. River water with elevated concentration of magnesium, if used for irrigation purpose damages soil structure and causes high salinity. Calcium and magnesium are present in water in an equilibrium state and they behave independently in soil system. After analysis it has been found that Magnesium Absorption Ratio (MAR) comes in the range of 25~40 % which is less than 50% i.e. suitable for irrigation purposes. More content of magnesium in water will adversely affect crop yields as the soils become more alkaline and not suitable for irrigation. Doneen (1964) described potential salinity (PS) of irrigation water by pointing out that the suitability of water for irrigation is not only dependent on the concentration of soluble salts. He was also reported that the low solubility salts precipitate and accumulate in the soil for successive irrigation whereas the concentration of highly soluble salts increases the salinity of the soil. In the study area PS comes exceedingly high around 300 ~ 3000 meq/l due to presence of high concentration of chloride in water, therefore not suitable for irrigation purpose. It

has been reported that chloride is not adsorbed or held back by soils, but it moves readily with the soil-water into the crop. It travels in the transpiration stream and accumulates in the leaves. Thus, excessive chloride could cause necrosis (dead tissue) in plants which is often accompanied by early leaf drop or defoliation. Here, Cl content after analysis comes in the range of 300~3000 mg/l and beyond the permissible limit of BIS and WHO. Hence, chloride concentrations obtained in this study is injurious to plants and it will effect crops. Water with a carbonate concentration larger than the calcium and magnesium concentration is recognized by the term “residual sodium carbonate”. Residual Sodium Carbonate index (RSC) refers alkalinity hazard to soil. If the sodium in clayey soil is higher it causes swelling and reduces infiltration capacity. Generally, carbonate appeared in the form of bicarbonate (HCO_3) in all the water samples, because carbonate alkalinity was zero in all samples. Here, bicarbonate (HCO_3) value comes in the range of 60-180 which is beyond permissible limit. Higher values of bicarbonate cause problem like corrosion in water pipelines. RSBC after analysis comes in the range of -1 to 70. At very few points in U/S mainly, value of RSBC comes within range of 5 which is suitable for irrigation. However, most of the places in are outside the desirable limit and not suitable for irrigation. Entire stretch of River water is falling under unsuitable category of water for irrigation purposes. Thus, the use of river water for irrigation (without treatment) in the study area will damage crops and also reduce the production of crop. However, more saline or salt-tolerable crops could be grown with a good irrigation system to stop soil salinization by using lime/gypsum treatment to bout permeability of the soils i.e. base-exchange process).

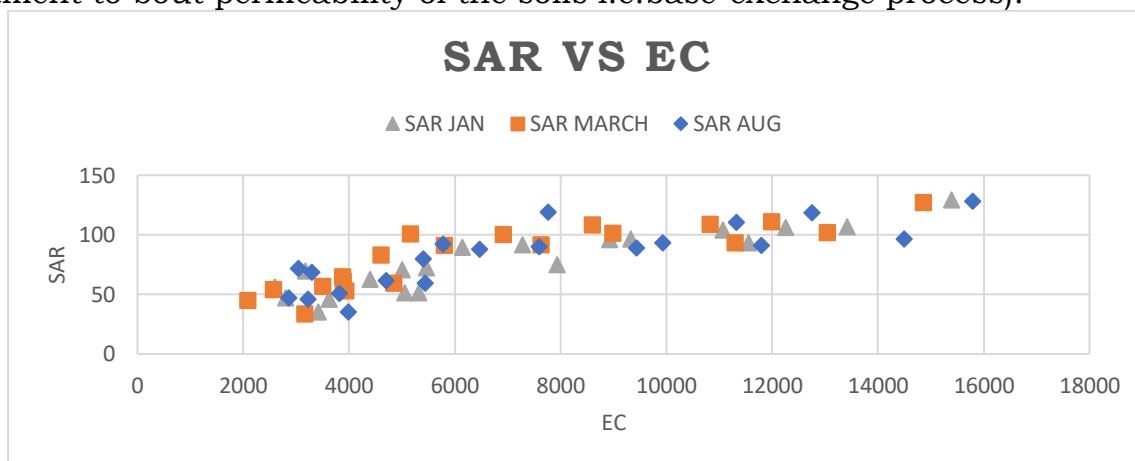


Fig 5.7 : Graph showing seasonal variation for SAR vs EC

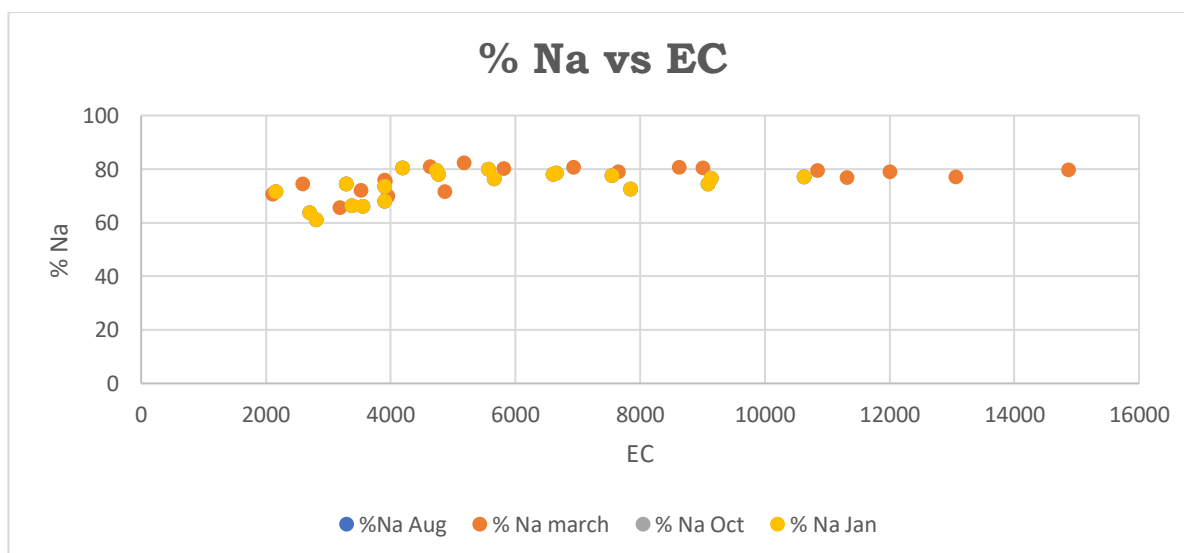


Fig 5.8 : Graph showing seasonal variation for %Na vs EC

The suitability of water for industrial purposes depends upon its ability to form scale and its corrosive nature. Scaling is one of the most critical water quality issues in India. Scale can be formed from a variety of dissolved chemical species but two reliable indicators are hardness and alkalinity. Calcium carbonate is the most common form of scale deposition attributable to water. Two indices commonly used in the water treatment industry to evaluate the nature of a water source are the Langelier Saturation Index (LSI or Saturation index) and the Ryznar Stability Index (RSI or Stability index) and in both cases these indices are based upon a calculated pH of saturation for calcium carbonate (pHs).

The Langelier Saturation Index (LSI) is the unbiased measure of water balance and most water treatment industries use the LSI. In the 1930s, Dr. Wilfred Langelier developed his index to know whether water becomes corrosive or scale-forming. In short, the LSI tells us how saturated our water is with calcium carbonate (CaCO_3). The correlation of pH and LSI presented here, indicate clearly that alkaline waters are scale forming and acidic waters corrosive in nature. Perfect saturation value is 0.00 LSI and but after analysis value comes in the range of -1 to -1.5, therefore water is aggressive in nature as it is under-saturated with calcium carbonate. LSI values indicated that collected samples are unsuitable due to scale formation problems. Ryznar Stability Index (RSI) values mainly indicates corrosiveness due to formation of scale. Ryznar attempted to quantify the relationship between calcium carbonate saturation state and scale formation. Here RSI value mainly in the range of 8.5 ~ 9.8, therefore very aggressive in nature and will create high corrosivity in pipeline. Waters with high corrosive property cannot be transported in metallic pipes and non-corrosive PVC pipes may have to be used. Thus, both the scaling as well as corrosive nature of water will make the pipes unfit for regular domestic use. Therefore, it becomes highly imperative for the civic authorities to pay due attention to scale forming and corrosivity and reduce the adverse effects that may be caused.

5.6 Gibb's Plot

J.R. Gibbs in 1970 first published the concept of controlling world water chemistry. The Gibbs Diagram depicting the boomerang contour applied in groundwater hydrochemistry. The main processes includes evaporation, precipitation, and water-rock interaction plotting sodium/(calcium + sodium) ratios (x-axis) are plotted against total dissolved solids (salinity) on y-axis. The quality of groundwater is significantly changed by the influence of weathering and anthropogenic inputs. The Gibbs diagram is widely used to establish the relationship of water composition and aquifer lithological characteristics. According water samples were evaluated and plotted in Gibb's diagram from Fig 5.8 to 5.11 and it has been found that major contributing ions are rock dominance and rest of the ions are beyond the limit and shows high precipitation or runoff having tendency to move towards sea water. the Gibbs Diagram does not provide information about SO_4 concentrations such as pyrite oxidation or gypsum dissolution which is also important to groundwater major element compositions.

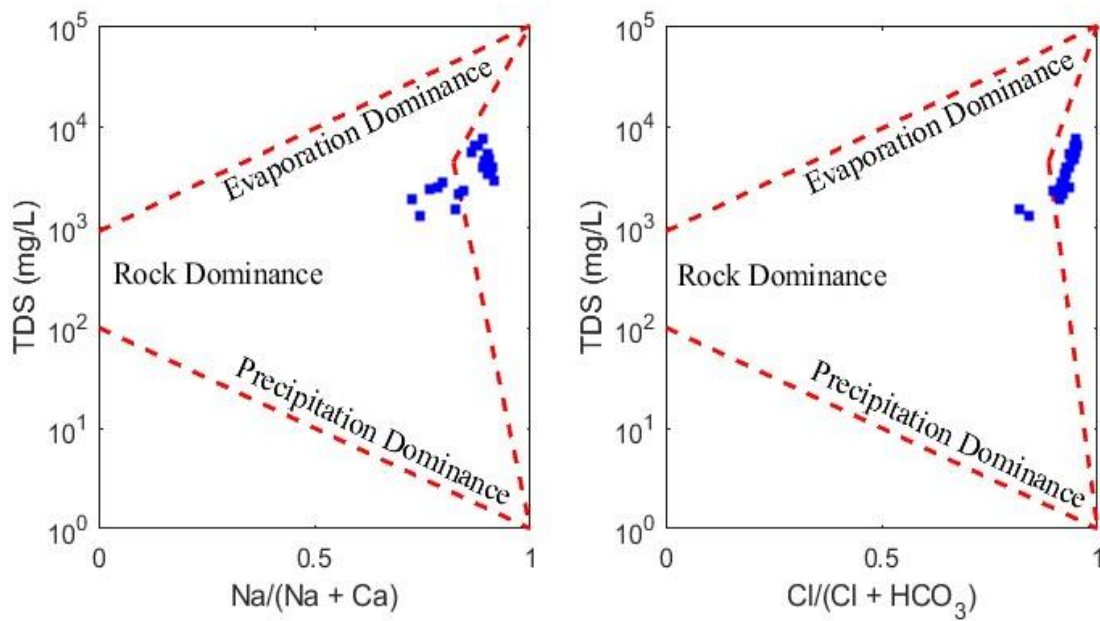


Fig 5.9 Gibbs plot showing processes controlling major ion chemistry for monsoon season

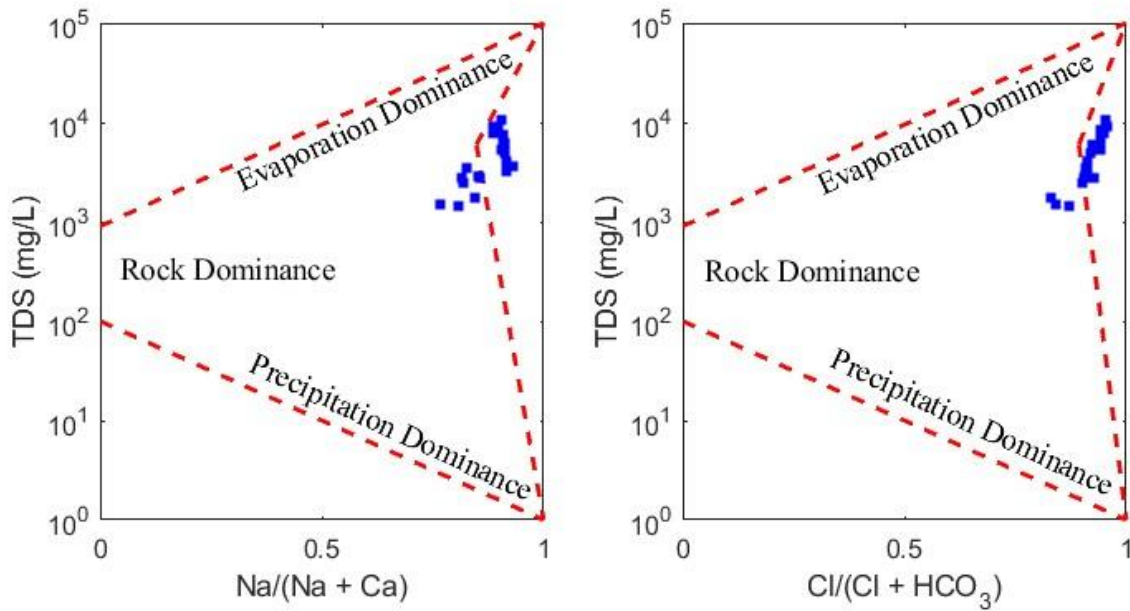


Fig 5.10 Gibbs plot showing processes controlling major ion chemistry for pre-monsoon season

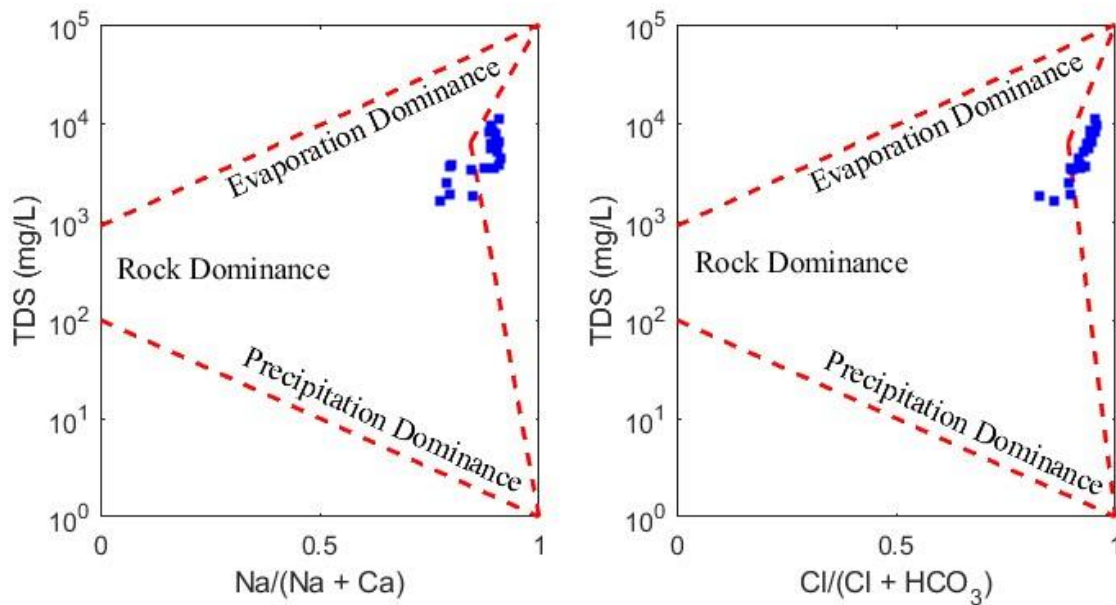


Fig 5.11 Gibbs plot showing processes controlling major ion chemistry for winter season

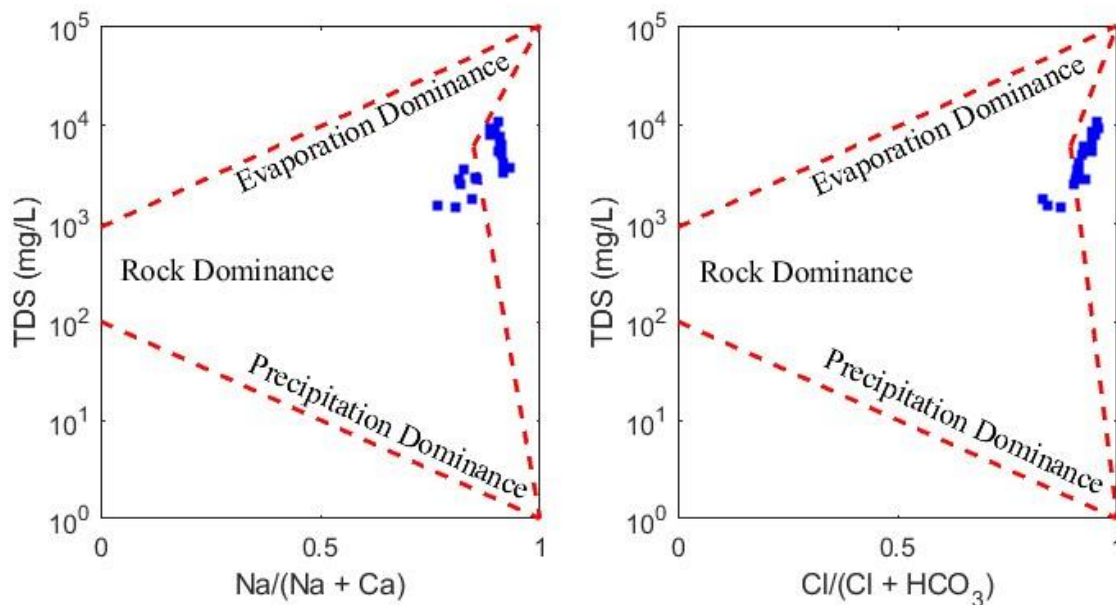


Fig 5.12 Gibbs plot showing processes controlling major ion chemistry for Pre-monsoon season

5.7 Piper's Plot

In 1994, Arthur M. Piper, proposed an effective graphic procedure to segregate relevant analytical data to understand the sources of the dissolved constituents in water. Most natural waters contain cations and anions in chemical equilibrium. It is assumed that the most abundant cations are two “alkaline earths” calcium (Ca) and magnesium (Mg) and one “Alkali” sodium (Na). The most common anions are one “weak acid” bicarbonate (HCO_3) and two “strong acids” sulphate (SO_4) and chloride (Cl). Two triangles corresponding with the cations and anions, respectively, and one diamond that summarize both triangles. The left triangle represents the

cations and the right one the anions. From Piper's Plot it has been shown that Chloride (Cl^-) and Alkalinity (HCO_3^-) are the most dominant ions and cations like Ca^{+2} , Mg^{+2} are not contributing too much over these anions, therefore high concentration of total dissolved solids in the river water seen. Accordingly, Piper's plot prepared based on the analytical data and given in Fig. 5.12 to 5.15. This graph not only helps to identify the type of water, but also to understanding geochemical processes that affect its composition and it is also used in geochemistry to illustrate the composition of water or sediment samples based on their chemical constituents.

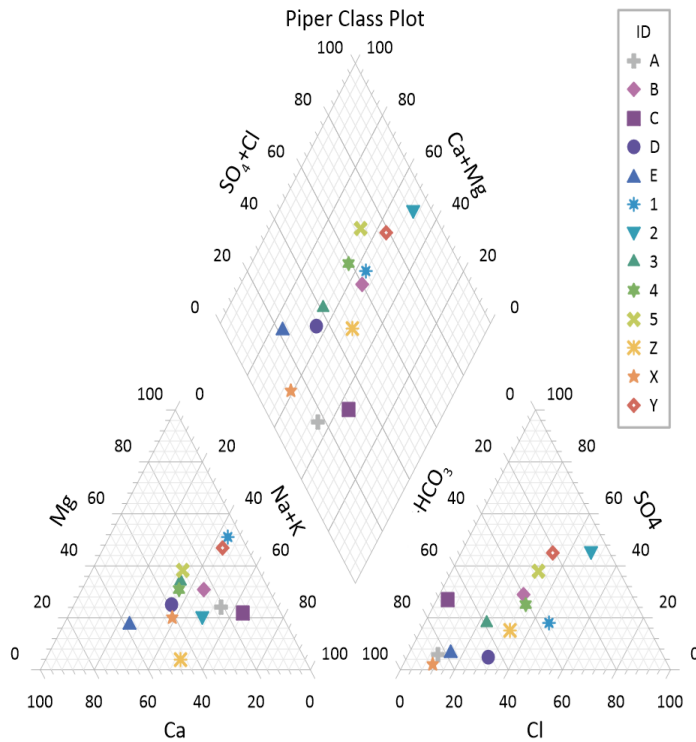


Fig 5.13 : Piper plot showing dominant cation and anion in monsoon season

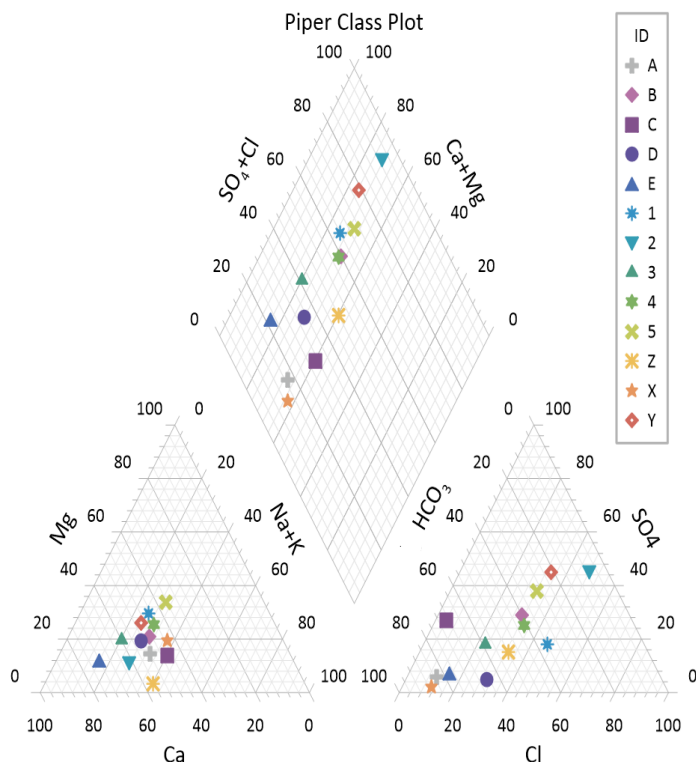


Fig 5.14 : Piper plot showing dominant cation and anion in Post-monsoon season

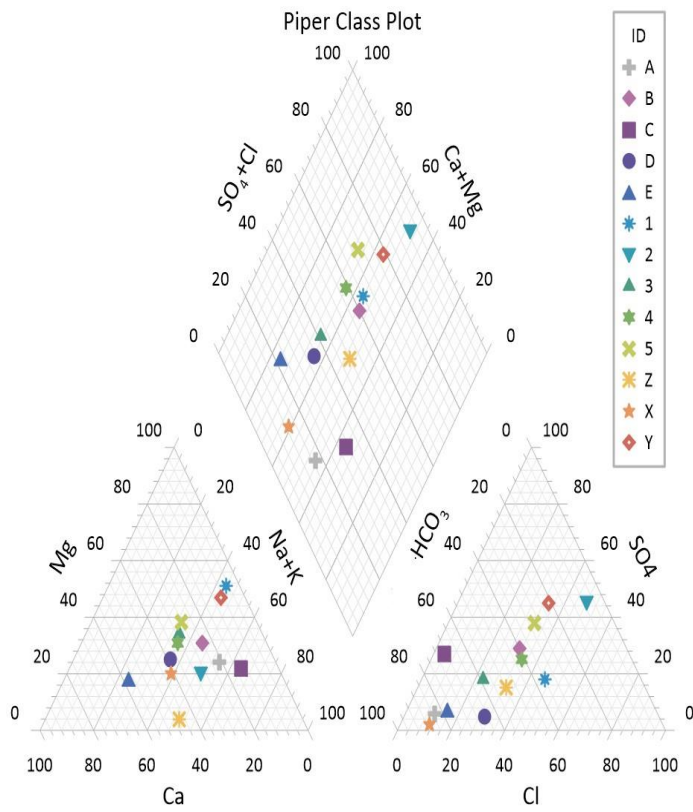


Fig 5.15 : Piper plot showing dominant cation and anion in winter season

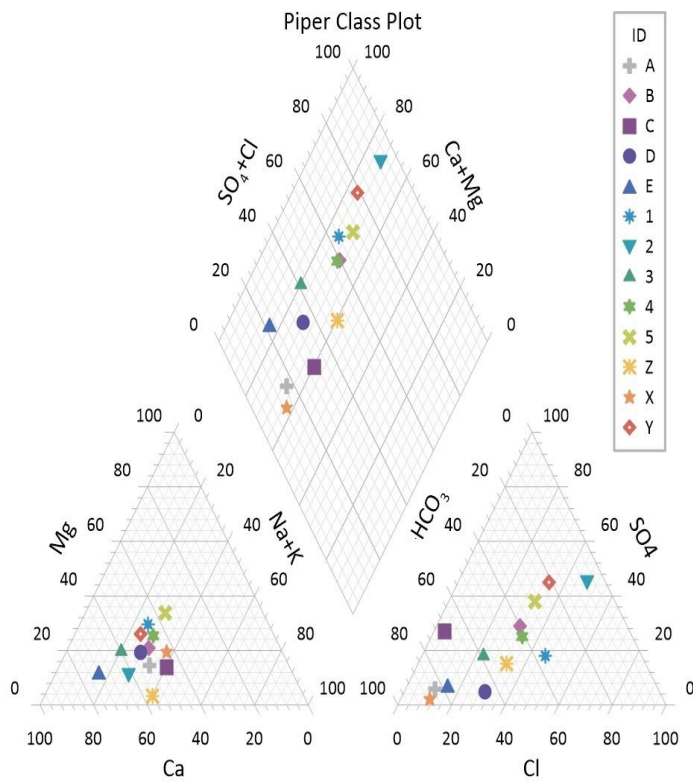


Fig 5.16 : Piper plot showing dominant cation and anion in Pre-monsoon season

6. Conclusion:

A stretch of Hooghly river has been considered in this study to understand the suitability of river water for human activities, agricultural and industrial use etc. As we all know that tidal effect in Hooghly river is very high, therefore all the major cations and anions show significant changes in tidal variation as well as seasonal variation. This river also in the mouth of Bay of Bengal and last point considered in this study which is Haldia Dock is very close to Sagar Island. Therefore, Salinity is very high which is undesirable for all purposes like household, irrigation, horticulture etc. From U/S to D/S changes in Salinity with tidal and seasonal variation is noticeable. Considering the fact, after analysis it has been found that river is rich in TDS, Chloride and Sodium ions are the most abundant in nature and contributing extensively in the dissolved solids concentration. Therefore all the parameters considering Cl^- and Na^+ are high and not fit for use of different purposes. As TDS is high, EC is also very high and shown same approach like TDS and not suitable for use of irrigation and other purposes. To understand the suitability of river water for irrigation purposes SAR, %Na, KI, PI, PS, MH, RSBC have been determined. The value of the parameters indicate that this water is not suitable for irrigation and required treatment before use to reduce soil salinization by using lime/gypsum treatment process etc. From the value of LSI, it can be stated that most of the area of water is aggressive in nature and unsuitable for industrial purposes due to formation of scale. Also the value of RSI indicates that the river water is highly corrosive and high scale forming, therefore not fit for industrial use. Due to these high corrosivity pipeline will be corroded and will become highly imperative and not usable for domestic use also. The WQI in the study will help to understand the quality of river which is very poor neither suitable for household use nor suitable for irrigation. During the study it has been observed that salinity is high in Hooghly river, therefore desalination plant may be installed at intake to remove salinity. Most popular methods like Reverse Osmosis, Ion Exchange methods etc. can be used for desalination plant. The increases in salinity affects the crop growth also in the soil, hence proper drainage is necessary in the areas of high salinity to have the satisfactory growth of the soil. These river water needs serious observation before further reduction in WQI. Huge number of industries have been grown up from decade in the entire stretch of Hooghly river and accordingly so many habitation are also there centering the Hooghly river. In the era of scarcity of water if Water Treatment Plant (WTP) can be installed to treat river water it will be beneficial for all the users. Due to presence of several industries and household, effluents also been discharged at river and the proper treatment of water by constructing Sewage treatment plant (STP) will help to use river water at different purposes. However, use of pesticides, fertilizers etc. in agricultural land needs to be curtailed so that during surface runoff river water not get polluted through non point source.

7 Limitation and Future scope of Study

The study has several limitations that should be noted. Firstly, the study focused solely on a stretch of a Hooghly river. The confluence point of difference river with Hooghly river should be taken into account. So that if any change in parameter noticed same may be include in the analysis. WQI gives an indicative value of water quality in which few parameters have not been considered. Only few parameters has been considered and therefore Parameter like Arsenic has not been included in this study. The discharge point of several industry in the river should be taken so that actual scenario of metallic ions may be analyzed in future. Finally, the study did not take into account the potential impacts of climate change or other environmental factors on pesticide contamination upon the water quality of river. Despite the limitations, this study lays the foundation for future research in the field of water treatment and industrial and agricultural contamination. Further research could expand the scope to include a wider range of design of treatment plant to serve the local people a good and environment friendly water. The region of future study upon Hooghly river required to be expand to get the more accurate picture of water quality.

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