Assessment of Water Quality of Adi Ganga at Bansdroni and Kalighat points using WAWQI and CCMEWQI Methods

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I hereby declare that this thesis contains a literature survey and original research by the undersigned candidate, as part of my **Master of Engineering** in **Water Resources & Hydraulic Engineering** in the Faculty of Interdisciplinary Studies, Jadavpur University during the academic session 2019-2022.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

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This is to certify that the thesis entitled **"Assessment of Water Quality of Adi Ganga at Kalighat and Bansdroni points using WAWQI and CCMEWQI Methods"** is a bonafide work carried out by Mr. Uttam Kumar Mandal under my supervision and guidance for partial fulfilment of the requirement for the Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academic session 2021-2022.

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This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned does not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approves the thesis only for the purpose for which it has been submitted.

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ABSTRACT

In this study, the water quality of Adi Ganga (Tolly Nullah) was assessed for two sampling points at Kalighat and Bansdroni located in South Kolkata, West Bengal, India.The West Bengal Pollution Control Board (WBPCB) collected raw water samples from the above stations and in the months of June, July, September, October in 2014 and February, May, August, November every year from the year 2015 to 2020 and subsequently tested different water quality monitoring parameters.

These results have been studied in the present study to determine the Water Quality Index (WQI). The WQI is a standard tool that is internationally accepted for assessing water quality. It includes the concentration of several constituents present in it. WQI reduces a large number of water quality indicators into helpful for the selection of appropriate treatment techniques to meet the concerned issues.

The objective of this study is to evaluate the water quality of raw water of Kalighat and Bansdroni in terms of WQI under the influence of several physical, chemical and biological parameters by using the Weighted Arithmetic Water Quality Index (WA WQI) and the Canadian Council of Ministers of Environment Water Quality Index (CCME WQI) methods. No radioactive substances were considered. This study also partly reflects the water quality of the Hooghly river at the sampling points as tidal ingression occurs here. The evaluation is done as per data available for seven physico-chemical and biological parameters i.e. pH, biochemical oxygen demand (BOD), Dissolved Oxygen (DO), total coliform, Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), fecal coliform for consecutive seven years from 2014 to 2020. The results were compared with the standards set by the Bureau of Indian Standards (BIS).A total of 441test reports of water were collected andevaluated by comparing their values with the BIS.

The obtained CCME WQI values for Bansdroni (out of 31 values, 24 are poor, 6 are marginal and only one is fair) and for Kalighat (out of 32 values, 25 are poor and 7 are marginal) indicate the "poor" and not suitable for drinking without treatment. WA WQI values for both the above stations (all values of WA WQI >100) also indicate the raw water quality is "unfit for consumption" by humans without proper treatment. CCME WQI values of Bansdroni and Kalighat are observed the highest in August 2019 and the lowest in August 2015 for Bansdroni and November 2014 for Kalighat, respectively. It specifies that BOD was one of the main parameters affecting water quality for this study during this period.

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List of Symbols

Mg/l	Milligrams per litre
NTU	Nephelometric Turbidity Unit
TU	Turbidity Unit
pCi/L	Picocurie per litre
MLD	Millions of Litres per Day
MGD	Million Gallons per Day
MPN	Most Probable Number

CHAPTER-I

1.1 Introduction

Water is the basic necessity for the functioning of all life forms that exist on Earth. Life without water is not possible. Water is present on the planet in different forms. However, despite its vast abundance, its usability is strictly restricted to fresh water and its quality for regular human consumption and usage. The scarcity of water in particular affects all developmental programmes and projects in all aspects of economic and social life.

The volume of water on the Earth is about 1.386 km^3 with almost 97.5% being salt water and 2.5% being fresh water. Most of that freshwater is located in freezing places and only 0.3% is in liquid form in rivers, lakes, ponds, reservoirs, soil and the atmosphere. Earth's water is finite which means the amount of water in, on and above our planet does not increase or decrease. In today's world, the river is considered one of the major sources of surface water and has a significant contribution to carrying water and nutrients to areas across the world. It plays a major role in the water cycle, acting as a drainage channel for surface water. About 40% of the world's food supply is grown under irrigation and a wide variety of industrial processes depend on water (BCAS, 2000). It has introduced river is now an important source of safe water which globally serves about 2,000 $km^3$of fresh water.

It is therefore a growing civilization with lots of human activities seen on the banks of rivers. Now the rising trend of civilization has put a great threat to the river water quality, particularly in developing countries. It is noted that increasing scenario of population density, land development along the river basin, urbanization and industrialization have been subject to water pollution and environmental deterioration of the water of the river (Sumok, 2001). One of the reasons behind the deterioration of river water quality is demonstrated that most rivers are considered the end point of urban effluent discharges without any prior treatment. It was also found that and extent of the industrial, agricultural and other anthropogenic activities in the basin and reduced river discharges have introduced the foremost problem for safe water (Chowdhury et al., 2004).

Water pollution is a serious issue for the environment and human health. Water pollution is the release of substances into bodies of water that makes water unsafe for human use and disrupts aquatic ecosystems. Good quality drinking water is one of the necessities of life. The aesthetic quality of drinking water should be pleasant, clear, colourless, and well-aerated without unpalatable taste and order. Suitability in terms of public health is also used to determine the microbiological, physical, chemical and radiological characteristics of water. This paper is based on the initiative taken to study the raw water quality of Kalighat and Bansdroni water quality monitoring stations of West Bengal Pollution Control Board (WBPCB) which are the main sources of surface water in the heart of South Kolkata.

Water quality is a measure of the condition of water relative to the requirements of one or more biotic species or any human need purpose (Johnson et al., 1997). It also refers to the physical, chemical and biological characteristics of water (Diersing and Mancy, 2009). A reference to a set of standards is most frequently used against which compliance can be assessed. One of the most common standards used to assess water quality relates to the safety of human contact, the health of ecosystems and drinking water.

The water quality index (WQI) provides a single number that expresses the overall water quality, at a certain location in the urban, rural and industrial areas and time based on several water quality parameters. The WQI is a mathematical means of calculating a single value from multiple test results. The water quality index represents a numerical expression that predicts and learns from natural processes in the environment and determines human impacts on an ecosystem. It is also necessary to determine physical, chemical and biological parameters.

Raw water samples have been collected from water quality monitoring stations Adi Ganga at Khalighat and Bansdroni by West Bengal Pollution Control Board in South Kolkata. This study attempted to know the raw water quality of the Kalighat and Bansdroni areas. This study also represents the analysis of the water quality of Adi Ganga which is the Hooghly river. South Kolkata is one of the integrated parts of Kolkata, known for its lush green park, ancient temples, gardens, hospitals and port area with the development of transportation, roads, multi-storeyed buildings, the lifestyle of the people of south Kolkata has changed and population density has been increasing rapidly comparing with north Kolkata. With this rapid growth of population, the demand for fresh water is increasing. Hooghly river is the main source of water in this South Kolkata zone. So, evaluation of water quality is important to know the present status of water of Hooghly river and also to find the solution to protect this water body for a better future for South Kolkata. Thus, the Canadian Council of Ministers of the Environment (CCME WQI) & Weighted Arithmetic Water Quality Index (WA WQI) methods have been applied to evaluate the raw water quality in this study.

1.2 Water Quality Parameters

There are three types of water quality parameters physical, chemical & biological (Gray, 2008; Spellman, 2017). Testing of water quality is very much essential before it is used for drinking, domestic, agricultural or industrial purposes. The test of water must be included with deferent parameters most of them are described here. The selection of parameters for testing of water is solely dependent upon for which purpose we are going to use that water and to what extent we need its quality and purity. Different parameters considered for water quality are given below.

1.2.1 Organoleptic and Physical Parameters

1.2.1.1Turbidity: Turbidity is the cloudiness of water (APHA, 2005). It is a measure of the ability of light to pass through water. It is caused by suspended materials such as clay, silt, organic material, plankton, and other particulate materials in water (Alley, 2007). Aesthetically, turbidity water is not acceptable in drinking water, which makes the water look unappetizing. Although, drinking water should have a turbidity of less than 5 NTU. Turbidity is measured by an instrument called a nephelometric turbid meter which expresses turbidity in terms of NTU or TU. A TU is equivalent to1 mg/l of silica in suspension (APHA, 2005). Turbidity of more than 5 NTU can be visible to the average person while turbidity in muddy water exceeds 100 NTU. Groundwater normally has very low turbidity because of the natural filtration that occurs as the water penetrates through the soil (Spellman, 2017; Viessman, Hammer, 2004)

1.2.1.2 Color: Materials decayed from organic matter, namely, vegetation and inorganic matter such as soil, stones, and rocks impart colour to the water, which is objectionable for aesthetic reasons, not for health reasons (APHA, 2005; Tomar, 1999). Colour is measured by comparing the water sample with standard colour solutions or coloured glass disks (APHA, 2005). One colour unit is equivalent to the colour produced by a 1 mg/l solution of platinum Potassium chloroplatinate (K_2PtCl_6) (APHA, 2005). The guide line value (maximum acceptable level) for the colour of drinking water is 15 TCU (True Color Unit).

1.2.1.3 Temperature: Palatability, viscosity, solubility, odours, and chemical reactions are influenced by temperature (APHA, 2005). Thereby, the sedimentation and chlorination processes and biological oxygen demand (BOD) is temperature-dependent (Davis, 2010). It also affects the bio sorption process of dissolved heavy metals in water (Abbas, 2014, White et al., 1997). Most people find water at temperatures of 10-15°C most palatable (APHA, 2005; Tchobanoglous et al., 1985). There is no guideline value for the temperature of drinking water.

1.2.1.4 Solid: Solids may present in water either in solution or in suspension (Tchobanoglous et al., 2003). They can be identified by using a glass fibre filter that the water sample passes through it. By definition, the suspended solids are retained on the top of the filter which is called Total Suspended Solids (TSS) and the dissolved solids pass through the filter with the water (APHA, 2005). If the filtered portionof the water sample is placed in a small dish and then evaporated, the solids as a residue. This material is usually called Total Dissolved Solids (TDS).

$$\text{Total Solid (TS)} = \text{TDS} + \text{TSS}.$$

1.2.2 Chemical Parameters

1.2.2.1 pH: One of the most important parameters of water quality is pH. It is defined as the negative logarithm of the hydrogen ion concentration (Spellman, 2017; Edzwald, 2010). It is a dimensionless number indicating the strength of an acidic or a basic solution (Hammer, 2011). The pH of water is a measure of how acidic/basic the water is (Tchobanoglouset al., 1985:Tomar, 1999). Acidic water contains extra hydrogen ions (H^+) and basic water contains extra hydroxyl (OH^-) ions (Alley, 2007). pH ranges from 0 to 14, with 7 being neutral. A pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base solution (Alley, 2007; Kiprono, 2017). Pure water is neutral; with a pH close to 7.0 at 25°C.Normal rainfall has a pH of approx. 5.6 (slightly acidic) owing to atmospheric carbon dioxide gas. Safe ranges of pH values are from 6.5 to 8.5 for drinking water and domestic use. It is also the need for living organisms (WHO, 2011).

1.2.2.2 Electrical conductivity (EC): The electrical conductivity (EC) of water is a measure of the ability of a solution to carry or conduct an electrical current (Tchobanoglous et al., 2003). Since the electrical current is carried by ions in solution, the conductivity increases as the concentration (APHA, 2005) of ions increases.

Units of its measurement are as follows (APHA, 2005; Tchobanoglous, 2003):

* U.S. units = micromhos/cm
* S.I. units = milli Siemens/m (mS/m) or dS/m (deci Siemens/m). The electrical conductivity can be used to estimate the TDS value of water as follows:

TDS (mg/L)≅EC (ds/m or umho/cm) × (0.55-0.7).

1.2.2.3 Acidity: Acids in a solution can be measured by acidity. The acidity of water is its quantitative capacity to neutralize a strong base to a selected pH level (APHA, 2005). Acidity in water is usually due to carbon dioxide, mineral acids, and hydrolyzed salts such as ferric and aluminium sulphates. Different processes like corrosion, chemical reactions and biological activities can be influenced by acids. The level of acid is determined by titration with standard sodium hydroxide (0.02N) using phenolphthalein as an indicator (APHA, 2005; Tomar, 1999).

1.2.2.4 Alkalinity: The alkalinity is the capacity of water to resist acidification. Alkalinity is the strength of buffer solution composed of weak acids and their conjugate bases. The measurement of the alkalinity of water is necessary to determine the amount of lime and soda needed for water softening (Tchobanoglous et al., 2003). The alkalinity of water is mainly caused by the presence of hydroxide ions (OH^-), bicarbonate ions ($HC0_3^-$) and carbonate ions (CO_3^{2-}) or a mixture of two of these ions in water.

1.2.2.5 Chloride: Chloride occurs naturally in groundwater, streams, and lakes, but the presence of relatively high chloride concentration in freshwater (about 250 mg/1 or more) may indicate wastewater pollution (Chatterjee, 2001). Chlorides may enter surface water from several sources including chloride-containing rock, agricultural runoff and wastewater. Chloride ions Cl^- in drinking water do not cause any harmful effects on public health, but high concentrations can cause an unpleasant salty taste for most people. Chlorides are not usually harmful to human beings; however, the sodium part of table salt has been connected to kidney and heart diseases (WHO, 1996). Small amounts of chlorides are essential to animal and plant life for ordinary cell functions. The standard chloride level for drinking water should not exceed 250 mg/L. One of the normal methods to measure the Chloride concentration in water is the titration by Silver nitrate (APHA, 2005).

1.2.2.6 Sulphate: Sulphate ions (SO_4^{2-}) occur in natural water and wastewater. The high concentration of sulphate in natural water is usually caused by the leaching of natural deposits of sodium sulphate or magnesium sulphate (Epson salt). If high concentrations are consumed in drinking water, there may be objectionable tastes or unwanted laxative effects (Davis, David, 2008), but there is no significant danger to public health.

1.2.2.7 Nitrogen: There are four forms of nitrogen in water and wastewater: organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. If water is contaminated with sewage, most of the nitrogen is in the forms of organic and ammonia, which are transformed by microbes to form nitrites and nitrates (Tchobanoglous et al., 2003)). Nitrogen in the nitrate form is a basic nutrient for the growth of plants and can be a growth-limiting nutrient factor (APHA, 2005). A high concentration of nitrate in surface water can stimulate the rapid growth of the algae which degrades the water quality. Nitrates can enter the groundwater from chemical fertilizers used in agricultural areas. Excessive nitrate concentration (more than 10 mg/L) in drinking water causes an immediate and severe health threat to infants (Tchobanoglous et al., 1985). The nitrate ions react with blood haemoglobin, thereby reducing the blood's ability to hold oxygen which leads to a disease called blue baby or methemoglobinemia (APHA, 2005; Tchobanoglous et al., 1985).

1.2.2.8 Fluoride:A moderate amount of fluoride ions (F^-) in drinking water contributes to good dental health (APHA, 2005:Tchobanoglous et al., 1985). The maximum allowable concentration of fluoride for potable water is 1.4 mg/1. Excessive amounts of fluoride causes discoloured tooth that is known as dental fluorosis (Davis, 2010; Tchobanoglous et al., 1985; Davis and David, 2008).

1.2.2.9 Iron and Manganese: Although iron (Fe) and manganese (Mn) do not cause health problems, they impart a noticeable bitter taste to drinking water even at a very low concentration (APHA, 2005; Davis, 2010).These metals usually occur in groundwater in solution as ferrous (Fe^{2+}) and manganous (Mn^{2+}) ions. These ions can also cause a black or brown stain on laundry and plumbing fixtures.

1.2.2.10 Copper and Zinc: Copper (Cu) and zinc (Zn) are nontoxic if found in small concentrations. They are essential and beneficial for human health and the growth of plants and animals (WHO, 1996). At high concentrations, zinc imparts a milky appearance to the water (APHA, 2005).They can cause undesirable tastes in drinking water.

1.2.2.11 Hardness: Hardness is a term used to express the properties of highly mineralized waters. Calcium (Ca) and magnesium (Mg) ions cause the greatest portion of hardness in naturally occurring waters (Spellman, 2017). These ions are present as bicarbonates, sulphates, and sometimes chlorides and nitrates (APHA, 2005; Davis and David, 2008). Generally, groundwater is harder than surface water. There are two types of hardness temporary hardness and permanent hardness (APHA, 2005; DeZuane, 1997; Tchobanoglous et al., 2003). From a health viewpoint, hardness up to 500 mg/1 is safe, but more than that may cause a laxative effect. Hardness is normally determined by titration with ethylene diamine tetra acidic acid (EDTA) and Eriochrome Black and Blue indicators. It is usually expressed in terms ofmg/L of $CaCO_3$(APHA, 2005; Tchobanoglous et al., 1985).

Total hardness mg/1 (as $CaC0_3$) = calcium hardness mg/1 (as $CaCO_3$) +magnesium hardness mg /1 (as $CaCO_3$).

1.2.2.12 Dissolved oxygen (DO): DO is considered to be one of the most important parameters of water quality in streams, rivers and lakes. The higher concentration of dissolved oxygen is the better water quality. Oxygen is slightly soluble in water and very sensitive to temperature. For example, the saturation concentration at 20°C is about 9 mg/l and 0°Cis 14.6 (Techobanoglous et al., 2003) mg/l. The actual amount of dissolved oxygen varies depending on the pressure, temperature, and salinity of the water. Dissolved oxygen has no direct effect on public health. There are three main methods used for measuring dissolved oxygen concentration: The calorimeter method (quick and expensive), the Winkler titration – traditional method and the electrometric method (APHA, 2005).

1.2.2.13 Biochemical oxygen demand (BOD): The BOD is the amount of oxygen consumed by bacteria in the decomposition of organic material (APHA, 2005; Tchobanoglous et al., 2003). BOD is determined by measuring the dissolved oxygen level in a freshly collected sample and comparing it to the dissolved oxygen level in a sample that was collected at the same time but incubated under specific conditions fora certain number of days at a certain temperature.

A graph of the BOD versus time is illustrated in Figure 1.1. This is called the BOD curve, which can be expressed mathematically by the following equation:

$$BOD_t = BOD_L \times (1-10^{-kt})$$

Where BODt = BOD at any time *t*, mg/L; BOD_L = ultimate BOD, mg/L; *k* = a constant representing the rate of the BOD reaction; *t* = time. The value of the constant rate *k* depends on the temperature, the type of organic materials, and the type of microbes exerting the BOD.

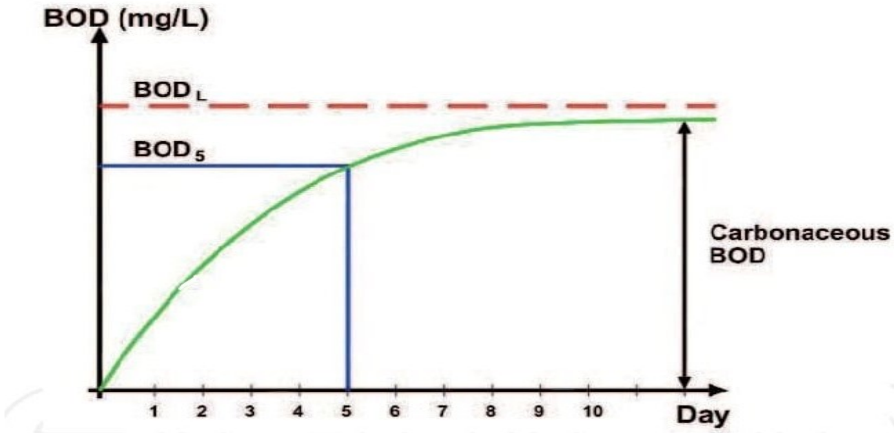

Fig.1.1 BOD curve.

1.2.2.14 Chemical oxygen demand (COD): The chemical oxygen demand (COD) is a parameter that measures all organics: the biodegradable and the non-biodegradable substances. It is a chemical test using strong oxidizing chemicals (potassium dichromate), sulphuric acid, and heat, and the result can be available in just 2 h (APHA, 2005). COD values are always higher than BOD values for the same sample (Tchobanoglous et al., 2003).

1.2.3Toxic Inorganic Parameters

1.2.3.1 Metallic compounds: This group includes some toxic heavy metals, namely, cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), silver (Ag), arsenic (As), barium (Ba), thallium (Tl), and selenium (Se) (Tchobanoglous et al., 2003; Jarup, 2003). They have a wide range of dangerous effects that differ from one metal to another. The heavy metals concentration can be determined by atomic absorption photometers, spectrophotometers, or inductively coupled plasma (ICP) for very low concentrations.

1.2.3.2Nonmetallic compounds: This group includes nitrates (NO_3^-) and cyanides (CN^-). Nitrate has previously been discussed. Regarding cyanide, as Mackenzie stated (Davis,2010) it causes oxygen deprivation by binding the haemoglobin sites and prevents the red blood cell from carrying the oxygen. This causes a blue skin colour syndrome, which is called cyanosis. It also causes chronic effects on the central nervous system and thyroid (Dojlido and Best, 1993). Cyanide is normally measured by colourimetric, titrimetric, or electrometric methods (APHA, 2005).

1.2.4 Parameters Concerning Radioactive Substances: The main sources of radioactive substances in water include wastes from nuclear power plants, industriesand medical research using radioactive chemicals and mining of uranium ores or other radioactive materials (Davis, 2010; DeZuane, 1997).There are established standards commonly used for alpha particles, beta particles, photons emitters, radium-226 and -228, and uranium (Skeppstrom et al., 2007; Cothern et al., 2014) for drinking water. The unit of radioactivity used in water quality applications is the picocurie per litre (pCi/L); IpCi is equivalent to about two atoms disintegrating per minute. There are many sophisticated instrumental methods to measure it (Cothern et al., 2014).

1.2.5 Bacteriological Parameters

1.2.5.1 Bacteria: Bacteria are considered to be single-celled plants because of their cell structure and the way they ingest food (APHA, 2005; Nathanson, 2004). Under favourable conditions of food supply, temperature, and pH, bacteria can reproduce so rapidly that a bacterial culture may contain twenty million cells per millilitre after just one day (Tchobanoglous et al., 2003; Nathanson, 2004). This rapid growth of visible colonies of bacteria on a suitable nutrient medium makes it possible to detect and count the number of bacteria in water. There are several distinctions among the various species of bacteria. One distinction depends on how they metabolize their food (Wiesmann et al., 2007). A lot of dangerous waterborne diseases are caused by bacteria, namely, typhoid and paratyphoid fever, leptospirosis, tularemia, shigellosis, and cholera (Tchobanoglous et al., 1985).

1.2.5.2 Algae: Algae are microscopic plants, which contain photosynthetic pigments, such as chlorophyll (Nathanson, 2004; Mara and Horan, 2003). They are autotrophic organisms and support themselves by converting inorganic materials into organic matter by using energy from the sun, during this process they take in carbon dioxide and give off oxygen (Wiesmann et al., 2007; Mara and Horan, 2003). They are also important for wastewater treatment in stabilization ponds (Tchobanoglous et al., 2003). Algae are primarily nuisance organisms in the water supply because of the taste and odour problems they create (Alley, 2007; Viessman and Hammer, 2004). Certain species of algae cause serious environmental and public health problems; for example, blue-green algae can kill cattle and other domestic animals if the animals drink water containing those species (Nathanson, 2004; Mara and Horan, 2003).

1.2.5.3 Viruses: Viruses are the smallest biological structures known to contain all genetic information necessary for their reproduction (Tchobanoglous et al., 1985). Viruses are parasites that need a host to live. They can pass through filters that do not permit the passage of bacteria (Nathanson, 2004). Waterborne viral pathogens are known to cause infectious hepatitis and poliomyelitis (Tchobanoglous et al., 1985; WHO, 1996). Most waterborne viruses can be deactivated by the disinfection process conducted in the water treatment plant (Tchobanoglous et al., 1985).

1.2.5.4 Protozoa: Protozoa are single-celled microscopic animals; thatconsume solid organic particles, bacteria and algae for food and they are in turn ingested as food by higher-level multicellular animals (Nathanson, 2004). Aquatic protozoa are floating freely in water and are sometimes called zooplankton (Nathanson, 2004). They form cysts that are difficult to inactivate by disinfection (Tchobanoglous et al., 1985).

1.2.5.5 Indicator organisms: A very important biological indicator of water and pollution is the group of bacteria called coliforms. Coliform bacteria are aggressive organisms and survive in the water longer than most pathogens. There are normally two methods to test coliform bacteria—the membrane filter method and the multiple-tube fermentation method (APHA, 2005; Nathanson, 2004).

1.2.5.6 Testing for coliforms: Membrane filter method a measured volume of sample is filtered through a special membrane filter by applying a partial vacuum (Mara and Horan, 2003). The filter, a flat paper-like disk, has uniform microscopic pores small enough to retain the bacteria on its surface while allowing the water to pass through. The filter paper is then placed in a sterile container called a petri dish, which contains a special culture medium that the bacteria use as a food source (Mara and Horan, 2003). Then, the petri dish is usually placed in an incubator, which keeps the temperature at 35°C, for 24 h. After incubation, colonies of coliform bacteria each containing millions of organisms will be visible (APHA, 2005). The coliform concentration is obtained by counting the number of colonies on the filter; each colony counted represents only one coliform in the original sample (APHA, 2005; Mara and Horan, 2003). Coliform concentrations are expressed in terms of the number of organisms per 100 ml of water as follows: coliforms per 100 ml = the number of colonies × 100/ml of sample.

1.3 History of Water Quality Index

The importance of standardization of water quality was well understood by humans back in the 19th century when a scientist named Horton et al. proposed the WQI method in 1965, using the Arithmetic Aggregation function considering the 10 most commonly used parameters. Brown et al. (1970) selected nine parameters to identify the WQI which was accepted by the Nation Sanitation Foundation (NSF). Subsequently, many other researchers contributed to the process of developing a standardized WQI method, a small snapshot is available in Table 1.1.

Table 1.1. Structure, aggregation formula, and the number of variables in the WQI.

WQI	No. of Variables	Structure	Aggregation	Example of Studies using WQI Application Area
Horton	10	Formulas	Weighted geometrical avera	Pune, Maharashtra, India Suquia River, Argentian Rio Lerma basin, Mexico Balikhlou River, Iran
NSFWQI	9	Diagrams	Weighted geometrical average	Cazenovia Creek, USA Dakhla Oasis, Egypt Dourou River, Portugal Brazil Owo River, Nigeria Aydughmush Dam, Iran
Bhargava	According to the use	Formulas	Weighted product	Subernarekha, India
Dinius	12	Equations	Weighted geometrical average	
CCMEWQI	Up to 47	Formulas	Harmonic Square Sun	Atlantic region, Canada Mackenzie River basin, Canada Algeria Canada
Oregon	8	Equations	Unweighted harmonic Square Mean	
New WQI Said et al. (2004)	5	Formula	Logarithmic	

The most important key to identifying the correct Water Quality Index depends on the selection of relevant parameters based on the geographical and anthropological factors along with the purpose of the water quality check. The various methods tried and tested to identify the impact of various parameters or water component variables are multiplicative aggregation, weighted geometric mean aggregation, harmonic mean without weighing individual parameters, harmonic square sum, and logarithmic aggregation. At present in 2021, some of the most acceptable and standard methods of measuring WQI in the world are the Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), WAWQI, National Sanitation Foundation Water Quality Index (NSFWQI), Oregon Water Quality Index (OWQI) and British Columbia water quality index (BCWQI). Since there is no single method proven to be accepted by all, we should consider multiple factors like environment, climate, specific indicators, etc. to find the best suited WQI method for the selected water body.

1.4 Details of Various Water Quality Indices:

1.4.1 British Columbia Water Quality Index (BC WQI)

The British Columbia water quality index was developed by the Canadian Ministry of Environment in 1995 as an increasing index to evaluate water quality. This index is similar to the CCMEWQI where water quality parameters are measured and their violation is determined by comparison with a predefined limit. It provides the possibility to make a classification based on all existing measurement parameters. To calculate the final index value the following equation is used:

$$BC\_WQI = 100 - \left[\sqrt{\frac{F_1^2 + F_2^2 + \left(\frac{F_3^2}{3}\right)}{1.453}} \right] \text{------------------Eq.1.1}$$

Where,
Scope (F_1) - number of parameters that is not compliant with the water quality guidelines.
Frequency (F_2) - number of times that the guidelines are not respected.
Amplitude (F_3) - the difference between non-compliant measurements and the corresponding guidelines.

The number 1.453 was selected to give assurance to the scale index number from zero to 100. It is important to note that repeated samplings and increasing stations increase the accuracy of the British Columbia index. The disadvantages of this method are that this index does not indicate the water quality trend until it deviates from the standard limit and is due to the usage of the maximum percentage of deviation.

1.4.2 National Sanitation Foundation Water Quality Index (NSFWQI)

A usual water quality index method was developed by paying great rigour in selecting parameters, developing a common scale and assigning weights. The attempt was supported by the National Sanitation Foundation (NSF) and therefore NSFWQI in order to calculate the WQI of various water bodies critically polluted. The proposed method for comparing the water quality of various water sources is based upon nine water quality parameters such as temperature, pH, turbidity, faecal coliform, dissolved oxygen, BOD, total phosphates, nitrates, and total solids (Brown et al., 1970: Tyagi et al., 2013). The water quality data are recorded and transferred to a weighting curve chart, where a numerical value of Qi is obtained. The mathematical expression for NSF WQI is given by

$$NSF\_WQI = \sum_{i=1}^{n} Q_i\ W_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 1.2}$$

Where Q_i = Sub-index for i^{th} water quality parameter
W_i =Weight associated with i^{th} water quality parameter
n = Number of water quality parameters

Table 1.2 Water Quality Rating according to NSFWQI

Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very Bad

1.4.3 Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI)

The CCMEWQI method compares the observations of selected parameters to a benchmark rather than normalizing the observed values to subjective rating curves, where the benchmark could be an acceptable standard of water quality or any specific background concentration as per site properties (CCME, 2001; Khan et al., 2004; Lumb et al., 2006). The index quality of the CCMEWQI method is derived from the British Columbia Water Quality Index (BCWQI) found in 1990. The main objective of modelling this method was to identify a measuring index that would use to manage the quality of water by the water treatment and distribution agencies of Canada. The CCMEWQI provides flexibility in the alteration of variables as per the requirement of the geographical and anthropological factors. Hence this method can be used for diverse scenarios and can easily adjust the morphoclimatic characteristic features of hydrographic basins. In this method of calculating the WQI, after assigning a relevant weightage to the parameters mainly three factors are identified:

i) The number of parameters that do not fall within the acceptable standards of quality
ii) The percentage of samples that has non-standard parameters
iii) Excursion calculation is conducted, which is followed by adding the sum of excursion values divided by the total number of tests

The mathematical expression for CCME WQI is given in 4.2. 1.

1.4.4 Weighted Arithmetic Water Quality Index (WAWQI)

In this method, the Water Quality is classified based on the purity of the water as per the standard water rating range to which the obtained WQI value belongs. The method has been followed by various scientists around the globe to identify the quality of water in different types of water bodies. The WAWQI (Dendnkuri et al., 2017) method assigns a weightage to the different parameters selected based on the impact they can have on the water quality. As a result, this method has proven to be quite useful in describing the suitability of both groundwater and surface water sources for human usage. One of the debatable demerits of this method is that the assumed value of a single parameter and its presence beyond a permissible standard can highly affect the total WQI of the water. The mathematical expression for WA WQI is given in Eq. 4.2.5.

1.4.5 Oregon Water Quality Index (OWQI)

The Oregon Water Quality Index, developed by the Oregon Department of Environmental Quality (ODEQ) in the late 1970s and updated several times since then is another frequently used WQI in the public domain. The Oregon Water Quality Index (OWQI) is a single number that expresses water quality by integrating measurements of eight water-quality variables (temperature, dissolved oxygen, BOD, pH, ammonia+nitrate nitrogen, total phosphorus, total solids, and faecal coliform) (Dunnette, 1979; Dinius, 1987). Its purpose is to provide a simple and concise method for expressing the ambient water quality of Oregon's streams for general recreational use, including fishing and swimming. The OWQI, originally developed in the 1970s, has been updated based on an improved understanding of water quality behaviour. This report describes the historical basis of the OWQI and defines the improved design of the present OWQI. The index allows users to easily interpret data and relate overall water quality variation to variations in specific categories of impairment. This report demonstrates the value of the OWQI in presenting spatial and temporal water quality information. The OWQI improves comprehension of general water quality issues, communicates water quality status, and illustrates the need for and effectiveness of protective practices. The mathematical expression for this method utilizes the concept of arithmetical average and it is given by

$$OWQI = \sqrt{\frac{n}{\sum_{i=1}^{n}\frac{1}{S_i^2}}} \qquad \text{..........Eq. 1.3}$$

1.4.6 Overall Index of Pollution (OIP)

It was developed by Sargaonker et al. at the National Environmental Engineering Research Institute (NEERI), Nagpur, India in order to assess the status of surface waters, specifically under Indian conditions. Based on classification schemes developed by CPCB and one proposed by Prati et al. a general classification scheme has been formulated. OIP developed by Sargaonkar and Deshpande for Indian rivers is based on measurements and subsequent classification of hardness, total dissolved solids, pH, dissolved oxygen, BOD, turbidity, arsenic, fluoride, and total coliforms. According to BIS, WHO, and European Community standards, water quality observations are classified into six categories. The categories are: heavily polluted, polluted, slightly polluted, acceptable, and excellent. OIP was calculated as the average of each pollution index assigned to each observation.

The mathematical expression for this method is

$$IWQ = \prod_{i=1}^{n} I_i^{Wi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 1.4$$

Where P_i= pollution index for i^{th} parameter, n = number of parameters

1.4.7 Dinius Water Quality Index (DWQI)

It is a multiplicative water quality index developed by Dinius for six categories of water uses public water supply, recreation, fish, shellfish, agriculture, and industry. He employed the liberal use of Delphi for decision-making. The index included 12 parameters: dissolved oxygen, 5-day BOD, coliform count, E-coli count, pH, alkalinity, hardness, chloride, specific conductivity, temperature, colour, and nitrate. The weightage of each parameter was assigned based on the evaluation of importance by the Delphi panel members. The individual sub-index functions were combined with the help of a multiplicative aggregation function as follows:

$$IWQ = \prod_{i=1}^{n} I_i^{Wi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 1.5$$

where IWQ is the Dinius water quality index whose value ranges from 0-100,1, is the sub-index function of the pollutant parameter, Wi is the unit weight of the pollutant parameter whose value ranges from, 0-1, and n is the number of pollutant parameters.

1.4.8 Comprehensive pollution index (CPI)

CPI is applied to assess the overall status of water pollution and to classify surface water quality. To do this, the measured water quality parameters and, surface water quality standards are required. Based on the assessment of the single-factor index and considering the combined effect of all factors evaluated, CPI was calculated through different mathematical models and determines the pollution degrees by the appropriate method. The mathematical expression for this method is given by:

$$\boldsymbol{CPI = \frac{1}{n}\sum_{i=1}^{n}\frac{M_i}{S_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. Eq. 1.6$$

where; “CPI” is a comprehensive water pollution index, “Mi” represents the measured concentration of each parameter; “Si” is environmental quality standards for surface water; “n” denotes the total number of parameters. Based on the computed value of CPI, the water quality can be classified into five categories:

Table 1.3 Water Quality Rating according to CPI.

CPI values	Water quality classification / Categories	Description of status of water quality
CPI = 0-0.20	Category 1	Clean
CPI = 0.21-0.40	Category 2	Sub clean
CPI = 0.41-1.00	Category 3	Slightly polluted
CPI = 1.01-2.00	Category 4	Medium Polluted
CPI ≥ 2.01	Category 5	Heavily polluted

1.4.9 Nemerow's Pollution Index (NPI)

The Nemerow's Pollution Index is a powerful tool for assessing water quality. NPI denotes pollution computing which was developed by Nemerow and Sumitomo (1971). The pollution-causing parameters are evaluated through Nemerow's pollution index using the observed values and permissible values of the parameters. NPI is evaluated for all the parameters for each sample analysed, thus identifying the pollution-causing parameters. The NPI is given as one of the simplified pollution indexes. The equation used in evaluating the NPI is reproduced below:

$$\text{NPI} = \frac{C_i}{L_i} \text{----------------Eq.1.7}$$

Where, C_i = observed concentration of the i^{th} parameter
L_i=permissible limit of the i^{th} parameter.

In the above expressions unit of C_i and L_i should be identical. Each value of NPI shows the relative pollution contributed by a single parameter. It has no units. Li values for different water quality parameters are the permissible value of those parameters as per BIS. Each value of NPI shows the relative pollution contributed by a single parameter, It should be less than or equal to one. NPI values exceeding 1.0 indicate the presence of an impurity in water and hence require some treatment before use.

CHAPTER-II

2.1 Literature Review

Munna et al. (2013) studied the water quality of the Surma river of Bangladesh by using CCME WQI. The purpose of this study was to assess the degree of pollution in the context of CCME WQI as the water quality of the Surma river was frequently deteriorating over the last few decades of ever-growing human activities, poor drainage systems, and direct disposal of municipal and industrial waste. For this study water samples had been collected from six different locations throughout a year from March- 2008 to February- 2009 and various physico-chemical parameters i.e. pH, total solid (TS), total suspended and dissolve solid (TSS and TDS), DO, phosphate ($P0_4$), sulfate ($S0_4$), potassium (K), nitrate ($N0_3$), hardness (as $CaCO_3$), iron (Fe), zinc (Zn), chromium (Cr) had been analysed. The CCME WQI value of the Surma river was found to be 15.87 which indicates that water quality is poor and frequently impaired.

Chandra et al. (2014) conducted research in the city of Vijayawada in India with a population density of around 32320 per sq. km. They collected 380 samples, 190 numbers each pre-monsoon and post-monsoon for the year 2014. They analyzed the physico-chemical properties of all 380 samples and selected 38 samples from 19 different locations (two from each location, post-monsoon, and pre-monsoon) for the WQI identification of those areas where the physico-chemical properties were high. The Water Quality Index was calculated using the weighted average water quality index method. The different physico-chemical parameters used were pH, TDS, chlorine (Cl), sodium (Na), sulfates (SO_4), calcium (Ca), magnesium(Mg), potassium (K), and total hardness (TH) at the selected 19 different sample stations. They observed that the WQI of the pre-monsoon samples were having poor water quality as all the samples had a WQI value greater than 50 yet drinkable except for four (04) locations where the WQI value exceeded 100 and was not suitable for drinking purposes. However, the WQI values of the post-monsoon samples were significantly higher than that of the Pre-monsoon samples in almost all the locations. Out of 19 samples, 13 were unsuitable for drinking water purposes post-monsoon as the WQI value of those exceeded the permissible limit of 100. Thus, they concluded that pollution added to the water after monsoon was extremely high and it negatively affected the water quality to the extent of making it undrinkable in most cases.

Mahagamage and Manage (2014) evaluated the water quality of Kelani River to check its usability for various purposes like recreation, livestock, irrigation, and drinking. The researchers selected 27 sampling stations across the length of the Kelani River Basin. The water samples were collected over a year from October 2012 to September 2013. A total of 18 physico-chemical parameters were selected to be used in the CCMEWQI method for identifying the WQI. The parameters are pH, TDS, dissolved oxygen, total phosphate, nitrate, nitrite, total hardness, electrical conductivity, biological oxygen demand, chemical oxygen demand, total coliform, and feacal coliform bacterial counts, cadmium, lead, aluminium, zinc, copper, and chromium. These parameters were indexed using the guidelines of WHO standards and Sri Lankan standards for drinking water. Canadian Water Quality Guidelines (CWQGs) were used to index parameters for livestock and irrigation purposes. As per the calculations, the WQI values indicated that the water qualities for drinking and recreational purposes were poor due to the increasing impact of point and non-point sources of pollutants.

However, the water quality was fair and good for irrigation and livestock purposes respectively. The authors concluded that the situation was alarming and it was necessary to develop action plans to monitor the quality of water and manage the watershed.

Ali et al. (2016) used the WAWQI method for the assessment of the water quality index of the Gomti river. River Gomti, a tributary of the holy River Ganga is an important river of Uttar Pradesh and is also the lifeline of the capital Lucknow. The river contributes about 15% of the flow of the River Ganga. River Gomti has an average dry weather flow of 1500 MLD, while in monsoon season the flow becomes very as high as 55,000 MLD and in summer as low as 500 MLD. River Gomti has an effective area of about 25,735 sq. km. The river flows like a rivulet until it reaches Mohanadi (about 100 KM from its origin) where it is joined by the river Sarayan a prominent tributary. The samples were collected from the seven locations at Lucknow i.e. Manjhi Ghat, Upstream water intake, Kuriyaghat, Downstream Mohan Meakins, Downstream Nishat Ganj, Upstream Barrage, and Downstream after STP Bharwara. Ten physiochemical parameters such as pH, DO, EC, BOD, Total Hardness, Calcium, Magnesium, Chloride, Alkalinity, and TDS had been considered for analyzing water quality. The WQI value of the sampling stations was Manjhi Ghat- 140.27, upstream water intake- 150.61, Kuriyaghat- 217.35, Downstream Mohan Meakins- 260.42, Downstream Nishat Ganj- 319.90, Upstream Barrage- 362.21, and Downstream after STP Bharwara- 410.16. It was revealed from the assessment of WQI using the Weighted Arithmetic Method that the quality of River Gomti was deteriorating while entering Lucknow city due to the discharge of a huge quantity of sewage through the different drains into River Gomti. It had been found that the quality of river water was moderately polluted at the entrance of the city (Manjhi Ghat and Water intake point) and pollution at this point is mainly found due to some industrial as well as domestic discharge.

Ewaid et al. (2017) researched the water of the Al-Gharraf River stretched across 230 km. It is the main branch of the Tigris River and was used for domestic purposes by the people settled along its course. The researchers selected a total of 5 different sampling stations based on the different types of domestic and industrial settlements around them. The settlements included horticulture fields, residential towns, farm fields, water refinery stations, salt zones, and canals. The water samples were collected for one year from all the five sampling stations, which were then preserved and analyzed as per the standard methods of the American Public Health Association (APHA, 2012). The parameters considered for calculating the WQI are BOD, TDS, DO, turbidity, hydrogen ion concentration (pH), alkalinity, phosphates (PO_4), chlorides (Cl), nitrates (NO_3), electrical conductivity (EC) and total hardness (TH). The WAWQI method was used to calculate the WQI. The weightage unit (W_i) of each parameter was inversely proportional to the standard of the World Health Organization (S_i) as per calculations. As per calculations, the BOD of the water samples of the first four sample stations met the standard of the WHO, except for the fifth sample station which had an annual mean of 8.12 which exceeded the WHO standard of < 5 mg/1. The TDS level did not fluctuate much across the five stations but it did fluctuate heavily between seasons. The pH value of the river was marginally alkaline as it fell within the range of 6.8-8 with an annual mean of 7.4, which is common on the Iraqi surface as per multiple previous researches. Dissolved Oxygen ranged from 6.2 to 10 mg/1 with an annual mean of 7.48mg/l. This range and value both exceed the desired standard of<5mg/l as per WHO. Similarly, the identified Turbidity also exceeded the desired standard of 5 NTU by a mean of 45 NTU. The observed values of electrical conductivity were always way above the WHO standard value of 250 µcm with the range of 928 to 1270 µs/cm. The Alkalinity values of the sample ranged from 143 to 270 mg/1 which was sometimes above the permissible drinking water limit of WHO of 200 mg/1. It was concluded that the WQI value reduced long the downstream which confirmed the entry of various pollutants into the river along its course depending on the industrial and domestic waste waters flowing into the water body. The decrease in the water levels of the river promotes drainage from the groundwater into the river stream. The fluctuations in water level were witnessed largely due to seasonal factors especially in summers and autumns (dry seasons) when the water from reservoirs contains more organic matter reducing the pH and oxygen adversely affecting the water quality.

Datta et al. (2017) had an objective of determining the groundwater quality of various regions in and around Guwahati city. They wanted to compare the water quality of various sources and analyze its suitability for drinking usage. The study area included the major water supply facilities of the city which catered to only 30% of the residents, groundwater samples, and the water samples from the tankers provided to the residents in some areas. Around 66 samples of drinking water were collected from different parts of the city in March 2017 to get the pre-monsoon water quality. Composite sampling was adopted to have representative water samples which were then chemically analyzed. Groundwater samples from tube wells were collected after flushing out the water for approximately 10 minutes to get the fresh groundwater. Samples were collected in PVC containers and were nicely sealed. All precautionary measures were taken to avoid and minimize the possibilities of contamination. A total of 66 samples collected were analyzed for 16 physico-chemical parameters using the standard methods as per APHA, 2012. For calculating the WQI, the WA WQI method proposed by Brown et al., (1970) has been used. The following 12 quality parameters had been selected for the calculation: pH, turbidity, TDS, bicarbonates, chlorides, sulfates, nitrates, iron, calcium, magnesium, total hardness, and fluorides. All the twelve selected parameters were assigned a weight as per their relative importance in the overall WQI for permissible limit for drinking usage, with fluoride being assigned the maximum weight of 5 due to its major importance in the water quality assessment of the Guwahati region. The calculated values were compared with the standard recommendation of the Bureau of Indian Standards (BIS). The TDS of seven samples exceeded the permissible limit of 500 mg/1. Overall, three major water bodies (Bharulu River, Borsolabeel, and Deeporbeel) were showing contamination by the presence of heavy metals i.e. lead, cadmium and mercury at an elevated level that exceeded the permissible safe levels established by the Environment Protection Agency and estrogenic activities were identified. It posed a threat of human exposure to the metals through water or food poisoning in those areas. According to the calculated WQI values, three areas namely Gurudwara, Hajo, and GMC were having poor water quality and were unfit for drinking as the WQI value exceeded 75. The high value of WQI in these areas resulted from higher levels of TDS, fluoride, iron, and total hardness in the groundwater. The study also revealed that some degree of water treatment was necessary for the region to make it fit for consumption.

Awachat et al. (2017) worked to assess the bore well water quality of the Vishrambag area using different available methods to identify the water quality indices and find the inferences as per the calculated WQI value in each method. The samples were collected in the winter season within the time range of 1 P.M. 1ST to 5 P.M. 1ST from 16 different locations spread evenly to cover the study area. Grab sampling method was used to collect and store the samples which were then analyzed for the physico-chemical and bacteriological parameters like TDS, pH, conductivity, total hardness, total alkalinity, turbidity, chloride, magnesium, calcium, nitrate, and faecal coliforms. The results were compared with the prescribed standards of IS 10500: 2012. The WA WQI and National Sanitation Foundation Water

Quality Index (NSF WQI) methods were used to calculate the WQI value. As per the results, most parameters exceeded the standard acceptable limit according to IS: 10500-2012. The WQI value obtained as per the WA WQI method showed that all the samples were highly unsuitable for drinking purposes as the WQI ranged from 355 to 1361 which is way beyond the permissible limit of 100. According to NSF WQI, the WQI value ranged from Medium to Good because important parameters like Hardness and TDS are not considered for calculations in this method. Thus, it was concluded that the NSF WQI method should not be used to check the WQI for groundwater and the water in the Vishrambag area needs proper treatment to be fit for drinking usage.

Uddin et al. (2017) used CCME WQI to evaluate groundwater quality in the Rooppur Nuclear Power Plant (RNPP) area, Pabna, Bangladesh. Water samples used in this work were collected from the RNPP area in Iswardhi and Lokkhikunda, Pabna district, Bangladesh. The study was conducted in Ishwardi, the westernmost of 120km (75 miles) north of the capital, Dhaka. The area has a tropical monsoon climate with seasonality in rainfall distribution. The mean annual rainfall and temperature of the study area were 1872 mm and 36.8 C, respectively. Total 22 numbers of parameters i.e. Temp., pH, DO, BOD, COD, faecal coliform, conductivity, alkalinity, Na, K, Mg, Cl^-, $N0^-$, $S04^{2-}$, $N0_2^-$, Mn, Iron, Cu, As, Cr, Cd, Pb had been used to evaluate the quality of the water. All sampling locations were found faecal coliform, where the Bangladesh standard for drinking water quality faecal coliform guideline value is zero or nil. The WQI calculated drinking category rating is 37 indicates that groundwater quality for the RNPP area is ranked poor. The poor quality can be attributed to the water quality being almost always threatened or impaired; conditions usually depart from natural or desirable levels. Correlation analysis was done between the WQI, temperature, pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand, conductivity, alkalinity, magnesium, potassium, sodium, chloride, nitrate, nitrite, sulphate, manganese, arsenic, copper, iron, lead, cadmium, chromium and faecal coliforms (FC). Temperature, pH, dissolved oxygen, potassium, sodium, sulphate, chromium, and faecal coliforms (FC) parameters positively impacted the WQI, besides all other parameters negatively impacted the WQI. The SO_4^{2-} and Cr were highly positively correlated with WQI. Mn, As, Fe, Cd, and NO_2^{2-} are highly negatively correlated with WQI. The results highlight a strong correlation between all water quality parameters and WQI.

Bouslah et al. (2017) used the WAWQI method for analyzing the water quality index of Koudiat Medouar Reservoir located north-east of the city of Batna in the eastern part of Algeria. The climate of the Koudiat Medouar watershed was semi-arid and characterized by a cold and wet winter, a warm and dry summer, and rainfall between 300 and 450 mm per year. This study aimed to evaluate the quality of the water of Koudiat Medouar Dam and to assess its suitability for drinking purposes. The water samples were collected at a monthly interval, for one year from January-December 2015 at different sampling stations in the lake. The samples were assessed for ten physicochemical settings namely pH, electrical conductivity, total hardness, nitrate, sulphate, chloride, calcium, magnesium, dissolved oxygen, and turbidity. The WQI values ranged from 99.097 to 174.92 during 2015. It had been reflected that the water samples of February was in the range of very poor quality and ranged to be unsuitable for drinking purpose in all other months. It had been revealed from the WQI of the present study that dam water was contaminated and not suitable for drinking purposes without giving treatment.

Bilgin (2018) worked to evaluate the quality of water in the Coruh River Basin, located in the Eastern Black Sea Region of Turkey. He had used CCME WQI method. The data had been collected for a period of four years between the years 2011 to 2014 and measured by the State Hydraulic Works 26 Regional Directorate from four different sites. The water quality of the Comh River Basin was calculated ranging from 30.4 and 71.35 and categorized as poor, marginal, and fair. From the result, it was stated that the water of the Coruh River Basin deteriorated and was under threat and its quality of the same was very far from natural or desired levels.

Tokatli (2019) researched the water quality of Yazir pond in Turkey using the WA WQI method. He collected samples in the summer of 2019 from three locations: The input side, Sylvan de, and the Output side. A total of sixteen parameters were used to calculate the WQI. TDS, oxygen saturation, salinity, pH, dissolved oxygen, and electrical conductivity were determined using Hach Lange HQ40D Multiparameter. Turbidity was determined using the portable Turbidimeter of Hach Lange 2100Q. Nitrogen and phosphate were checked using the DR890Colorimeter of Hach Lange. Hach Lange DR3900 spectrophotometer was used for chemical oxygen demand and BOD Trak II was used to determine biological oxygen demand. The resultant value of parameters was checked with the standards as per Turkish Regulations. Although the WQI value obtained was within the permissible limit of 100, the water quality of Yazir Pond was found to be poor with a mean of 52.9 i.e. suitable for irrigation and industrial purposes. Turbidity was the major factor that negatively affected the water quality.

Ahmed et al. (2019) researched the water quality of a shallow aquifer and its impact on irrigation in the Mathura district area using the CCMEWQI method. They collected a total of 65 water samples from the piezometer borehole by the Central Ground Water Board (CGWB) from various parts of the city in July 2017 and determined the physico-chemical properties of twelve parameters: total hardness, pH, electric conductivity, calcium, sodium, magnesium, potassium, chloride, fluoride, nitrate, sulfate and bicarbonate following the standard of APHA-AWWA-WEF 2005. The obtained results were compared with the BIS (2012) and WHO (2011) standards. As per the results, the amount of TDS, TH, Cl^-, Mg^{2+} and $N0_3^-$ were having higher values beyond the permissible limit. The WQI value ranged from 1.862 to 82.254 which meant water quality ranged from good to poor. But even though the water quality was poor in major areas it could be used for irrigation purposes. Overall it was concluded that the water quality management strategy needed to be designed based on the regional demand for humans.

Hommadi et al. (2020) investigated the water quality upstream of Alhindya Barrage, Euphrates River, Iraq by the CCME WQI method. As the water quantities had decreased due to high temperature in summer and reduced the water quotas of Euphrates River in Iraq from the neighbouring countries and resulting in increased turbidity and concentration of elements. The water quality was investigated in the years 2008 and 2009 according to the available data. The result of WQI showed for 2008 was 94 which is good to excellent water quality compared to the WQI value of 79 for 2009.

Mohammed et al. (2020) checked the validity of groundwater found in wells located within the Green Belt area in Karbala city of Iraq, for irrigation of olive and palm trees. In the last five decades, a huge amount of water pollutants had been recorded in all water resources around the city. Thus, the water quality was an important indicator affecting the vitality and productivity of plants, which requires an effective technique to monitor all these pollutants. The purpose of the study was that saline groundwater could be used as an alternative to available fresh water and that helped in promoting the sustainable development of water resources. Groundwater samples were taken from the various wells and tested to find seven parameters i.e. pH, Cl^-, Mg^{2+}, EC, Na and Ca. The calculated values of CCME WQI ranged from 30 to 35 and according to which the groundwater of the wells was categorized as poor. The study indicated that the groundwater of the wells in the Green Belt area of Karbala city requires treatment before using it for irrigation purposes. This study concluded that good irrigation management is required in the study area.

Islam et al. (2021) studied the water quality of a tributary called Boalia Khal (canal) in lower Halda by using the weighted arithmetic WQI method. This tributary had been used for capturing fishery and also for carrying local agricultural and urban discharges to the Halda River. In this study status ten physico-chemical parameters from three selected stations of the tributary were studied for two years period from January 2017 to December 2018, which were ranged as: water temperature 24.84 ± 2.96°C to 29.71 ± 1.72°C, transparency 24.17 ± 4.40 cm to 36.89 ± 5.67 cm, electrical conductivity 86.39 ±33.86 µS/cm to 161.11 ± 11.52 µS/cm, TDS 30 ± 10mg/lto70± 10 mg/1, pH 7.04 ± 0.18 to 7.44 ± 0.06, DO 3.91 ± 0.81 mg/1 to 7.93 ± 1.98 mg/1, calcium 5.03±2.00mg/l to 10.78±2.40mg/l, total hardness 23.83±9.1mg/l to 47.83 ± 4.69 mg/1, total alkalinity 34.89 ± 15.93 mg/1 to 44.22 ± 11.56 mg/1 and BOD_5 1.23 ± 0.83 mg/1 to 1.55 ± 1.06 mg/1. The WQI ranged between 51.72 ± 4.36 to 54.68 ± 7.11 and classified the water of three stations as poor during different seasons except in winter. The water quality had been detected as unsuitable for drinking without treatment but could be used for irrigation and fish culture. It had been suggested to protect this tributary, proper management policy and conservation efforts must be taken.

CHAPTER-III

3.1 Study Area

The city of Calcutta was once the capital of the country during the British Raj, as it was the key hub for the East India Company in the 18 century. Regarded today as one of the biggest cities in the world, it is also the fourth largest in India in terms of population. It was later renamed Kolkata. Over the years, Kolkata has grown sporadically and haphazardly, not conforming to any master plan. The city of Kolkata is the capital of the state of West Bengal, India. Kolkata is also one of the oldest developed cities in the Country. The city of Kolkata is also known as the city of Joy. The main city forms the nucleus of the Kolkata Metropolitan Area (KMA), which comprises three municipal corporations - the Kolkata Municipal Corporation (KMC), the Howrah Municipal Corporation, and the Chandan Nagar Municipal Corporation, and has a population of around 1.5cr with a density of 24000 people per sq. km. Due to the historical past, the main city still has infrastructure as per old planning which is being changed slowly as per requirement and feasibility. The Hooghly River is the main source of water in the city, which has a total of five Water Treatment Plants and many booster pumping stations with underground reservoirs under the Kolkata Municipal Corporation.

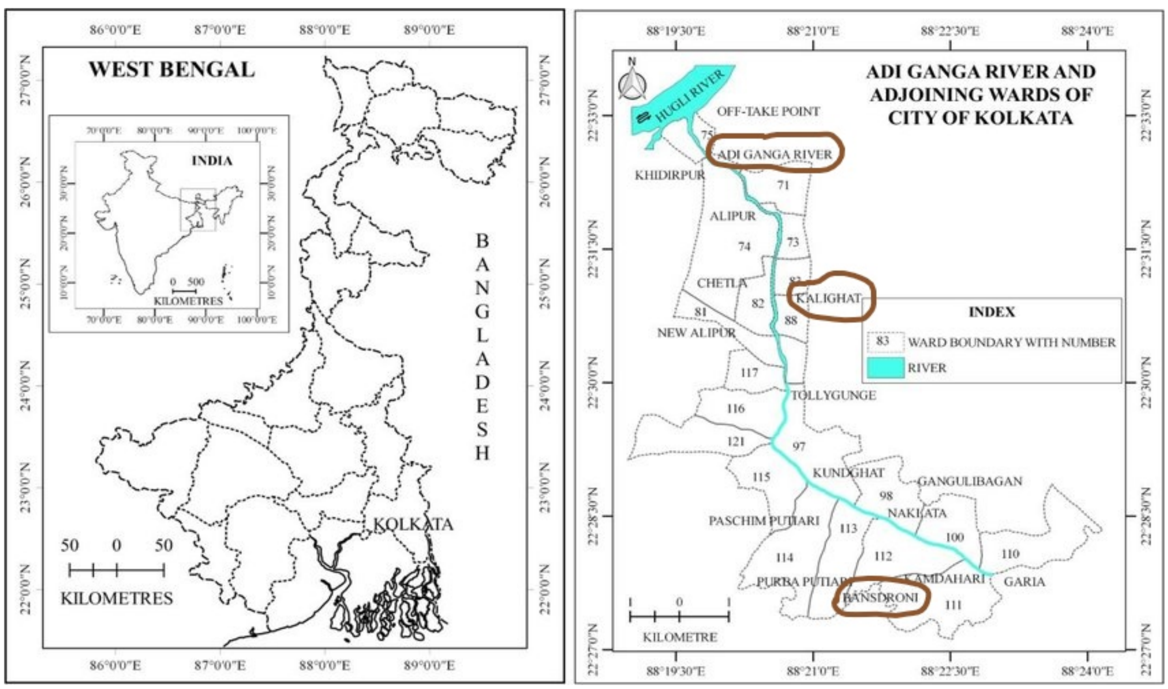

Fig.3.1 Location of the study area,

Kalighat and Bansdroniareas are located in the southern part of the city of Kolkata. These two are the water quality monitoring stations of WBPCB in south Kolkata. Kalighat sampling point is located on Ganga Devi Bridge near the Kalighat Temple at 22.5209° N latitudes, 88.3403° E longitudes and Bansdroni sampling point is located on Bansdroni Bridge near Khudiram Metro Station at 22.4708° N latitudes, 88.3618° E longitudes alongside the bank of Hooghly River. Surface water that is river water of Ganga is collected as a sample by the WBPCB fortnightly from those monitoring stations. Here,Adi means old and Ganga means Hooghly river.So, Adi Ganga means the old course of the Hooghly river which becomes a small canal presently known as Tolly Nullah. According to the test report of different parameters, it can be assessed the water quality of Ganga in those areas.

People of different areas of South Kolkata like Kalighat and Bansdroni receive the treated water supplied by Garden reach Water treatment plant and Jai Hind water project. This area of Kolkata is having lots of small to large-scale industries due to the availability of facilities like the supply of electricity, supply of water, good communication etc. Being an important part of developing Kolkata, population density is high in this area. So, drinking water is one of the major concerns of this part of Kolkata as the only source of water is the River Hooghly which is the Perennial River. The raw water is also directly used by the people of these areas from the river Hooghly as well as Adi Ganga. So, the assessment of raw water quality of Kalighat and Bansdroni may partially reflect the water quality of river Hooghly i.e Adi Ganga in these areas. This study also helps in ensuring the availability and sustainable management of good-quality water.

CHAPTER-IV

4.1 Objective

The objective of this study is to check the water quality and its possible uses. The raw water of Adi Ganga Kalighat and Bansdroni is supplied by the Hooghly River. After treatment of the raw water of Hooghly river by Garden reach water treatment plant and Jai Hind water project, this treated water is distributed to many areas of South Kolkata. Many areas around Kalighat and Bansdroni are yet to receive the treated water pipelines and use the raw water that comes from the Hooghly river. Thus, in this study, the raw water quality of the Adi Ganga at Kalighat and Bansdroni has been used to identify the WQI using the WAWQI and CCMEWQI methods. So, the study of raw water quality analysis of Adi Ganga at Kalighat and Bansdroni is also a study of the water quality of the Hooghly river. This study will not only help in getting the water quality status, but it can also help in selecting the proper treatment required for treating the raw water for using the water for drinking purposes. This study also helps in finding the reason for increasing pollution in river Hooghly and to find solutions to protect it further.

4.2 Methodology

To calculate the WQI value of the raw water of the Adi Ganga at Kalighat and Bansdroni, both CCMEWQI and WAWQI methods have to be used to compare and check the water quality status. The evaluation is conducted according to the data available under WBPCB for seven physico-chemical and biological parameters i.e., BOD (mg/l), DO (mg/l), pH, Total coliform, COD, Total Suspended Solids (TSS), Fecal Coliform for different months of the seven(7) consecutive years from 2014 to 2020 and by comparing their values with Bureau of Indian Standards (BIS).

4.2.1 Computation Method of Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI):

The following six stages indicate the method for computing the CCME WQI. Calculation of the index is based on three terms:
Scope (F_1) - number of parameters that are not compliant with the water quality guidelines,
Frequency (F_2) -the number of times that the guidelines are not respected and
Amplitude (F_3) - the difference between non-compliant measurements and the corresponding guidelines.

First of all, the term F_1 (scope) expresses the percentage of parameters for which at least one measurement did not comply with the corresponding guideline during the period under study:

$$F_1=\left(\frac{\textbf{Number of failed parameters}}{\textbf{Total number of parameters}}\right)\times \mathbf{100} \quad \text{Eq.4.1}$$

The term F_2 (frequency) represents the percentage of analytical results that do not comply with the guidelines.

$$F_2=\left(\frac{\textbf{Number of failed results}}{\textbf{Total number of results}}\right)\times \mathbf{100} \quad \text{Eq. 4.2}$$

Finally, the term F_3 (amplitude) represents the difference between the non-compliant analytical results and the guidelines to which they refer. The term F_3 is an asymptotic function, representing the normalized sum of excursions (nse) in relation to guidelines within the range of values from 0 to 100.

$$\mathbf{F_3}=\left(\frac{\mathbf{nse}}{\mathbf{0.01\times nse+0.01}}\right)\times \mathbf{100} \text{.. Eq. 4.3}$$

To calculate the overall degree of non-compliance, we add the excursions of non-compliant analytical results and divide the sum by the total number of analytical results. This variable is called the normalized sum of excursions (nse).

$$nse = \frac{\sum_i excursion}{Total\ number\ of\ results} \dots\dots\dots\dots\dots\dots Eq. 4.4$$

There are three possible ways of determining the excursion:

• If the finding must not exceed the guideline:

$$\mathbf{Excursion_i}=\left(\frac{\boldsymbol{Failed\ test\ result_i}}{\boldsymbol{Guidelinei}}\right)-\mathbf{1} \dots\dots\dots\dots\dots\dots..Eq. 4.5$$

• If the finding must not be lower than the guideline:

$$\mathbf{Excursion_i}=\left(\frac{\boldsymbol{Guideline_i}}{\boldsymbol{Failed\ test\ result_i}}\right)-\mathbf{1} \text{........................Eq. 4.6}$$

•If the guideline is zero (equal to zero):

$$\mathbf{Excursion_i=Failed\ test\ result} \text{.....................Eq. 4.7}$$

The division of these terms by 1.732 is based on the fact that each of the three factors contributing to the index can reach the value of 100. The maximal length is, therefore, expressed as:

$$\sqrt{\mathbf{100^2+100^2+100^2}}=\sqrt{\mathbf{30,0000}}=\mathbf{1.732} \text{...................Eq. 4.8}$$

Division by 1.732 reduces the maximal length to 100. The index produces a value from 0 to 100. The higher the number, is the better the water quality.

The final CCME WQI is expressed below

$$\mathbf{CCME\_WQI=100-}\left(\sqrt{\frac{F_1^2+F_2^2+F_3^2}{\mathbf{1.732}}}\right) \text{....................Eq. 4.9}$$

4.2.2 Index value categorization of CCME WQI

Once the index has been calculated, we obtain a value of 0 to 100. The higher the index value, the better the water quality. The index is then placed in one of the following water quality categories:

- **Excellent:** (CCME WQI value from 95.0 to 100.0) Water quality is intact.

Conditions are very close to natural or desired levels. These index values can only be obtained if all measurements comply with the guidelines almost all the time.

- **Good:** (CCME WQI value from 80.0 to 94.9) Water quality is intact and only one minor threat or deterioration is observed; conditions rarely differ from the natural or desirable levels.
- **Fair:** (CCME WQI value from 65.0 to 79.9) Water quality is usually intact, but occasionally endangered or deteriorated; conditions sometimes deviate from the natural or desirable levels.
- **Marginal:** (CCME WQI value of 45.0 to 64.9) Water quality is frequently endangered or deteriorated; conditions often deviate from the natural or desirable levels.
- **Poor:** (CCME WQI value from 0.0 to 44.9) Water quality is almost always endangered or deteriorated; conditions usually deviate from natural or desirable levels.

Below is a table to summarize the standard index value categorisation:

Table. 4.1 Water Quality Characteristics according to CCME WQI.

CCMEWQI	Ranking	Water Quality Characteristics
95-100	Excellent	Water quality is protected with a virtual absence of threat, and the condition is very close to natural and pristine levels
80-94	Good	Water quality is protected with only a minor degree of threat or impairment; Conditions rarely depart from desirable levels
65-79	Fair	Water quality is usually but occasionally threatened or impaired; conditions sometimes depart from desirable levels
45-64	Marginal	Water quality is frequently threatened or impaired; Conditions often depart from natural or desirable levels
0-44	Poor	Water quality is almost always threatened or impaired; Conditions usually depart from natural or desirable levels

4.2.3 Merits of CCMEWQI: (Terrado et al, 2010)

1. Represent measurements of a variety of variables in a single number.
2. Flexibility in the selection of input parameters and objectives.
3. Adaptability to different legal requirements and different water uses.
4. Statistical simplification of complex multivariate data.
5. Clear and intelligible diagnostic for managers and the general public.
6. Suitable tool for water quality evaluation in a specific location
7. Easy to calculate
8. Tolerance to missing data
9. Suitable for analysis of data coming from automated sampling.
10. Combine various measurements in a variety of different measurement units in a single metric.

4.2.4 Demerits of CCMEWQI: (Terrado et al, 2010)

1. Loss of information on single variables.
2. Loss of information about the objectives specific to each location and particular water use.
3. Sensitivity of the results to the formulation of the index.

4. Loss of information on interactions between variables.
5. Lack of portability of the index to different ecosystem types.
6. Easy to manipulate (biased).
7. The same importance is given to all variables.
8. No combination with other indicators or biological data
9. Only partial diagnostic of the water quality.
10. F_l not working appropriately when too few variables are considered or when too much covariance exists among them.

4.2.5 Computation Method of WAWQI

The WAWQI method is a powerful tool that enables easy communication of the quality of water to the public, especially the policymakers. It is an unambiguous tool that enables the integration of the water parameters, which are deemed important to the quality of the water accordingly. In this study, the WQI, which is calculated using the weighted arithmetic index method (DeZuane, 1997) is used to determine the effect of waste dumping on the immediate ground and surface water- bodies of the dumpsite, as it is deemed the most appropriate, based on the prevailing conditions. The WQI is given as:

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i} \ldots\ldots\ldots\ldots\ldots Eq. 4.10$$

Where qi= quality rating (sub-index) of i^{th} water quality parameter
Wi= unit weight of i^{th} water quality parameter; = 1

Also, qi, which relates the value of the parameter in polluted water to the standard permissible value, is obtained as follows:

$$\mathbf{q_i = 100\left(\frac{Vi-Vo}{Si-Vio}\right)} \text{..................Eq. 4.11}$$

Where,
Vi= estimated value of the n parameter
Vio= ideal value of the n^{th} parameter
Si= standard permissible value of the n^{th} parameter
In most cases, v_{io}=0 except for pH and DO (in mg/1)

For pH, Vio,= 7; For DO, V_{io}=l4.6 mg/1.
The unit weight (w ;), which is inversely proportional to the values of the recommended standards is obtained as:

$$W_i = \frac{K}{Si} \text{........................Eq. 4.12}$$

$$\text{Where, } K = \frac{1}{\sum_{i=1}^{n} \frac{1}{S_i}} \text{ ....Eq. 4.13}$$

The rating of the water quality using the above method is shown below in Table 4.2.

Table. 4.2 Water Quality Characteristics according to WAWQI (Brown et al.1972)

Water Quality Index	Water Quality Status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
> 100	Unfit for consumption

Table 4.3 Drinking Water Specification as per Bureau of Indian Standards 10500:2012.

Sl. No.	Characteristics Physical Parameters	Acceptable Limit	Permissible Limit
01	pH	8.5	No relaxation
	General Parameters concerning Substances undesirable in Excessive Amounts		
02	BOD (mg/l)	3	>5
03	DO (mg/l)	4	4
04	Total Coliform (MPN/100ml)	5000	5000
05	COD (mg/l)	250	250
06	TSS (mg/l)	500	2000
07	Fecal Coliform (MPN/100ml)	500	2500

4.2.6 Merit of WAWQI: (Akoteyol et al; 2011, Yogendra, Puttarab; 2008)

1. Describes the suitability of both surface and groundwater resources for human consumption
2. Useful for communication of overall water quality information to the concerned citizens and policymakers.
3. Incorporate data from multiple water quality parameters into a mathematical equation that rates the health of the water body with the number.
4. Reflects the composite influence of different parameters i.e. important for the assessment and management of water quality.
5. Less number of parameters is required in comparison to all water quality parameters for a particular use.

4.2.7 Demerit of WAWQI: (Akoteyol et al; 2011, Yogendra, Puttarab; 2008)

1. The eclipsing or over-emphasizing of a single bad parameter value
2. Many uses of water quality data cannot be met with an index.
3. WQI based on some very important parameters can provide a simple indicator of water quality.
4. A single number cannot tell the whole story of water quality; many other water quality parameters are not included in the index.
5. WQI may not carry enough information about the real quality situation of the water.

CHAPTER-V

5.1 Results and Discussion for Bansdroni:

5.1.1 Data Collected from Bansdroni (High Tide) Water Monitoring Station (WMS) of WBPCB.

Below are the tables of data collected as per availability with the WBPCB for raw water of Bansdroni, Water Monitoring Station for the years2014, 2015, 2016, 2017, 2018, 2019 and 2020. The collected data are given in ranges for all seven years.

Table: 5.1 Yearly ranges of Physicochemical & Biochemical Parameters of Raw Water of Bansdroni (2014-2020)

Sl. No.	Parameters	BIS Value	Test Result with respect to date						
			19.05.14	16.06.14	18.07.14	22.08.14	12.09.14	13.10.14	20.11.14
01	BOD (mg/l)	3	20.75	20.42	5.50	12.78	14.38	26.75	23.50
02	DO (mg/l)	4	NIL	NIL	2.40	NIL	NIL	NIL	NIL
03	pH (Unit)	8.5	8.20	7.72	7.71	8.05	7.80	7.60	7.56
04	TC (MPN/100ml)	5000	2400000	16000000	3000000	3000000	5000000	9000000	3000000
05	COD (mg/l)	250	60.46	52.65	26.71	38.28	27.06	42.28	42.16
06	TSS (mg/l)	500	26.00	24.00	34.00	10.00	6.00	36.00	28.00
07	FC (MPN/100ml)	500	1300000	9000000	1700000	2400000	2400000	5000000	2400000

Sl. No.	Parameters	BIS Value	Test Result with respect to date							
			20.02.15	22.05.15	09.08.15	17.11.15	12.02.16	10.05.16	09.08.16	02.11.16
01	BOD (mg/l)	3	28	17	5.47	24.46	38	17.29	5.5	43.54
02	DO (mg/l)	4	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
03	pH (Unit)	8.5	7.84	7.78	7.39	7.56	7.55	7.59	7.14	7.07
04	TC (MPN/100ml)	5000	1100000	5000000	9000000	9000000	5000000	5000000	9000000	5000000
05	COD (mg/l)	250	74.54	66.00	42.00	47.20	70.00	53.00	32.00	60.48
06	TSS (mg/l)	500	36.00	52.00	8.00	13.80	20.00	22.00	12.00	34.00
07	FC (MPN/100ml)	500	800000	3000000	50000000	5000000	3000000	3000000	5000000	3000000

Sl. No.	Parameters	BIS Value	Test Result with respect to date							
			17.02.17	04.08.17	03.05.17	22.11.17	16.02.18	28.05.18	10.08.18	15.11.18
01	BOD (mg/l)	3	16.96	9.5	15.78	29.06	10.25	14.16	14.44	20.68
02	DO (mg/l)	4	NIL	NIL	NIL	4	NIL	NIL	0.9	NIL
03	pH (Unit)	8.5	8.03	7.21	7.40	7.14	7.64	7.48	7.54	7.46
04	TC (MPN/100ml)	5000	9000000	3500000	5000000	9000000	5000000	9000000	3000000	900000
05	COD (mg/l)	250	50.33	31.416	56.00	87.38	67.20	49.99	79.64	62.26
06	TSS (mg/l)	500	14.00	26.00	30.00	38.00	48.00	32.00	208.00	12.00
07	FC (MPN/100ml)	500	5000000	2800000	3000000	3000000	2400000	7000000	2400000	700000

Sl. No.	Parameters	BIS Value	Test Result with respect to date							
			20.02.19	10.05.19	13.08.19	11.11.19	12.02.20	27.05.20	12.08.20	18.11.20
01	BOD (mg/l)	3	19.1	22.5	2.94	9.83	39.58	18.75	7.08	20.63
02	DO (mg/l)	4	NIL	NIL	0.50	1.40	NIL	NIL	0.50	NIL
03	pH (Unit)	8.5	7.35	7.62	7.49	7.72	7.09	7.05	7.14	7.25
04	TC (MPN/100ml)	5000	2200000	1400000	170000	1300000	1300000	1100000	1400000	2700000
05	COD (mg/l)	250	63.00	49.04	13.27	18.84	109.50	33.66	57.32	129.29
06	TSS (mg/l)	500	6.00	44.00	14.00	16.00	26.00	28.00	18.00	62.00
07	FC (MPN/100ml)	500	1700000	1100000	94000	800000	800000	700000	800000	1300000

5.1.2 Evaluation of CCMEWQI for Bansdroni:

5.1.2.1 CCME WQI Calculation for the year 2014:

Table. 5.2 Value considered for Table 4.2 and Table 5.1.

Parameters	pH	BOD (mgl)	DO (mg/l)	Total Coliform (MPN/100ml)	COD (mg/l)	TSS(mg/l)	Fecal Coliform (MPN/100ml)
BIS Standard	8.5	3	4	5000	250	500	500

Table: 5.3 CCME WQI Terms.

CCME WQI Terms	
Variables	Parameters
Objects	Standard Limit
No. of Failed Variables	No. of Parameters exceeding the limit
No. of Variables	Total No. of Parameters Studied
Total No. of Test	No. of Water Parameter Studied x No. of Sampling Season

Here, for the year 2014

Particulars	Code	CCME Data
No. of Failed Variables (Parameters)	X	3
Total No. of Variables (Parameter Studied)	Y	7
Total No. of Test/Results	Z	49
Total No. of Failed Test (All Parameters Exceeding)	E	21

Now,
As per eq. 4.1, Scope,

$$\mathbf{F_1}=\left(\frac{\textbf{No of failed variables}}{\textbf{Total no of variables}}\right)\times 100 \qquad =\left(\frac{X}{Y}\right)\times 100= \left(\frac{3}{7}\right)\times 100=\mathbf{42.8571}$$

As per eq. 4.2, Frequency,

$$\mathbf{F2}=\left(\frac{\textbf{Number of failed results}}{\textbf{Total number of results}}\right)\times 100 \quad =\left(\frac{E}{Z}\times 100\right)=\left(\frac{21}{49}\times 100\right) \quad =\mathbf{42.8571}$$

Calculation of Excursion Value:

Assuming, A= Failed Test Values

B = Standard values of that Particular Parameter

CCMEWQI values have been calculated as per equation 4.9

Parameters	**19.05.14**			**16.06.14**			**18.07.14**		
A	42.5	9000000	5000000	20.42	16000000	9000000	5.50	3000000	1700000
B	3	5000	5000	3	5000	5000	3	5000	5000
A/B	**14.1667**	**1800**	**1000**	**6.8067**	**3200**	**1800**	**1.8333**	**600**	**340**
C=(A/B)-1	**13.1667**	**1799**	**999**	**5.8067**	**3199**	**1799**	**0.8333**	**599**	**339**
Sum of C	**2811.1667**			**5003.8067**			**938.8333**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**12.5499**			**22.3384**			**4.1912**		
CCME WQI	**36.1915**			**34.6865**			**41.8209**		

Parameters	**22.08.14**			**12.09.14**			**13.10.14**		
A	12.78	3000000	2400000	14.38	5000000	2400000	26.75	9000000	5000000
B	3	5000	5000	3	5000	5000	3	5000	5000
A/B	**4.260**	**600**	**480**	**4.7933**	**1000**	**480**	**8.9167**	**1800**	**1000**
C=(A/B)-1	**3.260**	**599**	**479**	**3.7933**	**999**	**479**	**7.9167**	**1799**	**999**
Sum of C	**1081.2600**			**1481.7933**			**2805.9167**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**4.8271**			**6.6151**			**12.5264**		
CCME WQI	**40.8441**			**38.9477**			**36.1977**		

Parameters	**20.11.14**		
A	23.50	3000000	2400000
B	3	5000	5000
A/B	**7.8333**	**600**	**480**
C=(A/B)-1	**6.8333**	**599**	**479**
Sum of C	**1084.8333**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**4.8430**		
CCME WQI	**40.8222**		

nse& CCME WQI for the year 2014

	19.05.14	16.06.14	18.07.14	22.08.14	12.09.14	13.10.14	20.11.14
nse	12.5499	22.3384	4.1912	4.8271	6.6151	12.5264	4.8430
CCMEWQI	36.1915	34.6865	41.8209	40.8441	38.9477	36.1977	40.8222

From Table 4.1, we can see that the CCMEWQI values for the months from May to Nov in the year 2014 are in the range of 36-42 and the quality of water is classified as "Poor". So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.1.2.2 CCME WQI Calculation for the year 2015:

Similarly, as per the previous year's calculation

Scope, F_1=42.8571 and Frequency, F_2=42.8571

According to the Eq. 4.4 and 4.9 nse and CCME WQI for the year 2015.

Parameters	20.02.15			22.05.15		
A	28	1100000	800000	17	5000000	3000000
B	3	5000	5000	3	5000	5000
A/B	**9.3333**	**220**	**160**	**5.6667**	**1000**	**600**
C=(A/B)-1	**8.3333**	**219**	**159**	**4.6667**	**999**	**599**
Sum of C	**386.3333**			**1602.6667**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**1.7247**			**7.1548**		
CCME WQI	**49.5270**			**38.5349**		
Parameters	**09.08.15**			**17.11.15**		
A	5.47	9000000	50000000	24.46	9000000	5000000
B	3	5000	5000	3	5000	5000
A/B	**1.8233**	**1800**	**10000**	**8.1533**	**1800**	**1000**
C=(A/B)-1	**0.8233**	**1799**	**9999**	**7.1533**	**1799**	**999**
Sum of C	**11798.8233**			**2805.1533**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**52.6733**			**12.5230**		
CCME WQI	**33.4993**			**36.1986**		

Calculation of Normalized Sum Excursion (nse):
Similarly,

nse and CCME WQI for the year 2015:

	20.02.15	22.05.15	09.08.15	17.11.15
nse	**1.7247**	**7.1548**	**52.6733**	**12.5230**
CCMEWQI	**49.5270**	**38.5349**	**33.4993**	**36.1986**

From Table4.1, we can see that the CCMEWQI values for the months of Feb, May, Aug and Nov in the year 2015 are in the range of 36-50 and the quality of water is classified as "Poor" and "Marginal". So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.1.2.3 CCME WQI Calculation for the year 2016:

Similarly, as per the previous year's calculation
Scope,F_1=42.8571 and Frequency,F_2=42.8571

Parameters	**12.02.16**			**10.05.16**		
A	38	5000000	3000000	17.29	5000000	3000000
B	3	5000	5000	3	5000	5000
A/B	**12.6667**	**1000**	**600**	**5.7633**	**1000**	**600**
C=(A/B)-1	**11.6667**	**999**	**599**	**4.7633**	**999**	**599**
Sum of C	**1609.6667**			**1602.7633**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**7.1860**			**7.1552**		
CCME WQI	**38.5126**			**38.5346**		

Parameters	**09.08.16**			**02.11.16**		
A	5.5	9000000	5000000	43.54	5000000	3000000
B	3	5000	5000	3	5000	5000
A/B	**1.8333**	**1800**	**1000**	**14.5133**	**1000**	**600**
C=(A/B)-1	**0.8333**	**1799**	**999**	**13.5133**	**999**	**599**
Sum of C	**2798.8333**			**1611.5133**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**12.4948**			**7.1943**		
CCME WQI	**36.2061**			**38.5067**		

Calculation of Normalized Sum Excursion (nse):
Similarly,
nse & CCME WQI for the year 2016:

	12.02.16	10.05.16	09.08.16	02.11.16
nse	7.1860	7.1552	12.4948	7.1943
CCMEWQI	38.5126	38.5346	36.2061	38.5067

From Table 4.1, we can see that the CCMEWQI values for the months of Feb, May, Aug and Nov in the year 2016 are in the range of 36-39 and the quality of water is classified as "Poor". So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.1.2.4 CCME WQI Calculation for the year 2017:

Similarly, as per the previous year's calculation

Scope,F_1=42.8571 and Frequency,F_2=42.8571

Parameters	17.02.17			03.05.17		
A	16.96	9000000	5000000	15.78	5000000	3000000
B	3	5000	5000	3	5000	5000
A/B	5.6533	1800	1000	5.2600	1000	600
C=(A/B)-1	4.6533	1799	999	4.2600	999	599
Sum of C	2802.6533			1602.2600		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	12.5118			7.1529		
CCME WQI	36.2016			38.5362		

Parameters	04.08.17			22.11.17		
A	9.5	3500000	2800000	29.06	9000000	3000000
B	3	5000	5000	3	5000	5000
A/B	3.1667	700.0000	560.	9.6867	1800	600
C=(A/B)-1	2.1667	699.0000	559	8.6867	1799	599
Sum of C	1260.1667			2406.6867		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	5.6257			10.7441		
CCME WQI	39.8743			36.7396		

Calculation of Normalized Sum Excursion (nse):
Similarly,
nse& CCME WQI for the year 2017:

	17.02.17	03.05.17	04.08.17	22.11.17
nse	12.5118	7.1529	5.6257	10.7441
CCMEWQI	36.2016	38.5362	39.8743	36.7396

From Table 4.1, we can see that the CCMEWQI values for the months of Feb, May, Aug and Nov in the year 2017 are in the range of 36-40 and the quality of water is classified as “Poor”. So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.1.2.5 CCME WQI Calculation for the year 2018:

Similarly, as per the previous year's calculation

Scope,F_1=42.8571 and Frequency,F_2=42.8571

Parameters	16.02.18			28.05.18		
A	10.25	5000000	2400000	14.16	9000000	7000000
B	3	5000	5000	3	5000	5000
A/B	**3.4167**	**1000**	**480**	**4.7200**	**1800**	**1400**
C=(A/B)-1	**2.4167**	**999**	**479**	**3.7200**	**1799**	**1399**
Sum of C	**1480.4167**			**3201.7200**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**6.6090**			**14.2934**		
CCME WQI	**38.9527**			**35.7839**		

Parameters	10.08.18			15.11.18		
A	14.44	3000000	2400000	20.68	900000	700000
B	3	5000	5000	3	5000	5000
A/B	**4.8133**	**600**	**480**	**6.8933**	**180**	**140**
C=(A/B)-1	**3.8133**	**599**	**479.0000**	**5.8933**	**179**	**139**
Sum of C	**1081.8133**			**323.8933**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**4.8295**			**1.4460**		
CCME WQI	**40.8407**			**51.2471**		

Calculation of Normalized Sum Excursion (nse):
Similarly,

nse & CCME WQI for the year 2018:

	16.02.18	28.05.18	10.08.18	15.11.18
nse	**6.6090**	**14.2934**	**4.8295**	**1.4460**
CCMEWQI	**38.9527**	**35.7839**	**40.8407**	**51.2471**

From Table 4.1, we can see that the CCMEWQI values for the months of Feb, May, Aug and Nov in the year 2018 are in the range of 36-51 and the quality of water is classified as “Poor” and “Marginal”. So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.1.2.6 CCME WQI Calculation for the year 2019:

Similarly, as per the previous year's calculation

Scope,F_1=42.8571 and Frequency,F_2=42.8571

Parameters	20.02.19			10.05.19		
A	19.1	2200000	1700000	22.5	1400000	1100000
B	3	5000	5000	3	5000	5000
A/B	**6.3667**	**440**	**340**	**7.50**	**280**	**220**
C=(A/B)-1	**5.3667**	**439**	**339**	**6.50**	**279**	**219**
Sum of C	**783.3667**			**504.5000**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**3.4972**			**2.2522**		
CCME WQI	**43.1869**			**46.9852**		

Parameters	13.08.19		11.11.19		
A	170000	94000	9.83	1300000	800000
B	5000	5000	3	5000	5000
A/B	**34.0000**	**18.80**	**3.2767**	**260**	**160**
C=(A/B)-1	**33.0000**	**17.80**	**2.2767**	**259**	**159**
Sum of C	**53.0767**		**420.2767**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**0.2369**		**1.8762**		
CCME WQI	**68.6052**		**48.7128**		

Calculation of Normalized Sum Excursion (nse):
Similarly,
nse & CCME WQI for the year 2019:

	20.02.19	10.05.19	13.08.19	11.11.19
nse	**3.4972**	**2.2522**	**0.2369**	**1.8762**
CCMEWQI	**43.1869**	**46.9852**	**68.6052**	**48.7128**

From Table 4.1, we can see that the CCMEWQI values for the months of Feb, May, Aug and Nov in the year 2019 are in the range 43-69 and the quality of water is classified as “Marginal” and “Fair”. So, it is observed from the result that the quality of water is frequently and occasionally threatened or impaired and conditions sometimes depart from desirable levels.

5.1.2.7 CCME WQI Calculation for the year 2020:

Similarly, as per the previous year's calculation

Scope,F_1=42.8571 and Frequency,F_2=42.8571

Parameters	12.02.20			27.05.20		
A	39.58	1300000	800000	18.75	1100000	700000
B	3	5000	5000	3	5000	5000
A/B	**13.1933**	**260**	**160**	**6.25**	**220**	**140**
C=(A/B)-1	**12.1933**	**259**	**159**	**5.25**	**219**	**139**
Sum of C	**430.1933**			**363.2500**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**1.9205**			**1.6217**		
CCME WQI	**48.4890**			**50.1268**		
Parameters	**12.08.20**			**18.11.20**		
A	7.08	1400000	800000	20.63	2700000	1300000
B	3	5000	5000	3	5000	5000
A/B	**2.3600**	**280**	**160**	**6.8767**	**540**	**260**
C=(A/B)-1	**1.3600**	**279**	**159**	**5.8767**	**539**	**259**
Sum of C	**439.3600**			**803.8767**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**1.9614**			**3.5887**		
CCME WQI	**48.2873**			**42.9842**		

Calculation of Normalized Sum Excursion (nse):
Similarly,

According to the Eqs. 4.4 and 4.9 nse and CCME WQI for the year 2020

	12.02.20	27.05.20	12.08.20	18.11.20
nse	**1.9205**	**1.6217**	**1.9614**	**3.5887**
CCMEWQI	**48.4890**	**50.1268**	**48.2873**	**42.9842**

From Table 4.1, we can see that the CCMEWQI values for the months of Feb, May, Aug and Nov in the year 2018 are in the range of 43-51 and the quality of water is classified as “Poor” and “Marginal”. So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

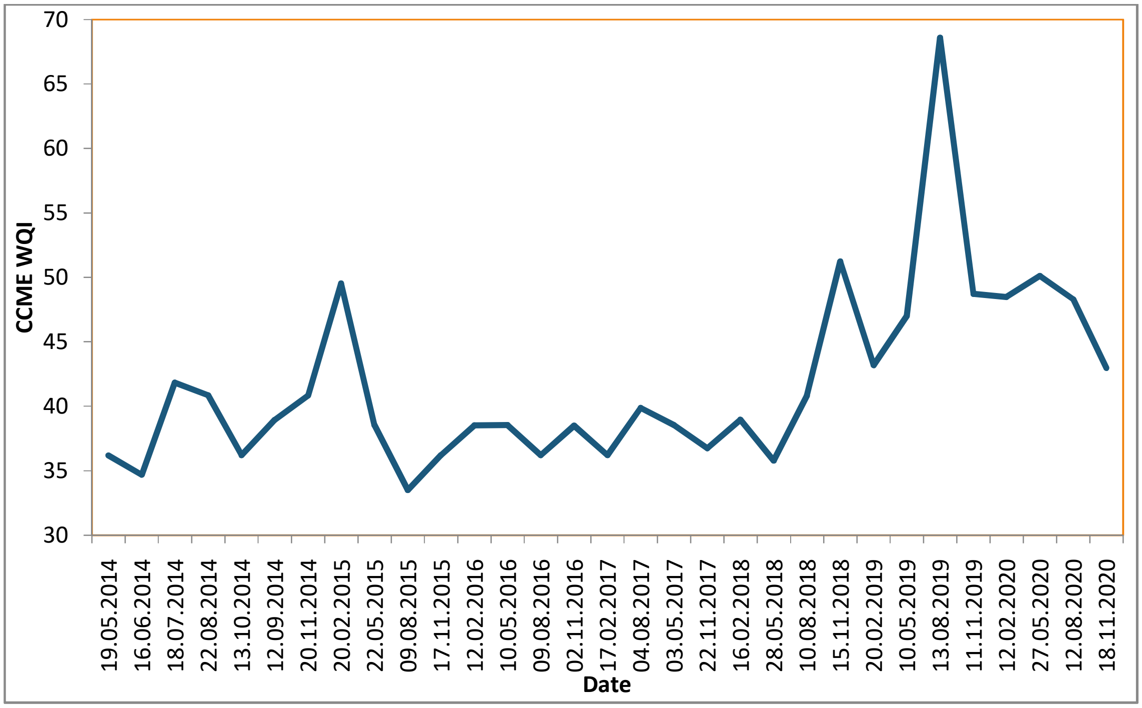

Fig. 5.1: Graph plotted against Date vs. CCMEWQI for Bansdroni

From Fig. 5.1, it can be stated that Water Quality Index is increasing mostly in the month of August each year which is a maximum of 68 on 13.08.2019. Whereas it is decreasing in the month of November in each year. But it is observed the lowest value of WQI is 33 on 09.08.2015. During the evaluation of the WQI value, it is observed that the WQI value is mainly affected due to the high-range BOD presence in raw water collected from the Hoogly River. It may be largely influenced by the interaction of untreated effluent to the river water by run-off during monsoon. It is also observed that F_1 and F_2 values are the same for all the years. Less no. of parameters may be the reason behind it.

5.1.3 Evaluation of WAWQI for Bansdroni:

5.1.3.1 Computation of Weighted Arithmetic WQI for the year 2014:

As per equations 4.10 and 4.11

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

$$q_i = 100\left(\frac{Vi - Vi0}{Si - Vi}\right)$$

Where,
v_i = observed value of the parameter

$v_i o$= ideal value of the parameter

S_i= standard permissible value of the parameter

As per equations 4.12 and 4.13

$$W_i = \frac{K}{Si}$$

$$K = \frac{1}{\sum_{i=1}^{n} \frac{1}{S_i}}$$

WAWQI for the year 2014:

WA WQI Calculation for Bansdroni for 19.05.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	20.75	691.6667	329.8153	410.7308
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	8.20	60	9.5368	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	2400000	48000	13.7330	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	60.46	24.1840	0.1384	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	26.00	0.5200	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	1300000	26000	7.4387	
			0.6990			1					

WA WQI = $\sum Q_i \times wi / \sum w_i$
= 410.7308
Say, WA WQI = 411

WA WQI Calculation for Bansdroni for 16.06.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	20.42	680.6667	324.5700	**523.5336**
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.72	36.0000	5.7221	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	16000000	320000.0000	91.5535	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	52.65	21.0600	0.1205	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	24.00	0.4800	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	9000000	180000.0000	51.4989	
			0.6990			1					

WA WQI Calculation for Bansdroni for 18.07.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	5.50	183.3333	87.4209	**161.5039**
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	2.40	116.0000	41.4852	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.71	35.5000	5.6426	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	26.71	10.6840	0.0611	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	34.00	0.6800	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	1700000	34000.0000	9.7276	
			0.6990			1					

WA WQI Calculation for Bandroni for28.08.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	12.78	426.0000	203.1344	**292.5345**
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	8.05	52.5000	8.3447	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	38.28	15.3120	0.0876	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	10.00	0.2000	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	2400000	48000.0000	13.7330	
			0.6990			1					

WA WQI Calculation for Bansdroni for12.09.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	14.38	479.3333	228.5660	327.3977
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.80	40.0000	6.3579	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	27.06	10.8240	0.0619	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	6.00	0.1200	0.0000	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	2400000	48000.0000	13.7330	
			0.6990			1					

WA WQI Calculation for Bansdroni for13.10.2014

Sl No	Parameters	BIS Standard (S_i)	(1/S_i)	Σ(1/S_i)	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	26.75	891.6667	425.1836	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.60	30.0000	4.7684	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	9000000	180000.0000	51.4989	560.2267
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	42.28	16.9120	0.0968	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	36.00	0.7200	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
			0.6990			1					

WA WQI Calculation for Bansdroni for20.11.2014

Sl No	Parameters	BIS Standard (S_i)	(1/S_i)	Σ(1/S_i)	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	23.50	783.3333	373.5258	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.56	28.0000	4.4505	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	459.0406
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	42.16	16.8640	0.0965	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	28.00	0.5600	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	2400000	48000.0000	13.7330	
			0.6990			1					

From Table 4.2, we can observe that the WAWQI values for the Year 2014, values are taken from the months of May, Jun, Jul, Aug, Sep, Oct. & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water

For the year 2015:

From Table 4.2, we can observe that the WAWQI value for the Year 2015, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water

WA WQI Calculation for Bansdroni for20.02.2015

Sl No	Parameters	BIS Standard (S_i)	(1/S_i)	Σ(1/S_i)	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	28.00	933.3333	445.0520	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.84	42.0000	6.6758	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	1100000	22000.0000	6.2943	512.8389
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	74.54	29.8160	0.1706	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	36.00	0.7200	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	800000	16000.0000	4.5777	
			0.6990			1					

WA WQI Calculation for Bansdroni for22.05.2015

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	17.00	566.6667	270.2101	372.4055
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.78	39.0000	6.1989	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	66.00	26.4000	0.1511	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	52.00	1.0400	0.0003	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Bansdroni for19.08.2015

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	5.47	182.3333	86.9441	220.3174
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.39	19.5000	3.0995	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	42.00	16.8000	0.0961	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	8.00	0.1600	0.0000	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
			0.6990			1					

WA WQI Calculation for Bansdroni for 17.11.2015

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	24.46	815.3333	388.7847	523.5210
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.56	28.0000	4.4505	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	47.20	18.8800	0.1080	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	13.80	0.2760	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
			0.6990			1					

WA WQI Calculation for Bansdroni for12.02.2016

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	38.00	1266.6667	603.9991	704.3756
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.55	27.5000	4.3710	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	70.00	28.0000	0.1602	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	20.00	0.4000	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Bansdroni for 10.05.2016

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	17.29	576.3333	274.8196	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.59	29.5000	4.6889	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	53.00	21.2000	0.1213	375.4751
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	22.00	0.4400	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Bansdroni for 09.08.2016

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	5.50	183.3333	87.4209	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.14	7.0000	1.1126	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	32.00	12.8000	0.0732	218.7846
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	12.00	0.2400	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
			0.6990			1					

WA WQI Calculation for Bansdroni for 02.11.2016

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	43.54	1451.3333	692.0558	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.07	3.5000	0.5563	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	60.48	24.1920	0.1384	788.5959
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	34.00	0.6800	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	
			0.6990			1					

From Table 4.2, we can observe that the WAWQI value for the Year 2016, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water

WA WQI Calculation for Bansdroni for 17.02.2017

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	16.96	565.3333	269.5743	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	8.03	51.5000	8.1858	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	50.33	20.1320	0.1152	408.0531
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	14.00	0.2800	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
			0.6990			1					

WA WQI Calculation for Bansdroni for 03.05.2017

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/Si)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	15.78	526.0000	250.8186	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.40	20.0000	3.1789	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	56.00	22.4000	0.1282	349.9710
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	30.00	0.6000	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Bansdroni for04.08.2017

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/Si)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	9.50	316.6667	150.9998	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.21	10.5000	1.6689	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	3500000	70000.0000	20.0273	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	31.42	12.5664	0.0719	238.8583
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	26.00	0.5200	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	2800000	56000.0000	16.0219	
			0.6990			1					

WA WQI Calculation for Bansdroni for22.11.2017

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/Si)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	29.06	968.6667	461.9004	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	4.00	100.0000	35.7631	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.14	7.0000	1.1126	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	87.38	34.9520	0.2000	567.6415
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	38.00	0.7600	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	
			0.6990			1					

From Table 4.2, we can observe that the WAWQI value for the Year 2017, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water

WA WQI Calculation for Bansdroni for16.02.2018

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/Si)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	10.25	341.6667	162.9208	
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.64	32.0000	5.0863	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	67.20	26.8800	0.1538	260.5731
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	48.00	0.9600	0.0003	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	2400000	48000.0000	13.7330	
			0.6990			1					

WA WQI Calculation for Bansdroni for 28.05.2018

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	14.16	472.0000	225.0691	370.6204
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.48	24.0000	3.8147	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	49.99	19.9960	0.1144	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	32.00	0.6400	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	7000000	140000.0000	40.0547	
			0.6990			1					

WA WQI Calculation for Bansdroni for10.08.2018

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	14.44	481.3333	229.5197	311.7437
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.90	131.0000	46.8497	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.54	27.0000	4.2916	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	3000000	60000.0000	17.1663	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	79.64	31.8560	0.1823	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	208.00	4.1600	0.0012	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	2400000	48000.0000	13.7330	
			0.6990			1					

WA WQI Calculation for Bansdroni for 15.11.2018

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	20.68	689.3333	328.7027	388.5061
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.90	131.0000	46.8497	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.46	23.0000	3.6558	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	900000	18000.0000	5.1499	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	62.26	24.9040	0.1425	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	12.00	0.2400	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	700000	14000.0000	4.0055	
			0.6990			1					

From Table 4.2, we can observe that the WAWQI value for the year 2018, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water.

WA WQI Calculation for Bansdroni for 20.02.2019

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	19.10	636.6667	303.5890	378.8994
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.35	17.5000	2.7816	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	2200000	44000.0000	12.5886	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	63.00	25.2000	0.1442	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	6.00	0.1200	0.0000	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	1700000	34000.0000	9.7276	
			0.6990			1					

WA WQI Calculation for Bansdroni for 10.05.2019

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	22.50	750.0000	357.6311	427.0445
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.62	31.0000	4.9274	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	1400000	28000.0000	8.0109	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	49.04	19.6160	0.1122	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	44.00	0.8800	0.0003	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	1100000	22000.0000	6.2943	
			0.6990			1					

WA WQI Calculation for Bansdroni for 13.08.2019

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	2.94	98.0000	46.7305	100.4459
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.50	135.0000	48.2802	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.49	24.5000	3.8942	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	170000	3400.0000	0.9728	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	13.27	5.3080	0.0304	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	14.00	0.2800	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	94000	1880.0000	0.5379	
			0.6990			1					

WA WQI Calculation for Bansdroni for 11.11.2019

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	9.83	327.6667	156.2450	219.0883
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	1.40	126.0000	45.0615	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.72	36.0000	5.7221	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	1300000	26000.0000	7.4387	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	18.84	7.5360	0.0431	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	16.00	0.3200	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	800000	16000.0000	4.5777	
			0.6990			1					

From Table 4.2, we can observe that the WAWQI value for the Year 2019, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water

WA WQI Calculation for Bansdroni for 12.02.2020

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	39.58	1319.3333	629.1128	692.1635
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.09	4.5000	0.7153	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	1300000	26000.0000	7.4387	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	109.50	43.8000	0.2506	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	26.00	0.5200	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	800000	16000.0000	4.5777	
			0.6990			1					

WA WQI Calculation for Bansdroni for 27.05.2020

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	18.75	625.0000	298.0259	358.8686
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.05	2.5000	0.3974	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	1100000	22000.0000	6.2943	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	33.66	13.4640	0.0770	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	28.00	0.5600	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	700000	14000.0000	4.0055	
			0.6990			1					

WA WQI Calculation for Bansdroni for 12.08.2020

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	7.08	236.0000	112.5346	174.1705
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.50	135.0000	48.2802	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.08	4.0000	0.6358	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	1400000	28000.0000	8.0109	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	57.32	22.9280	0.1312	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	18.00	0.3600	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	800000	16000.0000	4.5777	
			0.6990			1					

WA WQI Calculation for Bansdroni for 18.11.2020

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.6990	1.4305	0.4768	0.0000	20.63	687.6667	327.9079	403.1478
2	DO (mg/l)	4	0.2500	0.6990	1.4305	0.3576	14.0000	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.6990	1.4305	0.1589	7.0000	7.25	12.5000	1.9868	
4	TC (MPN/100ml)	5000	0.0002	0.6990	1.4305	0.0003	0.0000	2700000	54000.0000	15.4497	
5	COD (mg/l)	250	0.0040	0.6990	1.4305	0.0057	0.0000	129.29	51.7160	0.2959	
6	TSS (mg/l)	500	0.0002	0.6990	1.4305	0.0003	0.0000	62.00	1.2400	0.0004	
7	FC (MPN/100ml)	500	0.0002	0.6990	1.4305	0.0003	0.0000	1300000	26000.0000	7.4387	
			0.6990			1					

From Table 4.2, we can observe that the WAWQI value for the Year 2020, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. thus, the raw water quality of Bansdroni can be categorized under “Unfit for Consumption”.

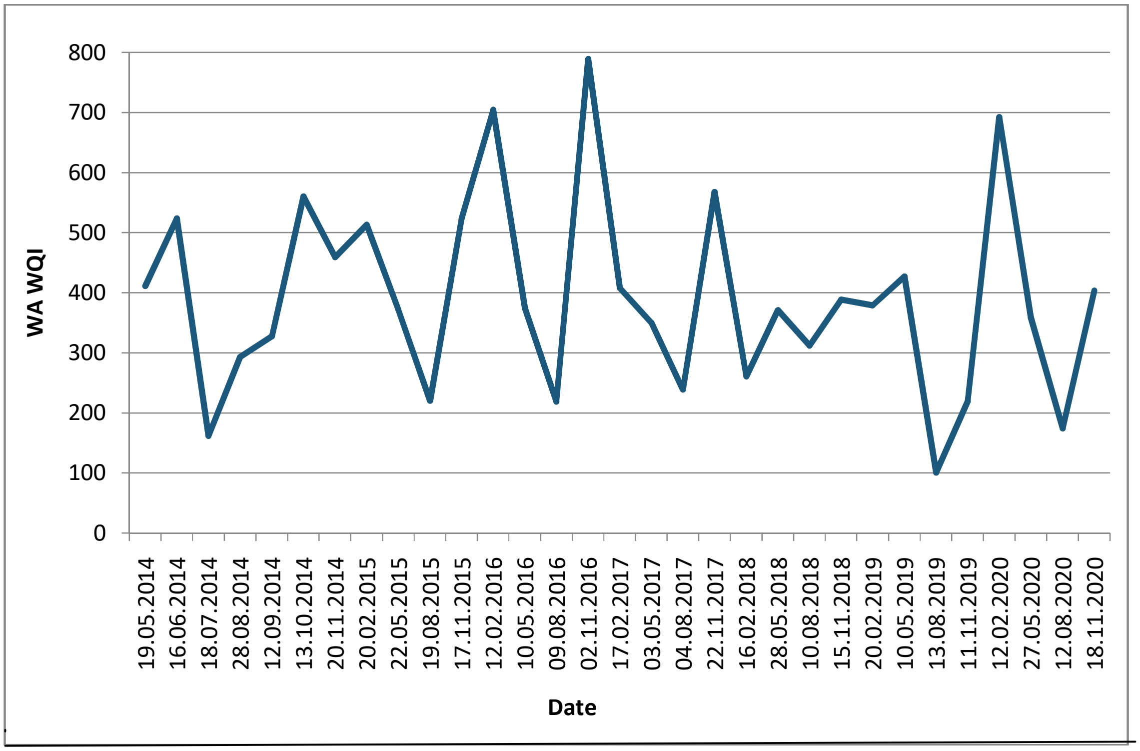

Fig.5.2 Graph showing the date-wise change in WA WQI for Bansdroni.

It is also observed from the graph that the WAWQI value is very higher in the month of November in the year 2016 for Bansdroni and in the month of February 2015 for Kalighat. Whereas a very lower value is found in the month of August 2019 and in the month of June 2014 which might be due to an increase in BOD in the monsoon season. It is also found that there is a huge variation between the month of May and Nov i.e. pre-monsoon and post-monsoon season and one of the main reasons behind it is increasing in BOD due to rainfall in the Hooghly river in the monsoon season. High BOD might be due to the decomposition of organic matter and the decay of vegetation in the river during the rainy season. Variation of BOD is clearly shown in the graph.

5.2 Results and Discussion for Kalighat:

5.2.1 Data Collected from Kalighat (High Tide) Water Monitoring Station (WMS) of WBPCB.

Below are the tables of data collected as per availability with the Kolkata for raw water of Adi Gangal Kalighat, Water Monitoring Station for the years 2014, 2015, 2016, 2017, 2018, 2019 and 2020. The collected data are given in ranges for all seven years.

Table: 5.4 Yearly ranges of Physicochemical & Biochemical Parameters of Raw Water of Kalighat (2014-2020).

Sl. No.	Parameters	BIS Value	Test Result with respect to date							
			27.02.14	19.05.14	16.06.14	18.7.14	22.08.14	12.09.14	13.10.14	20.11.14
1	BOD (mg/l)	3	42.5	19.25	3.15	35.75	7.67	9.7	8.5	35.75
2	DO (mg/l)	4	NIL	NIL	3.80	0.6	2.7	3.60	1.1	NIL
3	pH (Unit)	8.5	7.30	7.89	8.07	7.61	7.91	8.28	7.56	7.45
4	TC (MPN/100ml)	5000	9000000	5000000	1700000	5000000	9000000	5000000	5000000	16000000
5	COD (mg/l)	250	100.97	53	18.91	85.58	21.41	19.16	16.8	68.98
6	TSS (mg/l)	500	44	108.00	366.00	132	92	926	96	56
7	FC (MPN/100ml)	500	5000000	3000000	1300000	3000000	5000000	3000000	3000000	9000000

Sl. No.	Parameters	BIS Value	Test Result with respect to date							
			20.02.15	22.05.15	19.08.15	17.11.15	12.02.16	10.05.16	09.08.16	02.11.16
1	BOD (mg/l)	3	46.25	8.85	7.85	9	29.38	6.6	8.1	18.13
2	DO (mg/l)	4	NIL	4.1	NIL	NIL	NIL	0.7	0.3	NIL
3	pH (Unit)	8.5	7.67	7.96	7.65	7.40	7.55	7.66	7.24	7.13
4	TC (MPN/100ml)	5000	3000000	500000	5000000	3000000	2800000	2400000	1300000	9000000
5	COD (mg/l)	250	93.33	19.7	25	15.2	59	14	44	59.47
6	TSS (mg/l)	500	130	182	108	48	456	230	28	112
7	FC (MPN/100ml)	500	2400000	300000	2400000	2400000	2200000	1300000	800000	5000000

Sl. No.	Parameters	BIS Value	Test Result with respect to date							
			17.02.17	03.05.17	04.08.17	22.11.17	16.02.18	28.05.18	10.08.18	15.11.18
1	BOD (mg/l)	3	16.105	27.08	19.14	2.69	6.5	4.45	2.83	16.05
2	DO (mg/l)	4	NIL	NIL	NIL	NIL	NIL	2.9	3.4	NIL
3	pH (Unit)	8.5	7.84	7.27	7.24	7.68	7.85	7.96	7.40	7.25
4	TC (MPN/100ml)	5000	5000000	9000000	9000000	5000000	2800000	13000000	3000000	2200000
5	COD (mg/l)	250	39	58	40.936	8.73	45.36	11.76	22.12	51.89
6	TSS (mg/l)	500	6	30	32	40	82	60	348	6
7	FC (MPN/100ml)	500	3000000	3000000	5000000	3000000	2200000	8000000	2400000	1700000

Sl. No.	Parameters	BIS Value	Test Result with respect to date							
			20.02.19	10.05.19	13.08.2019	11.11.19	12.02.20	27.05.20	12.08.20	18.11.20
1	BOD (mg/l)	3	17.1	19.47	6.88	10.94	27.75	18.33	17	21.75
2	DO (mg/l)	4	NIL	NIL	0.7	0.7	NIL	NIL	NIL	NIL
3	pH (Unit)	8.5	7.32	7.56	7.45	7.35	7.06	6.98	7.08	7.15
4	TC (MPN/100ml)	5000	5000000	900000	220000	2200000	1700000	1700000	3300000	7000000
5	COD (mg/l)	250	36	52.88	53.1	28.63	61.7	38.15	66.56	69.62
6	TSS (mg/l)	500	34	26	40	16	10	28	46	72
7	FC (MPN/100ml)	500	3000000	700000	110000	1300000	800000	700000	2200000	2300000

5.2.2 Evaluation of CCME WQI for Kalighat:

5.2.2.1 CCME WQI Calculation for the year 2014:

Value considered from Table 4.2 and Table 5.1

CCME WQI Terms same as Table no.5.3

CCME WQI Terms	
Variables	Parameters
Objects	Standard Limit
No. of Fail Variables	No. of Parameters exceeding the limit
No. of Variables	Total No. of Parameters Studied
Total No. of Test	No. of Water Parameter Studied x No. of Sampling Season

Here,

Particulars	Code	CCME Data
No. of Failed Variables (Parameters)	X	3
Total No. of Variables (Parameter Studied)	Y	7
Total No. of Test/Result	Z	49
Total No. of Failed Test (All Parameters Exceeding)	E	21

Now, as per eq. 4.1, Scope,

$$F_1=\left(\frac{\textbf{No of failed variables}}{\textbf{Total no of variables}}\right)\times \mathbf{100}$$

$$=\left(\frac{X}{Y}\right)\times \mathbf{100}=\left(\frac{3}{7}\right)\times \mathbf{100}$$

=42.8571

As per eq. 4.2, Frequency,

$$F_2=\left(\frac{\textbf{Number of failed results}}{\textbf{Total number of results}}\right)\times \mathbf{100}$$

$$=\left(\frac{E}{Z}\times \mathbf{100}\right)=\left(\frac{21}{49}\times \mathbf{100}\right)$$

=42.8571

Calculation of Excursion Value:

Assuming, A= Failed Test Values

B = Standard values of that Particular Parameter

CCME WQI Values have been calculated as per equation 4.9

Parameters	**27.02.14**			**19.05.14**			**16.06.14**		
A	42.5	9000000	5000000	19.25	5000000	3000000	3.15	1700000	1300000
B	3	5000	5000	3	5000	5000	3	5000	5000
A/B	**14.1667**	**1800**	**1000**	**6.4167**	**1000**	**600**	**1.05**	**340**	**260**
C=(A/B)-1	**13.1667**	**1799**	**999**	**5.4167**	**999**	**599**	**0.05**	**339**	**259**
Sum of C	**2811.1667**			**1603.4167**			**598.0500**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**12.1696**			**6.9412**			**2.5890**		
CCME WQI	**36.2916**			**38.6886**			**45.7144**		

Parameters	**18.7.14**			**22.08.14**			**12.09.14**		
A	35.75	5000000	3000000	7.67	9000000	5000000	9.7	5000000	3000000
B	3	5000	5000	3	5000	5000	3	5000	5000
A/B	**11.9167**	**1000**	**600**	**2.5567**	**1800**	**1000**	**3.2333**	**1000**	**600**
C=(A/B)-1	**10.9167**	**999**	**599**	**1.5567**	**1799**	**999**	**2.2333**	**999**	**599**
Sum of C	**1608.9167**			**2799.5567**			**1600.2333**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**6.9650**			**12.1193**			**6.9274**		
CCME WQI	**38.6707**			**36.3057**			**38.6990**		

Parameters	13.10.14			20.11.14		
A	8.5	5000000	3000000	35.75	16000000	9000000
B	3	5000	5000	3	5000	5000
A/B	**2.8333**	**1000**	**600**	**11.9167**	**3200**	**1800**
C=(A/B)-1	**1.8333**	**999**	**599**	**10.9167**	**3199**	**1799**
Sum of C	**1599.8333**			**5008.9167**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**6.9257**			**21.6836**		
CCME WQI	**38.7003**			**34.7440**		

CCME WQI & nse for the year 2014:

	27.02.14	19.05.14	16.06.14	18.7.14	22.08.14	12.09.14	13.10.14	20.11.14
nse	12.1696	6.9412	2.5890	6.9650	12.1193	6.9274	6.9257	21.6836
CCMEWQI	36.2916	38.6886	45.7144	38.6707	36.3057	38.6990	38.7003	34.7440

From Table4.1, we can see that the CCMEWQI values for the months from Feb to Nov in the year 2014 are in the range of 36-46 and the quality of water is classified as mostly “Poor”. So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.2.2.2 CCME WQI Calculation for the year 2015:

Similarly, as per the previous year's calculation
Scope,F1=42.8571 and Frequency,F2=42.8571

Parameters	20.02.15			22.05.15			
A	46.25	3000000	2400000	8.85	4.1	500000	300000
B	3	5000	5000	3	4	5000	5000
A/B	**15.4167**	**600**	**480**	**2.95**	**1.025**	**100**	**60**
C=(A/B)-1	**14.4167**	**599**	**479**	**1.95**	**0.025**	**99**	**59**
Sum of C	**1092.4167**			**159.9750**			
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**4.7291**			**0.6925**			
CCME WQI	**40.9778**			**52.6020**			

Parameters	19.08.15			17.11.15		
A	7.85	5000000	**2400000**	9	3000000	**2400000**
B	3	5000	5000	3	5000	5000
A/B	**2.6167**	**1000**	**480**	**3**	**600**	**480**
C=(A/B)-1	**1.6167**	**999**	**479**	**2**	**599**	**479**
Sum of C	**1479.6167**			**1080**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**6.4053**			**4.6753**		
CCME WQI	**39.1209**			**41.0548**		

CCME WQI & nse for the year 2015:

	20.02.15	22.05.15	19.08.15	17.11.15
nse	4.7291	**0.6925**	**6.4053**	**4.6753**
CCMEWQI	**40.9778**	**52.6020**	**39.1209**	**41.0548**

From Table4.1, we can see that the CCMEWQI values for the months of Feb, May, Aug and Nov in the year 2015 are in the range of 39-53 and the quality of water is classified as "Poor" and "Marginal". So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.2.2.3 CCME WQI Calculation for the year 2016:

Similarly, as per the previous year's calculation

Scope,F_1=42.8571 and Frequency,F_2=42.8571

Parameters	12.02.16			10.05.16		
A	29.38	2800000	**2200000**	6.6	2400000	**1300000**
B	3	5000	5000	3	5000	5000
A/B	**9.7933**	**560**	**440**	**2.2**	**480**	**260**
C=(A/B)-1	**8.7933**	**559**	**439**	**1.2**	**479**	**259**
Sum of C	**1006.7933**			**739.2**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**4.3584**			**3.2**		
CCME WQI	**41.5392**			**43.8986**		

Parameters	09.08.16			02.11.16		
A	8.1	1300000	**800000**	18.13	9000000	**5000000**
B	3	5000	5000	3	5000	5000
A/B	**2.7**	**260**	**160**	**6.0433**	**1800**	**1000**
C=(A/B)-1	**1.7**	**259**	**159**	**5.0433**	**1799**	**999**
Sum of C	**419.7**			**2803.0433**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**1.81688**			**12.1344**		
CCME WQI	**49.01886**			**36.3015**		

According to the eqs. 4.4 and 4.9 nse & CCME WQI for the year 2016:

	12.02.2016	10.05.2016	09.08.2016	02.11.2016
nse	**4.3584**	**3.2**	**1.8168**	**12.1344**
CCMEWQI	**41.5392**	**43.8986**	**49.0188**	**36.3015**

From Table4.1, we can see that the CCMEWQI values for the months of Feb, May,Aug and Nov in the year 2016 are in the range of 36-50 and the quality of water is classified as "Poor" and "Marginal". So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.2.2.4 CCME WQI Calculation for the year 2017:

Similarly, as per the previous year's calculation
Scope,F_1=42.8571
Frequency,F_2=42.8571

Parameters	17.02.17			03.05.17		
A	16.105	5000000	3000000	27.08	9000000	3000000
B	3	5000	5000	3	5000	5000
A/B	**5.3683**	**1000**	**600**	**9.0267**	**1800**	**600**
C=(A/B)-1	**4.3683**	**999**	**599**	**8.0267**	**1799**	**599**
Sum of C	**1602.3683**			**2406.0267**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**6.9367**			**10.4157**		
CCME WQI	**38.6920**			**36.8546**		

Parameters	04.08.17			22.11.17	
A	19.14	9000000	**5000000**	5000000	**3000000**
B	3	5000	5000	5000	5000
A/B	**6.38**	**1800**	**1000**	**1000**	**600**
C=(A/B)-1	**5.38**	**1799**	**999**	**999**	**599**
Sum of C	**2803.38**			**1598**	
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**12.1358**			**6.9177**	
CCME WQI	**36.3011**			**41.5469**	

CCME WQI& nse for the year 2017:

	17.02.17	03.05.17	04.08.17	22.11.17
nse	**6.9367**	**10.4157**	**12.1358**	**6.9177**
CCMEWQI	**38.6920**	**36.8546**	**36.3011**	**41.5469**

From Table4.1, we can see that the CCMEWQI values for the months of Feb, May, Aug & Nov in the year 2017 are in the range of 36-42 and the quality of water is classified as "Poor". So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.2.2.5 CCME WQI Calculation for the year 2018:

Similarly, as per the previous year's calculation
Scope,F_1=42.8571 and Frequency,F_2=42.8571

Parameters	16.02.18			28.05.18		
A	6.5	2800000	2200000	4.45	13000000	8000000
B	3	5000	5000	3	5000	5000
A/B	**2.1667**	**560**	**440**	**1.4833**	**2600**	**1600**
C=(A/B)-1	**1.1667**	**559**	**439**	**0.4833**	**2599**	**1599**
Sum of C	**999.1667**			**4198.4833**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**4.3254**			**18.1753**		
CCME WQI	**41.5929**			**35.1374**		

Parameters	10.08.18		15.11.18		
A	3000000	**2400000**	16.05	2200000	**1700000**
B	5000	5000	3	5000	5000
A/B	**600**	**480**	**5.35**	**440**	**340**
C=(A/B)-1	**599**	**479**	**4.35**	**439**	**339**
Sum of C	**1598**		**782.3500**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**6.9177**		**3.3868**		
CCME WQI	**44.0277**		**43.4385**		

CCME WQI& nse for the year 2018:

	16.02.18	28.05.18	10.08.18	15.11.18
nse	**4.3254**	**18.1753**	**6.9177**	**3.3868**
CCMEWQI	**41.5929**	**35.1374**	**44.0277**	**43.4385**

As per table 4.1, we can see that the CCMEWQI values for the months of Feb, May, Aug & Nov in the year 2018 are in the range of 36-42 and the quality of water is classified as "Poor". So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.2.2.6 CCME WQI Calculation for the year 2019:

Similarly, as per the previous year's calculation
Scope,F_1=42.8571 and Frequency,F_2=42.8571

Parameters	20.02.19			10.05.19		
A	17.1	5000000	3000000	19.47	900000	700000
B	3	5000	5000	3	5000	5000
A/B	**5.7**	**1000**	**600**	**6.49**	**180**	**140**
C=(A/B)-1	**4.7**	**999**	**599**	**5.49**	**179**	**139**
Sum of C	**1602.7**			**323.49**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**6.9381**			**1.4004**		
CCME WQI	**38.6909**			**51.5558**		

Parameters	13.08.19			11.11.19		
A	6.88	220000	**110000**	10.94	2200000	1300000
B	3	5000	5000	3	5000	5000
A/B	**2.2933**	**44**	**22**	**3.6467**	**440**	**260**
C=(A/B)-1	**1.2933**	**43**	**21**	**2.6467**	**439**	**259**
Sum of C	**65.2933**			**700.6467**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**0.2827**			**3.0331**		
CCME WQI	**62.9307**			**44.3436**		

CCME WQI & nse for the year 2019:

	20.02.19	10.05.19	13.08.19	11.11.19
nse	**6.9381**	**1.4004**	**0.2827**	**3.0331**
CCMEWQI	**38.6909**	**51.5558**	**62.9307**	**44.3436**

From Table4.1, we can see that the CCMEWQI values for the months of Feb, May,Aug and Nov in the year 2019 are in the range of 39-63 and the quality of water is classified as "Poor" and "Marginal". So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

5.2.2.7 CCME WQI Calculation for the year 2020:

Similarly, as per the previous year's calculation
Scope,F_1=42.8571 and Frequency,F_2=42.8571

Parameters	12.02.20			27.05.20		
A	27.75	1700000	800000	18.33	1700000	700000
B	3	5000	5000	3	5000	5000
A/B	**9.25**	**340**	**160**	**6.11**	**340**	**140**
C=(A/B)-1	**8.25**	**339**	**159**	**5.11**	**339**	**139**
Sum of C	**506.25**			**483.11**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**2.1916**			**2.0914**		
CCME WQI	**47.2356**			**47.6746**		

Parameters	12.08.20			18.11.20		
A	17	3300000	2200000	21.75	7000000	2300000
B	3	5000	5000	3	5000	5000
A/B	**5.6667**	**660**	**440**	**7.25**	**1400**	**460**
C=(A/B)-1	**4.6667**	**659**	**439**	**6.25**	**1399**	**459**
Sum of C	**1102.6667**			**1864.25**		
Calculation of Normalized Sum Excursion (nse) nse=ΣC/Z	**4.7734**			**8.0703**		
CCME WQI	**40.9152**			**37.9415**		

CCME WQI& nse for the year 2020:

	12.02.20	27.05.20	12.08.20	18.11.20
nse	2.1916	2.0914	4.7734	8.0703
CCMEWQI	47.2356	47.6746	40.9152	37.9415

FromTable 4.1, we can see that the CCMEWQI values for the months of Feb, May,Aug and Nov in the year 2020 are in the range of 38-48 and the quality of water is classified as “Poor” and “Marginal”. So, it is observed from the result that the quality of water is almost always threatened or impaired and deviated from the natural or desirable levels.

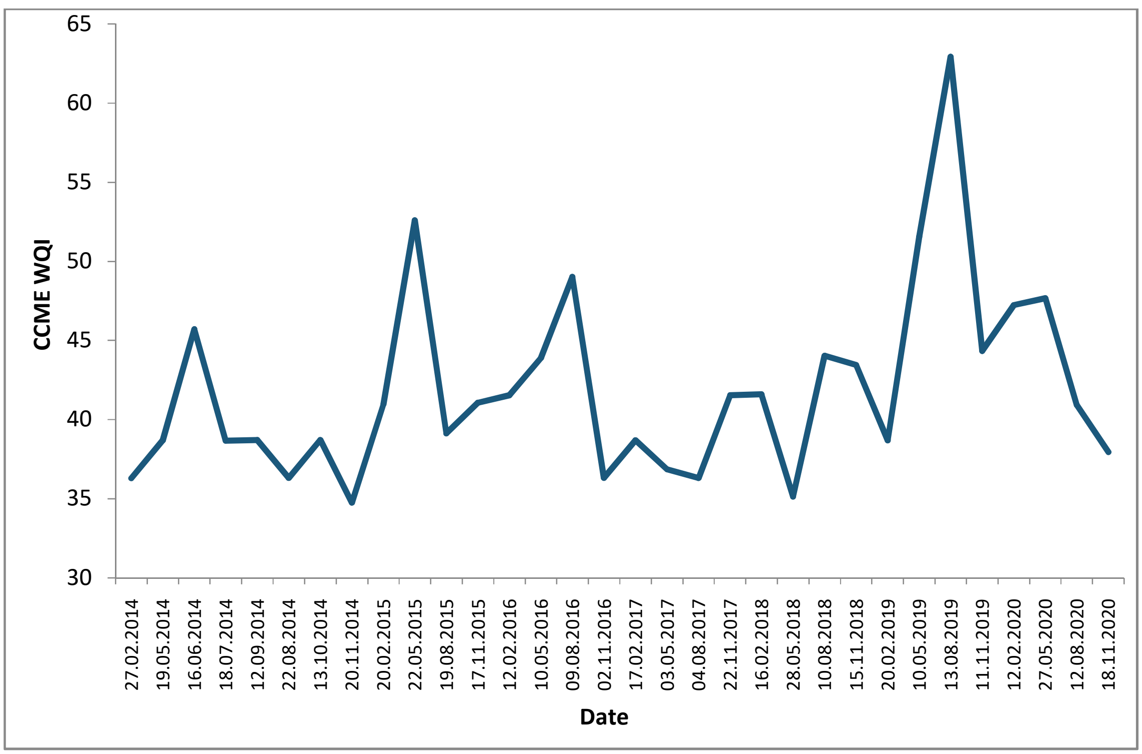

Fig. 5.3: Graph plotted against Date vs. CCMEWQI for Kalighat.

From Fig. 5.1, it can be stated that Water Quality Index is increasing mostly in the month of August each year which is max. 63 on 13.08.2019 whereas it is decreasing in the month of November each year. But it is observed the lowest value of WQI is 35 on 20.11.2014. During the evaluation of the WQI value, it is observed that the WQI value is mainly affected due to the high range of BOD presence in raw water collected from Adi Ganga.It is also observed that F_1 and F_2 values are the same for all the years. Less no. of parameters may be the reason behind it.

5.1.3 Evaluation of WAWQI for Kalighat:

5.1.3.1 Computation of Weighted Arithmetic WQI for the year 2014:
As per equations 4.10 and 4.11

$$WQI = \frac{\sum_{i=1}^{n} q_i w_i}{\sum_{i=1}^{n} w_i}$$

$$\mathbf{q_i = 100\left(\frac{Vi-Vi0}{Si-Vi0}\right)}$$

where,
v_i= observed value of the parameter
v_{io}= ideal value of the parameter
S_i= standard permissible value of the parameter
As per equations 4.12 and 4.13

$$\mathbf{W_i = \frac{K}{Si} \quad and \quad K = \frac{1}{\sum_{i=1}^{n} \frac{1}{S_i}}}$$

For the year of 2014:

WA WQI Calculation for Kalighat for 27.02.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	42.50	1416.6667	675.5253	808.3182
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.30	15.0000	2.3842	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	100.79	40.3160	0.2307	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	44.00	0.8800	0.0003	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
			0.6990			1					

WA WQI = $\sum Q_i \times wi / \sum w_I$ = 808.3182
Say, WA WQI = 808→it should be mentioned at the end of each calculation.

From Table 4.2, we can observe that the WAWQI value for the Year 2014, values are taken from the months of Feb, May, Jun, Jul, Aug, Sep, Oct. & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water.

WA WQI Calculation for Kalighat for19.05.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	19.25	641.6667	305.9732	409.0134
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.89	44.5000	7.0731	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	52.97	21.1880	0.1212	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	108.00	2.1600	0.0006	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Kalighat for 16.06.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	3.15	105.0000	50.0683	112.2621
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	3.80	102.0000	36.4784	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	8.07	53.5000	8.5037	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	1700000	34000.0000	9.7276	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	18.91	7.5640	0.0433	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	366.00	7.3200	0.0021	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	1300000	26000.0000	7.4387	
			0.6990			1					

WA WQI Calculation for Kalighat for 18.07.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	37.75	1191.6667	568.2360	666.9799
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.06	134.0000	47.9226	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.61	30.5000	4.8479	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	85.58	34.2320	0.1959	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	132.00	2.6400	0.0008	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Kalighat for 22.08.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	9.70	323.3333	154.1787	247.3709
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	3.60	104.0000	37.1936	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	8.28	64.0000	10.1726	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	19.16	7.6640	0.0439	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	926.00	18.5200	0.0053	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Kalighat for 12.09.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	7.67	255.6667	121.9125	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	2.70	113.0000	40.4123	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.91	45.5000	7.2321	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	21.41	8.5640	0.0490	249.7157
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	92.00	1.8400	0.0005	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
			0.6990			1					

WA WQI Calculation for Kalighat for 13.10.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	8.50	283.3333	135.1051	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	1.10	129.0000	46.1344	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.56	28.0000	4.4505	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	16.80	6.7200	0.0385	231.5058
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	96.00	1.9200	0.0005	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Kalighat for 20.11.2014

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	35.75	1191.6667	568.2360	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.45	22.5000	3.5763	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	16000000	320000.0000	91.5535	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	68.98	27.5920	0.1579	765.0913
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	56.00	1.1200	0.0003	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	9000000	180000.0000	51.4989	
			0.6990			1					

For the year 2015:

We can observe that the WAWQI value for the Year 2015, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water.

WA WQI Calculation for Kalighat for 20.02.2015

Sl No	Parameters	BIS Standard (S_i)	$(1/S_i)$	$\Sigma(1/S_i)$	K= 1/ $(\Sigma(1/S_i))$	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	46.25	1541.6667	735.1305	821.6373
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	9	0.1111	0.699	1.4305	0.1589	7	7.67	33.5000	5.3247	
4	TC (MPN/100ml)	NIL	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	93.33	37.3320	0.2136	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	130.00	2.6000	0.0007	
7	FC (MPN/100ml)	NIL	0.0002	0.699	1.4305	0.0003	0	2400000	48000.0000	13.7330	
			0.6990			1					

WA WQI Calculation for Kalighat for 22.05.2015

Sl No	Parameters	BIS Standard (S_i)	$(1/S_i)$	$\Sigma(1/S_i)$	K= 1/ $(\Sigma(1/S_i))$	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	8.85	295.0000	140.6682	188.3270
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	4.10	99.0000	35.4055	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.96	48.0000	7.6295	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	500000	10000.0000	2.8610	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	19.70	7.8800	0.0451	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	182.00	3.6400	0.0010	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	300000	6000.0000	1.7166	
			0.6990			1					

WA WQI Calculation for Kalighat for 19.08.2015

Sl No	Parameters	BIS Standard (S_i)	$(1/S_i)$	$\Sigma(1/S_i)$	K= 1/ $(\Sigma(1/S_i))$	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	7.85	261.6667	124.7735	222.4090
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.65	32.5000	5.1658	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	25.00	10.0000	0.0572	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	108.00	2.1600	0.0006	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	2400000	48000.0000	13.7330	
			0.6990			1					

WA WQI Calculation for Kalighat for 17.11.2015

Sl No	Parameters	BIS Standard (S_i)	$(1/S_i)$	$\Sigma(1/S_i)$	K= 1/ $(\Sigma(1/S_i))$	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	9.00	300.0000	143.0524	227.2341
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.40	20.0000	3.1789	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	15.20	6.0800	0.0348	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	48.00	0.9600	0.0003	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	2400000	48000.0000	13.7330	
			0.6990			1					

For the year 2016:

WA WQI Calculation for Kalighat for 12.02.2016

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	29.38	979.3333	466.9867	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.55	27.5000	4.3710	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	2800000	56000.0000	16.0219	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	59.00	23.6000	0.1350	550.1742
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	456.00	9.1200	0.0026	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	2200000	44000.0000	12.5886	
			0.6990			1					

We can observe that the WAWQI value for the Year 2016, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water.

WA WQI Calculation for Kalighat for 10.05.2016

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	6.60	220.0000	104.9051	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.70	133.0000	47.5649	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.66	33.0000	5.2453	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	2400000	48000.0000	13.7330	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	14.00	5.6000	0.0320	178.9204
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	230.00	4.6000	0.0013	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	1300000	26000.0000	7.4387	
			0.6990			1					

WA WQI Calculation for Kalighat for 09.08.2016

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	8.10	270.0000	128.7472	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.30	137.0000	48.9955	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.24	12.0000	1.9074	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	1300000	26000.0000	7.4387	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	44.00	17.6000	0.1007	191.7673
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	28.00	0.5600	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	800000	16000.0000	4.5777	
			0.6990			1					

WA WQI Calculation for Kalighat for 02.11.2016

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	18.13	604.333	288.1712	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.13	6.500	1.0332	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	9000000	180000.000	51.4989	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	59.47	23.788	0.1361	419.5188
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	112.00	2.240	0.0006	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	5000000	100000.000	28.6105	
			0.6990			1					

For the year 2017:

From Table 4.2, we can observe that the WAWQI value for the Year 2017, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water.

WA WQI Calculation for Kalighat for 17.02.2017

Sl No	Parameters	BIS Standard (S_i)	$(1/S_i)$	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	16.10	536.6667	255.9049	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.84	42.000	6.6758	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	39.00	15.6000	0.0893	358.5151
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	6.00	0.120	0.0000	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Kalighat for03.05.2017

Sl No	Parameters	BIS Standard (S_i)	$(1/S_i)$	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	27.08	902.6667	430.4288	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.27	13.5000	2.1458	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	58.00	23.2000	0.1328	551.4411
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	30.00	0.6000	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Kalighat for 04.08.2017

Sl No	Parameters	BIS Standard (S_i)	$(1/S_i)$	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	19.14	638.0000	304.2248	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.24	12.0000	1.9074	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	9000000	180000.0000	51.4989	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	40.94	16.3744	0.0937	436.4038
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	32.00	0.6400	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
			0.6990			1					

WA WQI Calculation for Kalighat for 22.11.2017

Sl No	Parameters	BIS Standard (S_i)	$(1/S_i)$	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	2.69	89.6667	42.7568	
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.68	34.0000	5.4042	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	8.73	3.4920	0.0200	144.0263
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	40.00	0.8000	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
			0.6990			1					

For the year of 2018:

WA WQI Calculation for Kalighat for 16.02.2018

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	6.50	216.6667	103.3156	188.8540
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.85	42.5000	6.7553	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	2800000	56000.0000	16.0219	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	45.36	18.1440	0.1038	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	82.00	1.6400	0.0005	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	2200000	44000.0000	12.5886	
			0.6990			1					

WA WQI Calculation for Kalighat for 28.05.2018

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	4.45	148.3333	70.7315	238.2493
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	2.90	111.0000	39.6970	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.96	48.0000	7.6295	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	13000000	260000.0000	74.3873	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	11.76	4.7040	0.0269	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	60.00	1.2000	0.0003	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	8000000	160000.0000	45.7768	
			0.6990			1					

WA WQI Calculation for Kalighat for 10.08.2018

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	2.83	94.3333	44.9820	117.0218
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	3.40	106.0000	37.9089	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.40	20.0000	3.1789	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	22.12	8.8480	0.0506	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	348.00	6.9600	0.0020	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	2400000	48000.0000	13.7330	
			0.6990			1					

WA WQI Calculation for Kalighat for 15.11.2018

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	16.05	535.0000	255.1102	329.6003
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.25	12.5000	1.9868	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	2200000	44000.0000	12.5886	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	51.89	20.7560	0.1188	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	6.00	0.1200	0.0000	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	1700000	34000.0000	9.7276	
			0.6990			1					

From Table 4.2, we can observe that the WAWQI value for the Year 2018, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water.

For the year 2019:

WA WQI Calculation for Kalighat for 20.02.2019

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	17.10	570.0000	271.7996	370.2705
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.32	16.0000	2.5432	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	5000000	100000.0000	28.6105	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	36.00	14.4000	0.0824	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	34.00	0.6800	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	3000000	60000.0000	17.1663	
			0.6990			1					

WA WQI Calculation for Kalighat for 10.05.2019

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	19.47	649.0000	309.4701	373.2655
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.56	28.0000	4.4505	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	900000	18000.0000	5.1499	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	52.88	21.1520	0.1210	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	26.00	0.5200	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	700000	14000.0000	4.0055	
			0.6990			1					

WA WQI Calculation for Kalighat for 13.08.2019

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	6.88	229.3333	109.3556	162.5069
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.70	133.0000	47.5649	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.45	22.5000	3.5763	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	220000	4400.0000	1.2589	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	53.10	21.2400	0.1215	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	40.00	0.8000	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	110000	2200.0000	0.6294	
			0.6990			1					

WA WQI Calculation for Kalighat for 11.11.2019

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ (Σ(1/Si))	W_i = K/S_i	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	10.94	364.6667	173.8882	244.3276
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.70	133.0000	47.5649	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.35	17.5000	2.7816	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	2200000	44000.0000	12.5886	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	28.63	11.4520	0.0655	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	16.00	0.3200	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	1300000	26000.0000	7.4387	
			0.6990			1					

From Table 4.2, we can observe that the WAWQI value for the Year 2019, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water

For the year 2020:

WA WQI Calculation for Kalighat for 12.02.2020

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	27.75	925.0000	441.0783	506.0700
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.06	3.0000	0.4768	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	1700000	34000.0000	9.7276	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	61.70	24.6800	0.1412	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	10.00	0.2000	0.0001	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	800000	16000.0000	4.5777	
			0.6990			1					

WA WQI Calculation for Kalighat for 27.05.2020

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	18.33	611.0000	291.3501	355.3979
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	6.98	1.0000	0.1589	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	1700000	34000.0000	9.7276	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	38.15	15.2600	0.0873	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	28.00	0.5600	0.0002	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	700000	14000.0000	4.0055	
			0.6990			1					

WA WQI Calculation for Kalighat for 12.08.2020

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	17.00	566.6667	270.2101	352.5384
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.08	4.0000	0.6358	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	3300000	66000.0000	18.8829	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	66.56	26.6240	0.1523	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	46.00	0.9200	0.0003	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	2200000	44000.0000	12.5886	
			0.6990			1					

WA WQI Calculation for Kalighat for 18.11.2020

Sl No	Parameters	BIS Standard (S_i)	($1/S_i$)	$\Sigma(1/S_i)$	K= 1/ ($\Sigma(1/S_i)$)	$W_i = K/S_i$	Ideal Value (V_{i0})	Observed Value (V_i)	q_i	$q_i \times W_i$	WA WQI
1	BOD (mg/l)	3	0.3333	0.699	1.4305	0.4768	0	21.75	725.0000	345.7100	450.3457
2	DO (mg/l)	4	0.2500	0.699	1.4305	0.3576	14	0.00	140.0000	50.0683	
3	pH (Unit)	8.5	0.1111	0.699	1.4305	0.1589	7	7.15	7.5000	1.1921	
4	TC (MPN/100ml)	5000	0.0002	0.699	1.4305	0.0003	0	7000000	140000.0000	40.0547	
5	COD (mg/l)	250	0.0040	0.699	1.4305	0.0057	0	69.62	27.8480	0.1593	
6	TSS (mg/l)	500	0.0002	0.699	1.4305	0.0003	0	72.00	1.4400	0.0004	
7	FC (MPN/100ml)	500	0.0002	0.699	1.4305	0.0003	0	2300000	46000.0000	13.1608	
			0.6990			1					

From Table 4.2, we can observe that the WAWQI value for the Year 2020, values are taken from the months of Feb, May, Aug & Nov. It is found all the values are greater than 100. So, the quality of water can be classified as "Unfit for consumption" without treatment of the raw water.

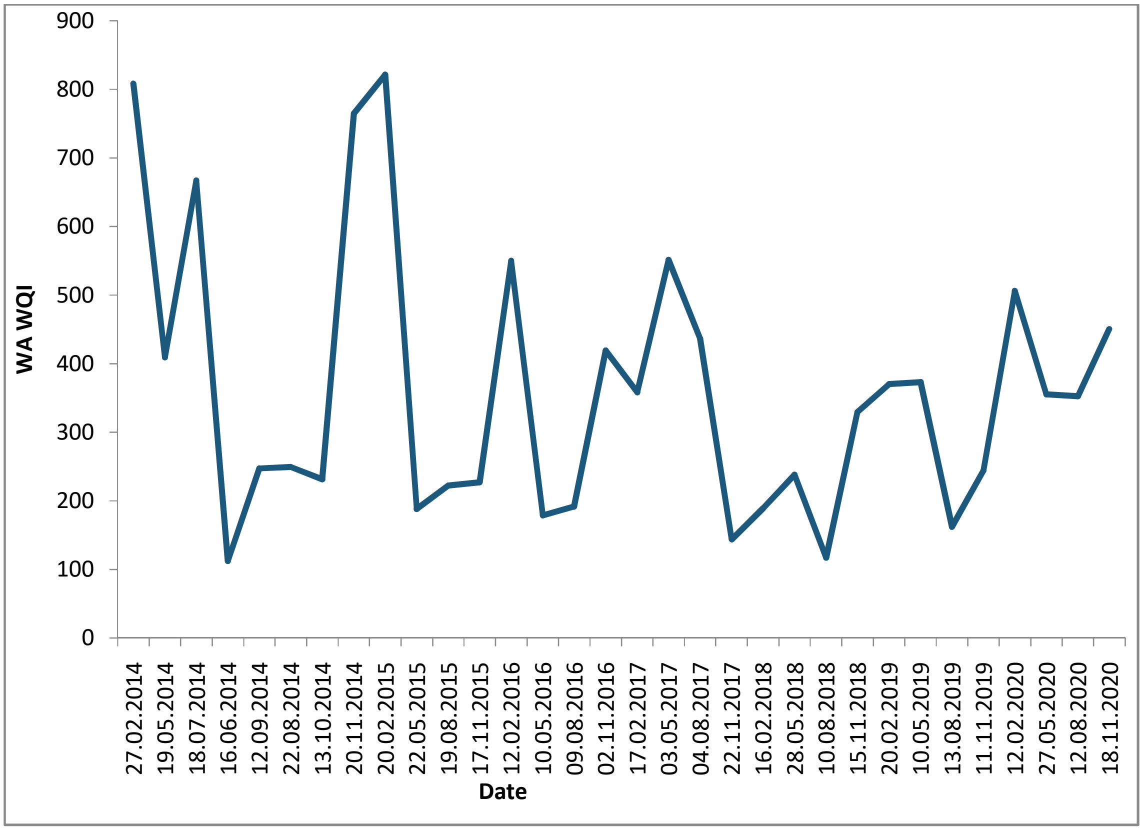

Fig. 5.4: Graph plotted against Date vs. WA WQI for Kalighat.

From Fig. 5.4, it is observed that the WAWQI values for all the seven years and different months (i.e. Feb, May, Aug, Nov) in each year are greater than 100 and thus, the raw water quality of Adi Ganga at Kalighat can be categorized under "Unfit for consumption" as per Table 4.2.

It is also observed from Fig. 5.4 that the WAWQI value is always very higher in the post-monsoon season (in the month of Nov) than in pre-monsoon (in the month of May) and winter (in the month of Feb) which might be due to an increase in BOD in the monsoon season. Also, from Fig. 5.4, it can be said that there is a huge variation in WA WQI value between pre-monsoon and post-monsoon seasons and one of the main reasons behind it is increasing in BOD due to the discharge of organic waste, excreta and refused in large amount by runoff during rain. Fig. 5.4 clearly shows the BOD variation in seven years having all four months (Feb, May, Aug, Nov) in each year.

Table 5.5 Desired and potential levels of pollutants in livestock water supplies.

Substance	Desired range	Problem range
Total bacteria per 100 millilitres	<200	>1,000,000
Faecal coliform per 100 millilitres	<1	>1 for young animals >10 for older animals
Faecal strep per 100 millilitres	<1	>3 for young animals >30 for older animals
pH	6.8 to 7.5	<5.5 or >8.5
Dissolved solids, milligrams per litre	<500	>3,000
Total alkalinity, milligrams per litre	<400	>5,000
Sulfate, milligrams per litre	<250	>2,000
Phosphate, milligrams per litre	<1	not established
Turbidity, Jackson units	<30	not established

Source: From the *Agricultural Waste Management Field Handbook*, pages 1 to 16. Based on research literature and field experience in the northeastern United States.

Note: 1 milligram per liter (mg/l) is approximately equal to 1 part per million (ppm).

5.3 Details of Physico-chemical and biological parameters

5.1.5 pH Value at Bansdroni sampling point

Variation of pH values for the years 2014 to 2020 is found inFig.5.5. The lowest pH (7.05) was recorded in the pre-monsoon (May) and the highest (8.20) in the pre-monsoon(May).

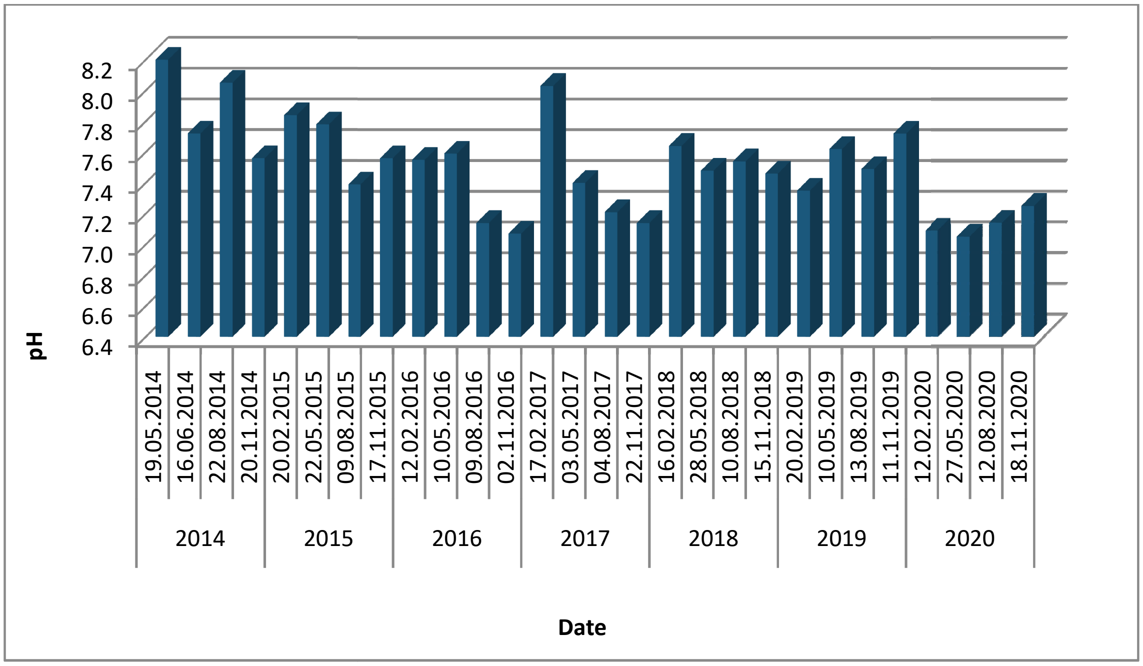

Fig. 5.5: Date-wise variations of pH at Bansdroni sampling point.

5.3.2 BOD Valueat Bansdroni sampling point

Variation of BOD- values for the years 2014 to 2020 is found inFig.5.6. The lowest BOD(2.94 mg/l) was recorded in monsoon (Aug) and highest (43.54 mg/l) in post-monsoon(Nov).

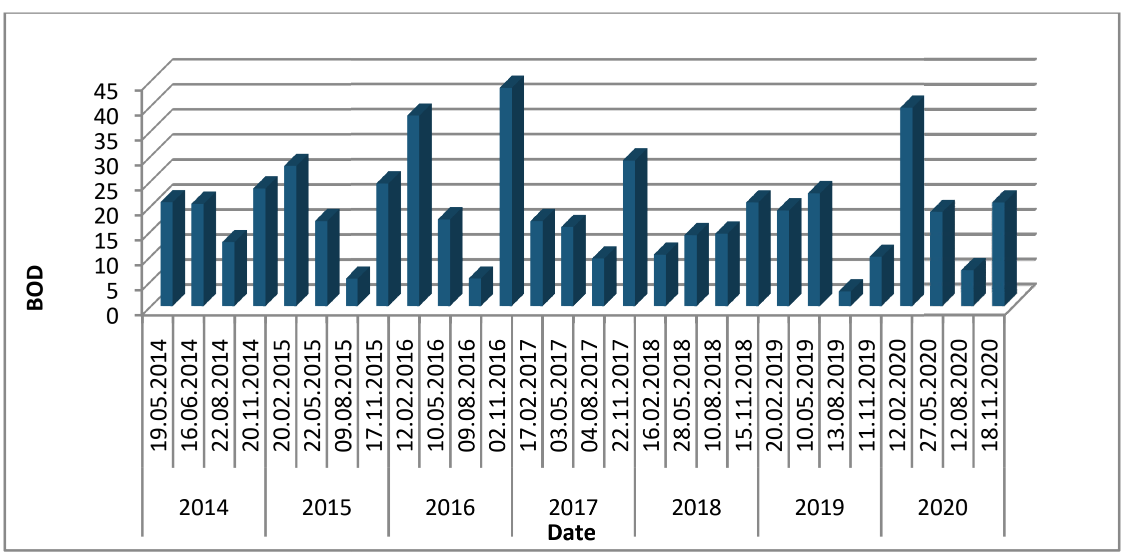

Fig.5.6: Date-wise variations of BOD at Bansdroni sampling point.

5.3.3 Dissolved O_2 (DO) at Bansdroni sampling point

Variation of DO values for the years 2014 to 2020 is found in Fig. 5.7. The lowest DO (0 mg/l) was recorded in most of the years and the highest (4 mg/l) in post-monsoon(Feb).

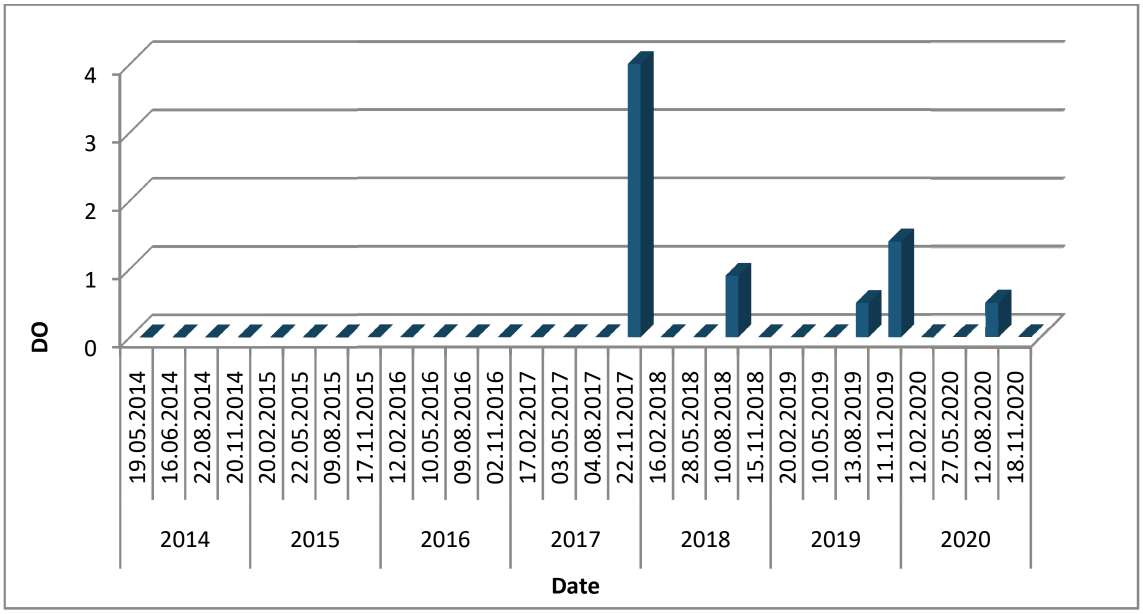

Fig.5.7: Date-wise variations of DO at Bansdroni sampling point.

5.3.4 Fecal Coliform at Bansdroni sampling point

Variation of Fecal Coliform values for the years 2014 to 2020 is found in Fig. 5.8. The lowest fecal coliform (94000 MPN/100 ml) and the highest fecal coliform (50000000MPN/100 ml) both were recorded in the monsoon(August).

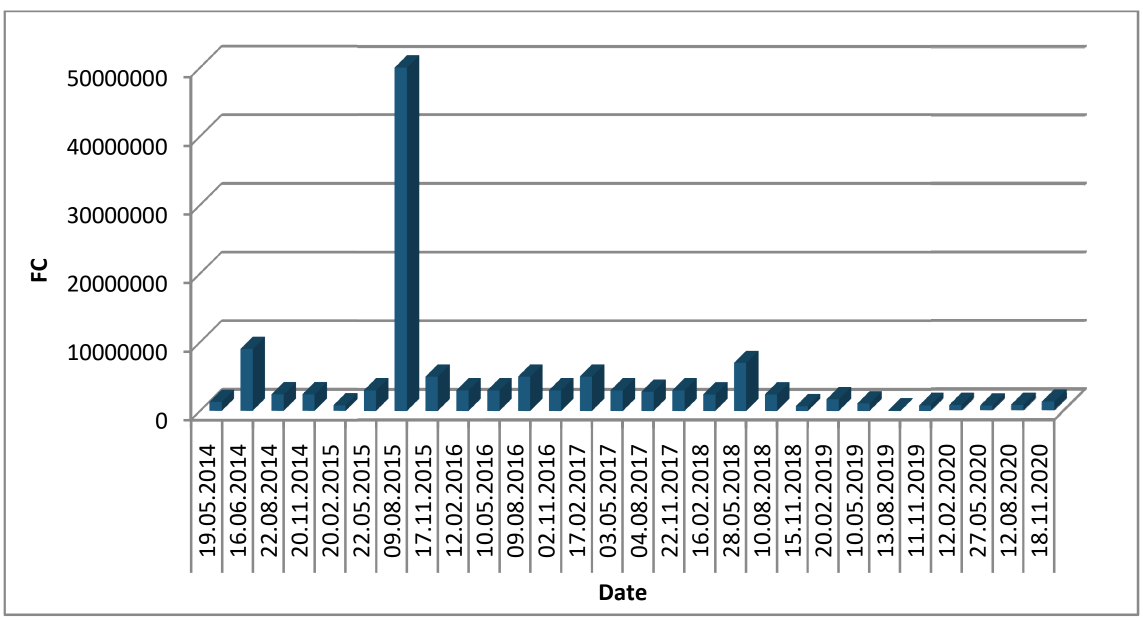

Fig.5.8: Date-wise variations of fecal coliform at Bansdroni sampling point.

5.3.5Total Coliform at Bansdroni sampling point

Variation of BOD values for the years 2014 to 2020 is found in Fig. 5.9. The lowest BOD (2.94 mg/l) was recorded in the pre-monsoon (May) and the highest (43.54 mg/l) in the pre-monsoon(May).

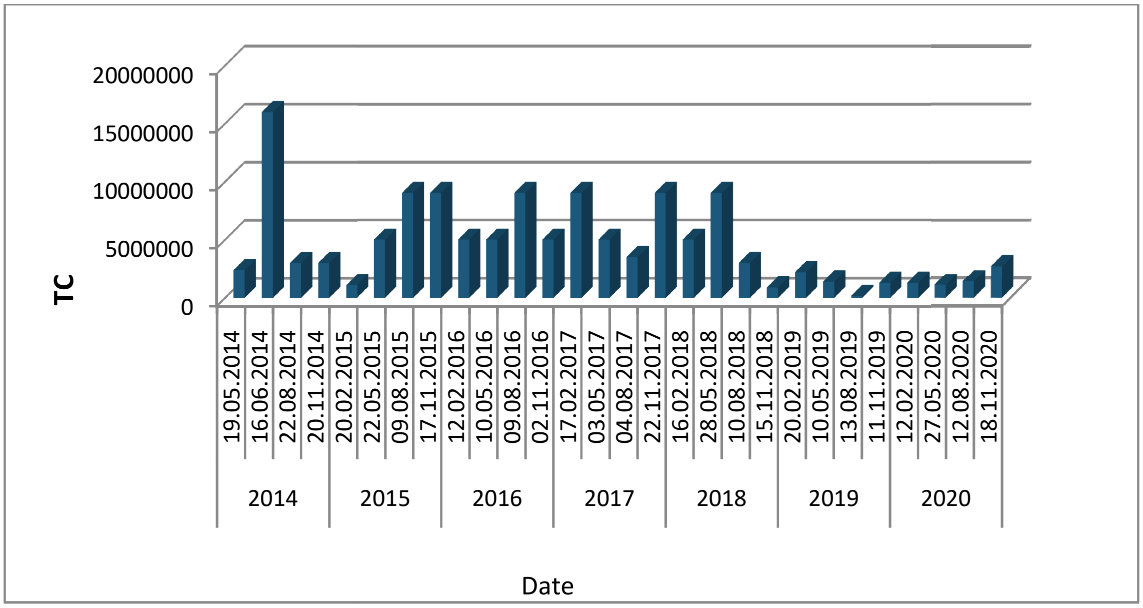

Fig.5.9: Date-wise variations of total coliform at Bansdroni sampling point.

5.3.6 COD at Bansdroni sampling point

Variation of CODvalues for the years 2014 to 2020 is observedinFig.5.10. The lowest COD (13.27 mg/l) was recorded during the monsoon (Aug) and the highest (129.29 mg/l) in post-monsoon (Nov).

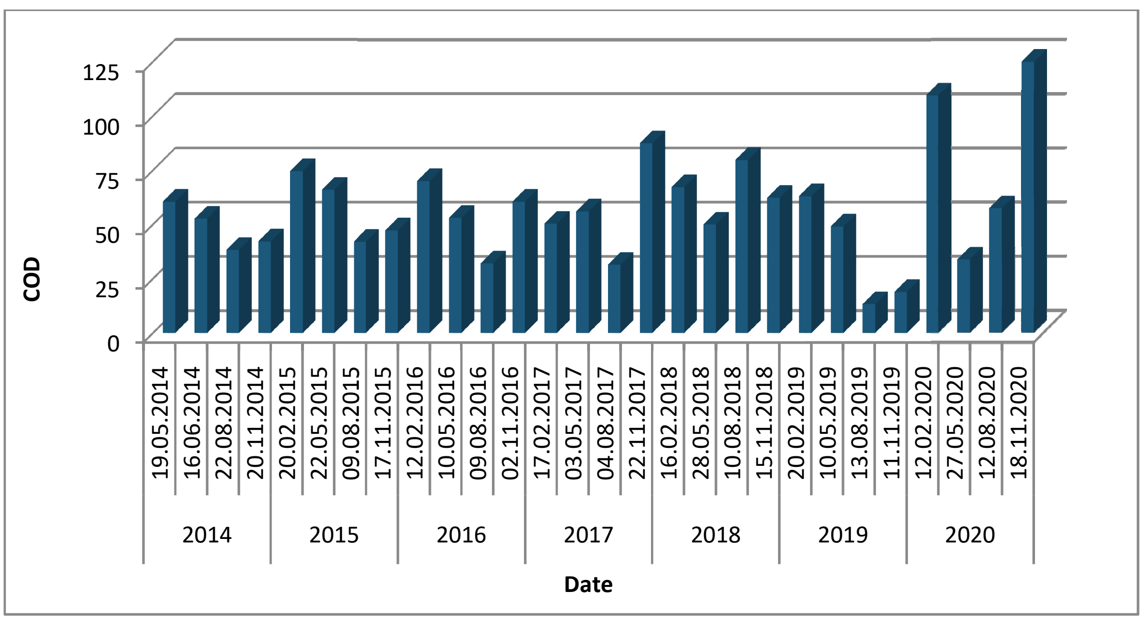

Fig.5.10: Date-wise variations of COD at Bansdroni sampling point.

5.3.7Total Suspended Solids (TSS) at Bansdroni sampling point

Variation of TSS values for the years 2014 to 2020 is observedinFig.5.11. The lowest TSS(6 mg/l) was recorded in the winter (Feb) and the highest (208 mg/l) in monsoon(Aug).

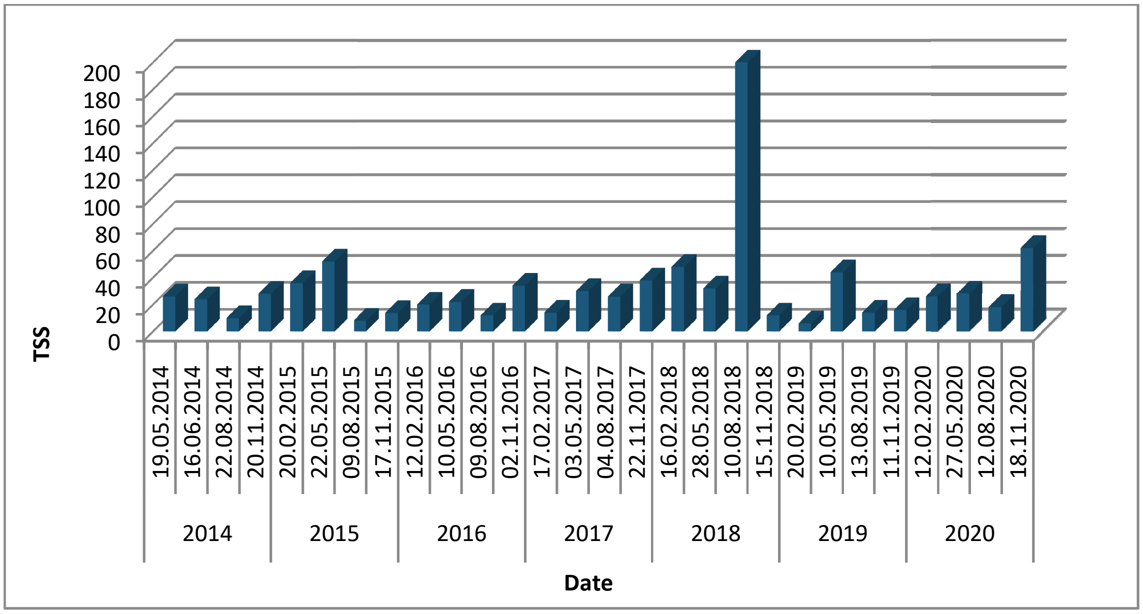

Fig.5.11: Date-wise variations of TSS at Bansdroni sampling point.

5.4.1 pH at Kalighat sampling point

Variation of pHvalues for the years 2014 to 2020 is seeninFig.5.12. The lowest pH (6.98) was recorded in the pre-monsoon (May) and the highest (8.07) in monsoon(June).

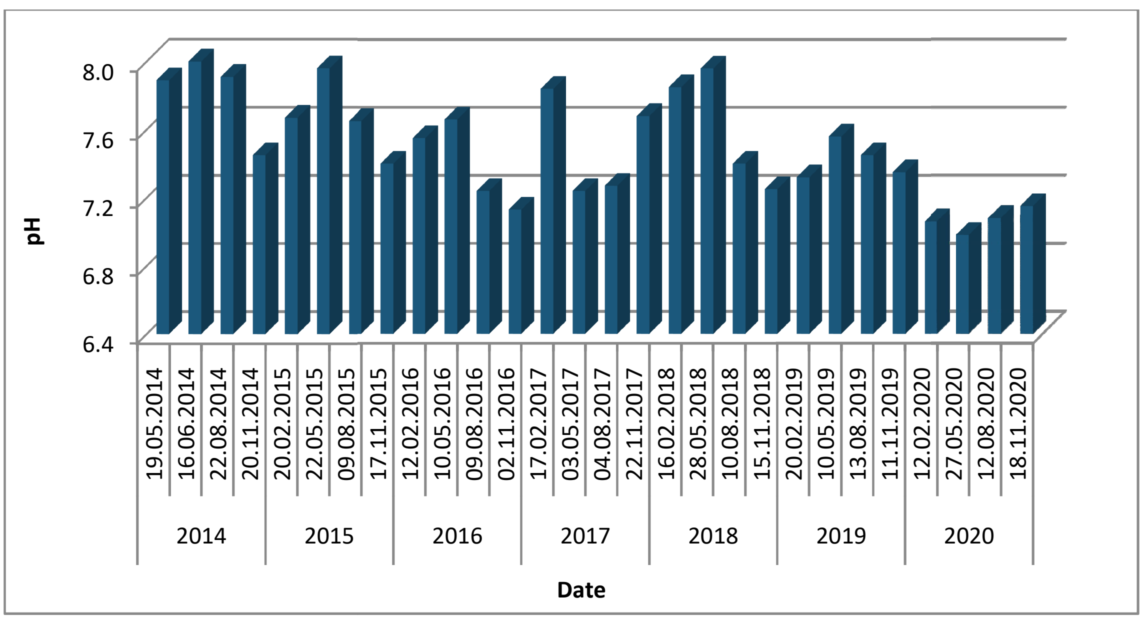

Fig.5.12 Date-wise variations of pH at Kalighat sampling point.

5.4.2 BOD at Kalighat sampling point

Variation of BOD values for the years 2014 to 2020 is showninFig.5.13. The lowest BOD (2.69 mg/l) was recorded in the post-monsoon (November) and the highest (46.25 mg/l) in winter (February).

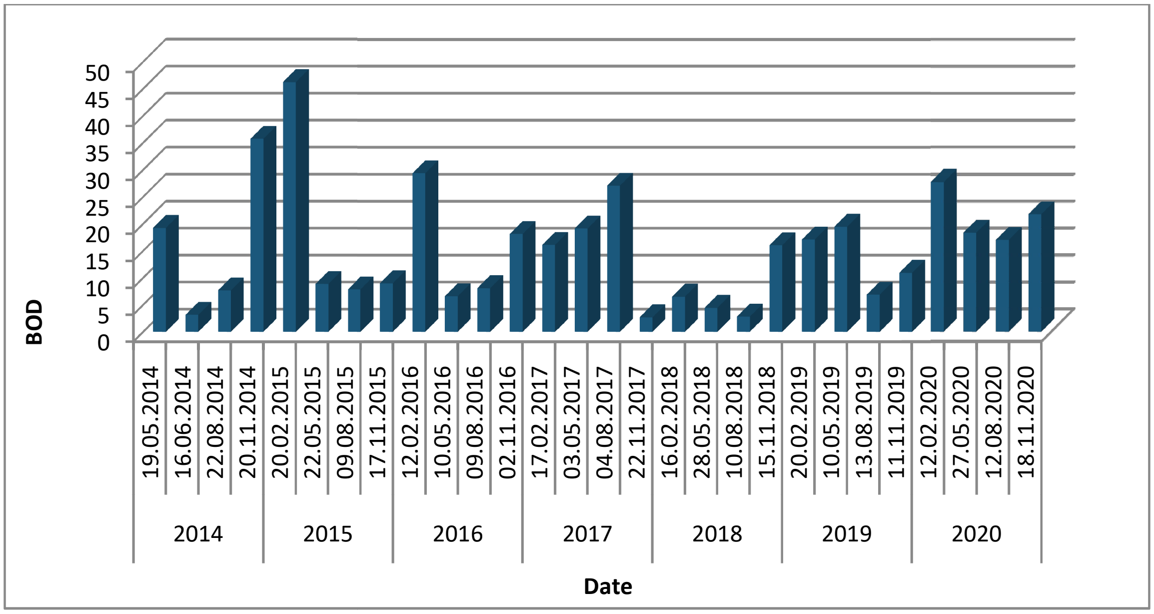

Fig: 5.13 Date-wise variation of BOD at Kalighat sampling point.

5.4.3 Dissolved Oxygen (DO) at Kalighat sampling point

Variation of DO values for the years 2014 to 2020 is seeninFig.5.14. The lowest DO(0 mg/l) was recorded in most of the years and the highest DO (4.1 mg/l) in pre-monsoon(May).

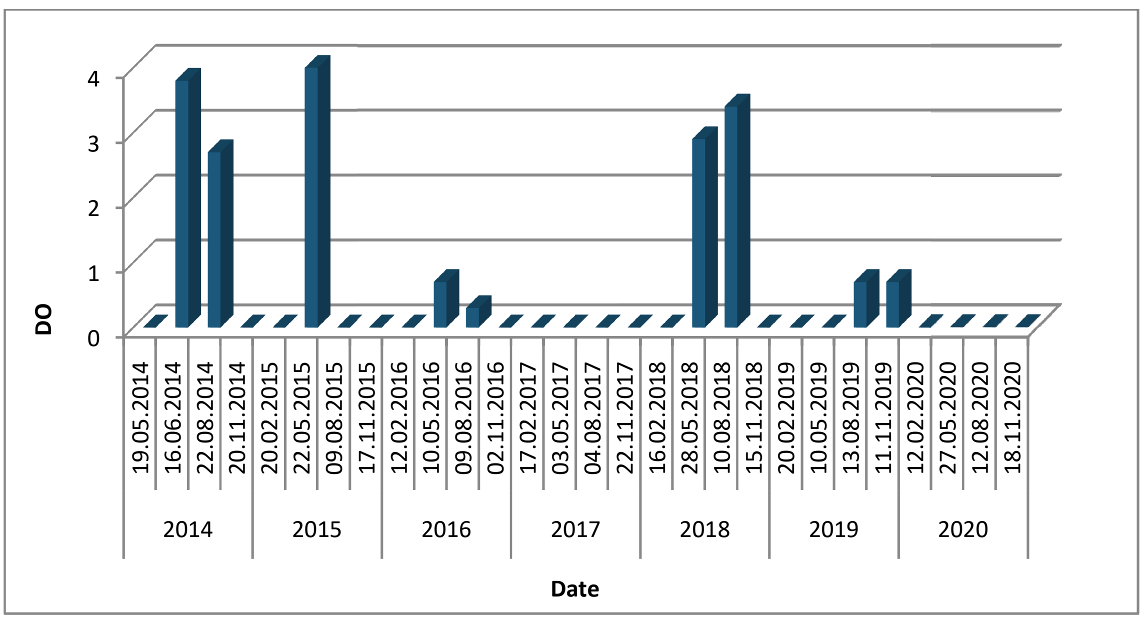

Fig: 5.14 Date-wise variation of DO at Kalighat sampling point.

5.4.4 Fecal Coliform at Kalighat sampling point

Variation of fecal coliform values for the years 2014 to 2020 is found in Fig. 5.15. The lowest fecal coliform (110000 MPN/100 ml) was recorded during the monsoon (Aug) and the highest (9000000MPN/100 ml) in the post-monsoon (November).

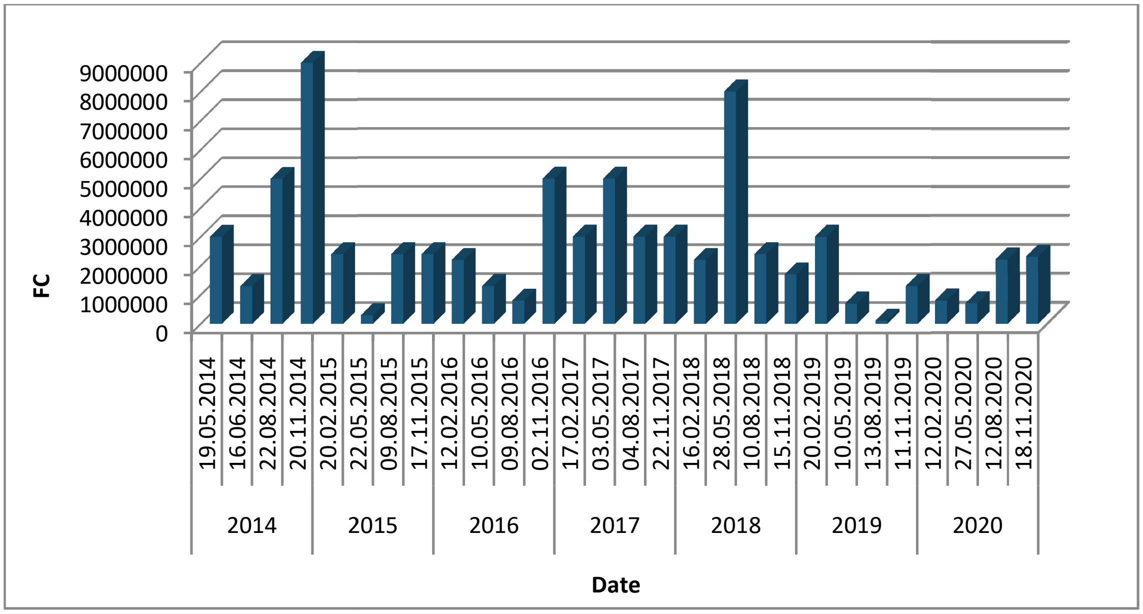

Fig: 5.15 Date-wise variation of Fecal Coliform at Kalighat sampling point.

5.4.5 Total Coliform at Kalighat sampling point

Variation of total coliform values for the years 2014 to 2020 is observed in Fig. 5.16. The lowest total coliform (220000MPN/100 ml) was recorded in the monsoon (August) and the highest (16000000MPN/100 ml) in the post-monsoon (November).

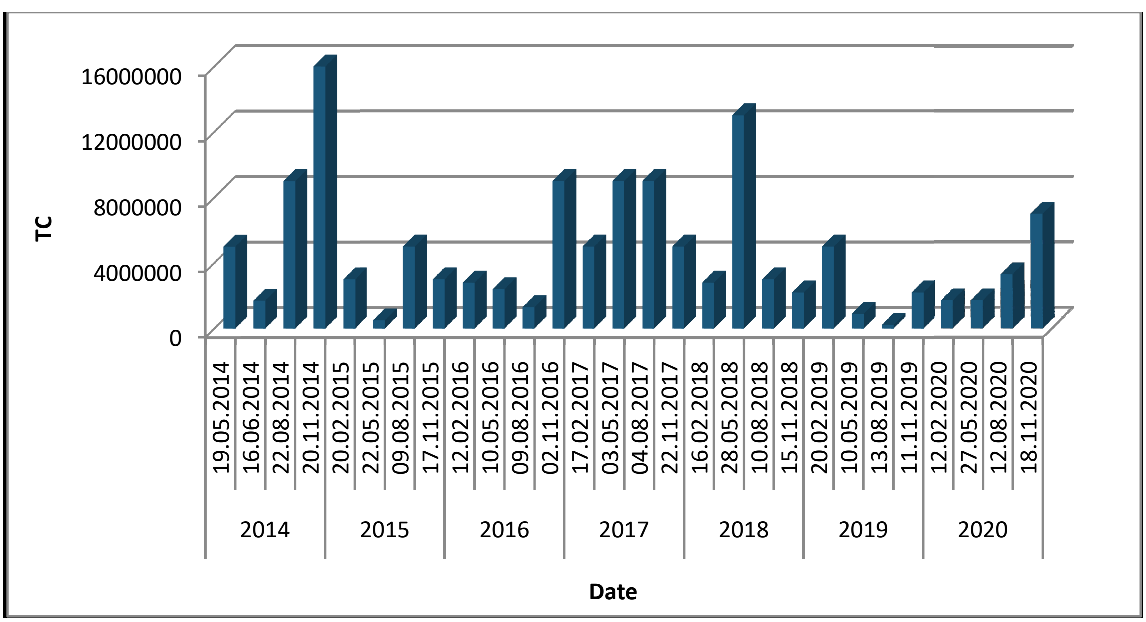

Fig: 5.16 Date-wise variation of total coliform at Kalighat sampling point.

5.4.6 COD at Kalighat sampling point

Variation of CODvalues for the years 2014 to 2020 is depictedinFig.5.17. The lowest COD (8.73 mg/l) was recorded in the post-monsoon (Nov) and the highest (93.33 mg/l) in winter.

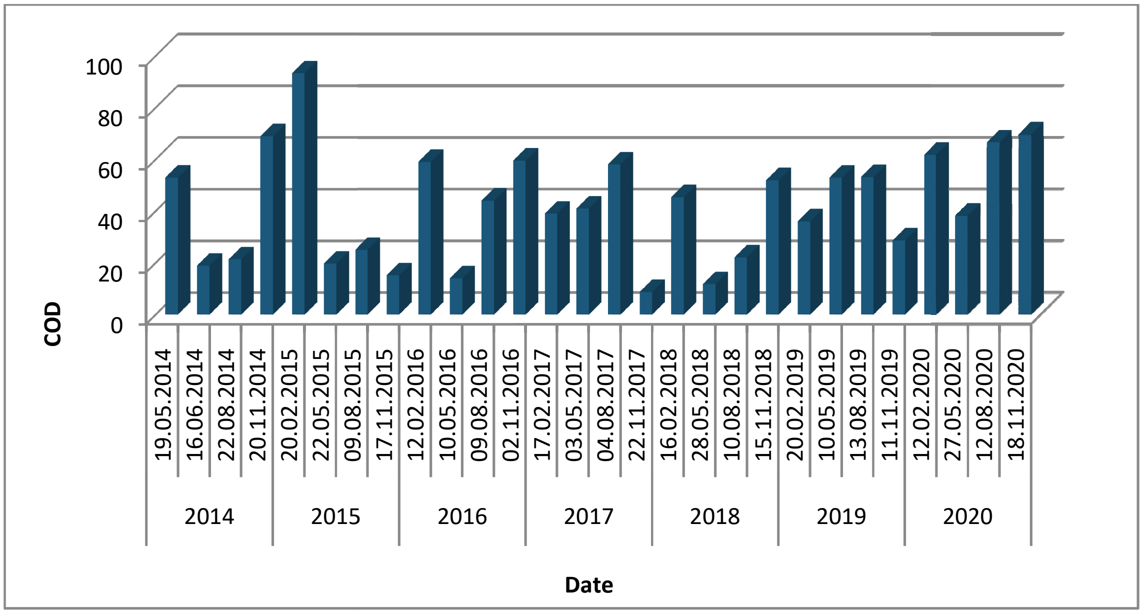

Fig: 5.17 Date-wise variations of COD at Kalighat sampling point.

5.4.7 Total Suspended Solids (TSS) at Kalighat sampling point

Variation of TSS values for the years 2014 to 2020 is seeninFig.5.18. The lowest TSS(6 mg/l) was recorded in the winter (February) and the highest (208 mg/l) in monsoon(May).

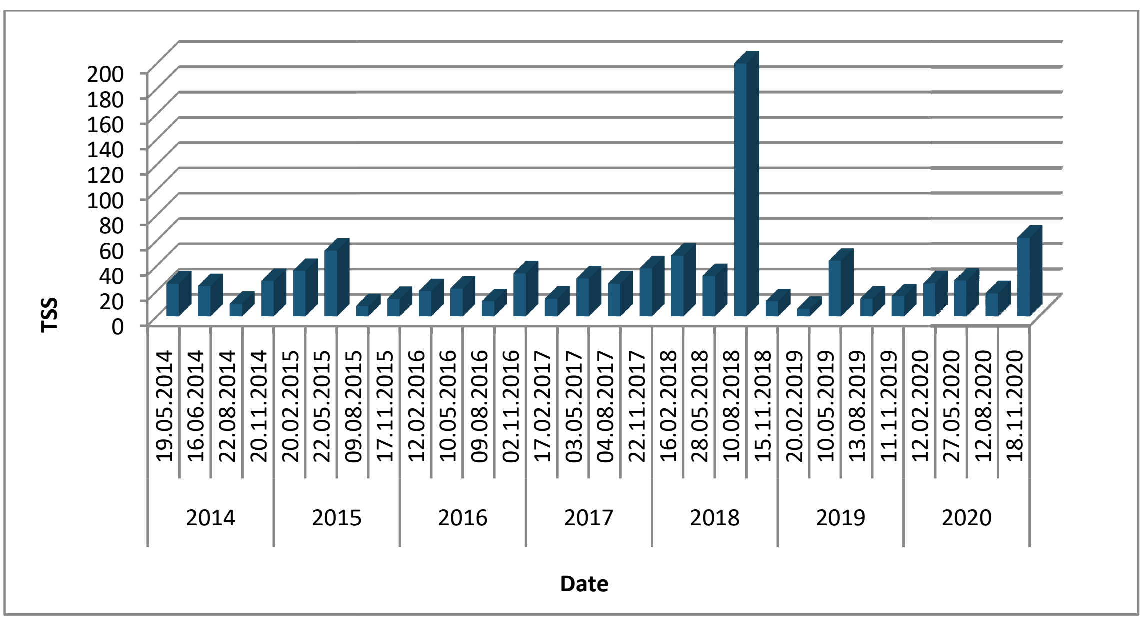

Fig: 5.18 Date-wise variations of TSS at Kalighat sampling point.

From the above analysis, it is seen that the water quality of Adi Ganga at Bansdroni and Kalighat sampling points is polluted and unfit for consumption due to a higher level of BOD as well as alarge number of fecal and total coliform. This may occur due to the sudden abnormal pollution introduced into the water body from the sources such as septic tank leakage, domestic sewage and fertilizer runoff. It may also be the cause of the huge amount of organic wastes finding their way into the canal due to the discharge of dead bodies, excreta and refused. This affected the water quality by altering mainly Dissolve Oxygen, BOD and CODin the water of Adi Ganga. Here, a very high range of total coliform may be due to the discharge of untreated or partially treated domestic sewage in this canal at these two points. Another source of fecal contaminants may be human and animal activities along the bank of the canal.

BOD can be reduced by adding hydrogen peroxide to the wastewater solution. Hydrogen peroxide chemically attacks the organics in the wastewater, degrading them and reducing the measured BOD. There are some other processes to reduce BOD such as adding Ozone, Advanced oxidation process, coagulation-sedimentation-electric flocculation etc. faecal and total coliform are usually killed by boiling water or by treating the water with chlorine. Only one procedure will not be enough to reduce this large amount of BOD and make it suitable for drinking water.

Hydrogen peroxide (H_2O_2) has been used to reduce the BOD and COD of industrial wastewaters for many years. While the cost of removing BOD and COD through chemical oxidation with hydrogen peroxide is typically greater than that through physical or biological means, there are nonetheless specific situations which justify the use of hydrogen peroxide. These include: Predigestion of wastewaters which contain moderate to high levels of compounds that are toxic, inhibitory, or recalcitrant to biological treatment (e.g., pesticides, plasticizers, resins, coolants, and dyestuffs);

Pretreatment of high strength / low flow wastewaters – where bio treatment may not be practical – prior to discharge to a Publicly Owned Treatment Works (POTW);Enhanced separation of entrained organics by flotation and settling processes; and A supply of supplemental DO is required when biological treatment systems experience temporary overloads or equipment failure.

As indicated by these examples, H_2O_2 can be used as a stand-alone treatment or as an enhancement to existing physical or biological treatment processes, depending on the situation.

Moreover, different animals (like street dog, cat, mongoose, squirrel etc.) and birds (like the sparrow, pigeon, shalik, jungle bubbler etc.) are also living surrounding the area of Adi Ganga at Bansdroni & Kalighat. Those animals and birds are drinking this canal water for a living. Survival of those species is essential for maintaining the ecosystem.

In this study, only two parameters $_pH$ and fecal coliform have been compared (Table 5.6) where the water quality ranges for drinking purpose of the above species is mentioned. Desired water quality range for $_pH$ 6.8-7.5 and problem range <5.5 or >8.5 and for Fecal Coliform/100ml <1 and problem range >1 for young animals, >10 for older animals whereas at Bansdroni $_pH$ range 7.05-8.20 and Fecal Coliform/1L 94000-7000000 and at Kalighat $_pH$ range 6.98-8.28 and Fecal Coliform/1L 11000-9000000.

From the above study, it is seen that the water available for drinking at Bansdroni and Kalighat sampling points is safe for these animals and birds.

The study has been carried out with the test results of WQMS Bansdroni and Kalighat for consecutive seven years from 2014 to 2020. The sample (raw/canal water) was collected from the Hooghly river by WBPCB. So, it is also an indirect analysis of Hoogly river water quality for the south Kolkata area. This study helps in assessing water quality for different water use purposes, such as domestic use, irrigation, conservation, and industrial usage in the south Kolkata area. In the future, the WQI value obtained can be helpful for further any research work and helpful for developing a strategy for sustainable water source management, maintaining and promoting human health, and other social and economic growth in this area.

Seven numbers of physico-chemical and biological parameters have been considered for this study as per the data available with WBPCB. Any parameter concerning toxic substances and radioactive substances parameters have not been considered in the study but they are also very important factors regarding the quality of drinking water and also for domestic and other purposes of water. Although according to the test reports of WBPCB, limited parameters are tested, the experiments for other parameters have not been considered here. This study can portray a better picture if other important parameters are considered during the study.

CHAPTER-VI

6.1 Conclusions

In this study, the quality of raw water is assessed using physical, chemical and biological analysis for two sampling locations of Adi Ganga at Bansdroni and Kalighat during high tide in South Kolkata. To perform this study, the raw water quality data was collected from the West Bengal Pollution Control Board (WBPCB) for four months i.e. February, May, August, and November for seven consecutive years from 2014 to 2020. Only seven physico-chemical and biological parameters such as pH, BOD, DO, total coliform, COD, total suspended solids (TSS), and fecal coliform are available to WBPCB for the said period. The CCME WQI and the WA WQI were used to assess and compare the raw water quality.

- By the CCME WQI method, the WQI values were estimated in the range of33 to69 for the said period. It indicates the raw water quality is "Poor" or "Marginal" according to the water quality characteristics given by CCME WQI and thus water quality is almost always threatened or impaired and not suitable for drinking without treatment.WQI is found 69 on 13.08.19 for Bansdroni which is fair and 63 on 13.08.19 for Kalighat which is marginal. However, for the rest of the six years, the quality of water never reached the required range for drinking water. Adequate treatment is, therefore, necessary to control the quality of raw water.

- When applying the WA WQI method, the WQI was found in the range from~100 to ~888. It indicates that raw water WQI is always greater than 100. The WQI values are more than 4 to8 times higher than the maximum value of the range. Thus, according to the WQI classes developed by Brown et al. (1972), the quality of raw water can be categorized as "Unfit for consumption" and can only be consumed by humans after proper treatment. Although there are large differences in lower and higher WA WQI values.

- It is observed that WQI is always higher in post-monsoon than pre-monsoon. The main reason for such an increase is perhaps due to the increase of BOD Rainfall in the monsoon helps in increasing BOD by runoff. Graphs plotted with year-wise BOD values confirm the high value of BOD in the post-monsoon than pre-monsoon for all seven years. Therefore, treatment for reducing BOD needs to be increased during monsoon and post-monsoon seasons for decreasing this high value of BOD level up to the drinking water range.

- During this study, it is seen that the BOD values are the controlling parameter of WQI values if the study is concentrated on these seven parameters. BOD is therefore the main polluting factor here. The reduction of BOD is therefore the main challenge for the authority when treating raw water.

- Several other important parameters such as TDS, electrical conductivity, toxic substances (cadmium, cyanide, lead, mercury, arsenic, etc.), and bacteriological parameters (bacteria,protozoa,virus,algae) were kept beyond the scope of this study due to non-availability of data. Although these are also important factors for determining the class of drinking water. Studies considering these parameters can provide a more accurate result for WQI values and a better insight into the water quality of the Bansdroni and Kalighat sampling points.

6.2 Future Scopes:

- Data on water quality parameters for seven years were considered for the above water quality study. If data on water quality parameters for many more years were considered, then the overall picture of WQI values would be more significant and it would also be possible to monitor changes in water quality and its parameters over a long period of time.

- Some other important parameters may have been considered during this water quality study. Therefore, in the future, the goal will be to collect or analyze more data on water quality parameters to evaluate a more accurate water quality index value. Also, a study considering many more parameters of the raw water can provide a clearer picture of the status of the Adi Ganga in this area. So, in the future, this study may provide a better picture if many more parameters of water quality are considered.

- Also, if it is possible to study the values of water quality parameters in other locations of Hooghly River, it would help to understand the water quality of Hooghly River, as well as the main reasons for its increasing pollution and the same, and can help in building sustainable management of quality water of Hooghly River, which is the main source of water in Kolkata.

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