Assessment of Groundwater Quality of Cossipore and Garia using WA-WQI and CCME-WQI Methods

A thesis
Submitted by

Soumak Patra
Examination Roll No.:M6WRP22010

For partial fulfilment of the requirements for the degree of

MASTER OF ENGINEERING
in Water Resources and Hydraulic Engineering
Course affiliated to Faculty of Engineering & Technology
Jadavpur University

Under the guidance of

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M.E. (Water Resources & Hydraulic Engineering) course affiliated to
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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

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 2021-2022.

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

I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

Name	**:Soumak Patra**
Examination Roll Number	**: M6WRP22010**
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Signature with Date: -

M.E. (Water Resources & Hydraulic Engineering) course affiliated to
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CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"Assessment of Groundwater Quality of Cossipore and Garia using WA-WQI and CCME-WQI Methods"** is a bonafide work carried out by Mr. Soumak Patra 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

Water Quality Index (WQI) is a standard tool that is internationally accepted for assessing water quality. This WQI reduces a large number of water quality indicators into helpful for the selection of appropriate treatment techniques to meet the concerned issues. In the present study, an attempt has been made to assess the WQI of groundwater at Garia and Cossipore areas situated in the south and north Kolkata of West Bengal in India. In these two areas, there are two groundwater sampling points which are being monitored by the West Bengal Pollution Control Board (WBPCB). The WBPCB usually collect groundwater samples from the above two stations in the months of April and October each year i.e., two times a year. For the present study, eleven years, from the year 2011 to 2021, of groundwater quality data were collected from the WBPCB website.

In this study, only physical and chemical parameters have been considered to determine the quality of ground water according to the data available from WBPCB. No radioactive substances have been considered. For these two locations, groundwater was assessed using WQI under the influence of several physical and chemical 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. The evaluation was done for seven physico-chemical parameters i.e. pH, turbidity, magnesium, total alkalinity chloride, calcium, and total hardness for the eleven consecutive years from 2011 to 2021 and by comparing their values with the standards set by the Bureau of Indian Standards.

The obtained CCME-WQI values for Garia (out of 15 values,4 are found fair,11are found marginal) and for Cassipore (out of 14 values, one is found fair, two are found marginal,11 are found poor) and three remaining values indicate the “poor” and not suitable for drinking without treatment. The WA-WQI values for Garia (out of 15 values,2 are found good, 5 are poor,3 are very poor and 5 are >100indicate the groundwater quality is unfit for the consumption of humans without proper treatment. WQI values for Cossipore (out of 14 values one is poor, one is very poor and the other 12 are >100) i.e. indicates the groundwater quality is unfit for humans consumption without proper treatment.

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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

CHAPTER I

Introduction

Water is an important and infinite natural source for the endurance of life and one of the essential components of the human health system. The water quality of drinking water is ultimately associated with human health, because of consumption of contaminated drinking water possesses many water-borne diseases one local to global scale (Panaskar et al. 2016). Water-borne diseases result in serious threats to public health and augmented the morbidity and mortality rate, particularly in children (WHO 2006, Mukate et al. 2017). It is estimated that in developing countries around 250 million populations are infected yearly which led to 10-20 million deaths globally (Anon 1996, Dzwairo et al. 2006). Over a period of time, owing to limited freshwater resources, people widely use groundwater for mitigating the needs of drinking, irrigation, industry etc. It is assumed that groundwater is one of the safe and reliable sources of drinking water owing to its natural quality and less susceptibility compared to freshwater resources. In fact, one-third part of the world's population meets their drinking needs from groundwater (UNEP 1999).

In general, groundwater quality depends on the composition of the rock, rock-water interface, water residence time, variability in climate and rainfall, water depth, soil media etc., and anthropogenic inputs from domestic, agricultural and industrial activities (Todd 1980). Thus, for sustainable water resource management, water quality evaluation is more vital in relation to public health and socio-economic development local to global scale (Pawar et al. 2014, Panaskar et al. 2014). Therefore, the water quality monitoring program is essential for sustainable management of available water resources and mitigating water quality issues in different regions. The water quality index (WQI) is one of the useful mathematical tools and a complex indicator of water quality that gives relative information based on diverse water quality variables into a single numerical value which can be simply communicated to the public (Pandith et al. 2017, Wagh et al. 2017a).

The most improved advantage of WQI is the estimation of water quality conditions devoid of interpreting the individual water quality variables separately. Nonetheless, more than 20 WQI were formulated and used for water quality assessment worldwide (Ott 1978, Bhargava 1983). Furthermore, the Canadian Council of Ministers of the Environment (CCME) has designed an index to make simpler the water quality data without losing its scientific base which is practicable to use over space and time to the public in an easier manner (Rocchini et al. 1995). This index is mainly based on the number of selected input water quality variables, the size of the dataset and the objectives or standards used for its development Values vary from 0 to 100 where 0 corresponds to the worst quality and 100 stands for the excellent quality of water, which conveys the water quality understanding among scientific and non-scientific communities. Worldwide, many researchers have been using the CCME-WQI model to categorise water quality for potable, recreational, irrigational and safeguard aquatic life (Rosemond et al. 2009, Wagh et al. 2017b). Groundwater is mainly used for drinking and agriculture purposes; so, its quality is closely related to local public health. Generally, the local populace extracts groundwater from dug and bore wells for drinking without any prior treatment. Therefore, water quality assessment is essential. The groundwater quality may pose serious threats owing to the application of chemical fertilizers, pesticides, soil amendments etc. (Wagh et al. 2017a). So, it is necessary to investigate the groundwater quality status which may attribute to natural or anthropogenic inputs.

1.2 Water Quality Parameters: -It is essential to test the groundwater before it is used for drinking, domestic, agriculture or industrial purpose. Water must be tested with different physio-chemical parameters. The selection of parameters for testing of water is solely dependent upon for what purpose we going to use the water. 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. It is a measure of the ability of light to pass through water. It is caused by suspended material such as clay, silt, organic material, plankton and other particulate materials in water. Turbidity is measured by an instrument called a nephelometric turbidimeter, which expresses in terms of NTU or TU. A TU is equivalent to 1mg/l of silica in suspension. 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.

1.2.1.2 Colour: Materials decayed from organic matter, namely, vegetation and organic matter such as soil, stones, and rock impart colour to the water. Colour is measured by comparing the water sample with slandered colour solutions or coloured glass disks.

1.2.1.3 Temperature: Most people find water at temperatures of 10-15°C most palatable. There is no guideline value for the temperature of drinking water.

1.2.1.4 Solid: If the filtered portion of 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).

Total Solid (TS) = TDS + TSS.

1.2.1.5 pH: pH is the most important parameter of water quality. It is defined as the negative logarithm of the hydrogen ion concentration. It is a dimensionless number indicating the strength of an acidic or a basic solution. The pH of water is the measure of how acidic/basic water is. Acidic water contains extra hydrogen ions (H^+) and basic water contains a hydroxyl (OH^-). A pH of less than 7 indicates acidity, whereas a pH of greater than 7 indicates a base solution. Safe ranges of pH values are from 6.5 to 8.5 for drinking water and domestic use. It is also the need of living organisms.

1.2.2Chemical Parameters

1.2.2.1Electrical conductivity (EC):

* 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:

$$TDS\ (mg/l) \cong EC\ (ds/m\ or\ umho/cm) \times (0.55\text{-}0.7)$$

1.2.2.2 Acidity: Acidity is the measure of acids in a solution. The acidity of water is its quantitative capacity to neutralize a strong base to a selected pH level. Acidity in water is usually due to carbon dioxide, mineral acids and hydrolyzed salts such as ferric and aluminium sulfates. It can influence corrosion and chemical reaction activities.

1.2.2.3 Alkalinity: The Alkalinity of water is its acid-neutralizing capacity compromised of a total of all titratable bases. The measurement of the alkalinity of water is necessary to determine the amount of lime and soda needed for water softening. The alkalinity of water is mainly caused by the presence of hydroxide ions (OH^-), bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^{2-}) or a mixture of two of these ions in water.

1.2.2.4 Chloride: Chloride occurs naturally in groundwater, streams, and lakes. 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 nitrated.

1.2.2.5 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, but there is no significant danger to public health.

1.2.2.6 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. Nitrogen in the nitrate form is a basic nutrient growth of plants and can be a growth-limiting nutrient factor. A high concentration of nitrate in surface water can stimulate the rapid growth of the algae which degrades the water quality.

1.2.2.7 Fluoride: A moderate amount of fluoride ions (F^-) in drinking water contributes to good dental health.

1.2.2.8 Iron and Manganese: Although iron (Fe) and manganese (Mg) do not cause health problems, they impart a noticeable bitter taste to drinking water even at a very low concentration.

1.2.2.9 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.

1.2.2.10 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. Total hardness mg/1 (as $CaCO_3$) = calcium hardness mg/1 (as $CaCO_3$) +magnesium hardness mg/1 (as $CaCO_3$). Hardness is normally determined by titration with ethylene diamine tetra acidic acid (EDTA) and Eriochrome black and blue indicators.

1.2.2.11 Dissolved oxygen (DO): Dissolved oxygen (DO) is considered to be one of the most important parameters of water quality in streams, rivers and lakes. The calorimeter method (quick and expensive), the Winkler titration – the traditional method and the electrometric method.

1.2.2.12 Biochemical oxygen demand (BOD): collected sample and compared it to the dissolved oxygen level in a sample that was collected at the same time but incubated under specific conditions for a certain number of days at a certain temperature which can be expressed mathematically by the equation (1.1) (APHA 2005, Tchobanoglous et al. 2003).

$$\mathbf{BOD_t = BOD_L \times (1 - 10^{-kt})} \qquad (1.1)$$

1.2.2.13 Chemical oxygen demand (COD): The COD is a parameter that measures all organics: the biodegradable and the non-biodegradable substances (Tchobanoglous et al. 2003)

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).

1.2.3.2 Nonmetallic compounds: This causes a blue skin colour syndrome, which is called cyanosis (Dojlido and Best 1993). It also causes chronic effects on the central nervous system and thyroid. Cyanide is normally measured by colourimetric, titrimetric, or electrometric methods.

1.2.4 Parameters Concerning Radioactive Substances: There are established standards commonly used for alpha particles, beta particles, photons emitters, radium-226 and -228, and uranium for drinking water. The unit of radioactivity used in water quality applications is the picocurie per litre (pCi/L;); one pCi is equivalent to about two atoms disintegrating per minute. There are many sophisticated instrumental methods to measure it.

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.

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 average	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	
CCME-WQI	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	

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. 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 equation (1.2) is used.

$$\mathbf{BC\ WQI = 100 - \left[\sqrt{\frac{F_1^2+F_2^2+\left(\frac{F_3^2}{3}\right)}{1.453}}\right]} \tag{1.2}$$

where,

Scope (F1) - number of parameters that is not compliant with the water quality guidelines.

Frequency (F2) - number of times that the guidelines are not respected.

Amplitude (F3) - 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, dissolved oxygen, biochemical oxygen demand, total phosphates, nitrates, and total solids. 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

$$\textbf{NSF WQI} = \sum_{i=1}^{n} Q_i W_i \qquad (1.3)$$

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 CCME-WQI 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, Lumb et al. 2006). The index quality of the CCME-WQI method is derived from the British Columbia Water Quality Index (BC-WQI) 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 CCME-WQI 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 morph climatic 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

1.4.4 Weighted Arithmetic Water Quality Index (WA-WQI)

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 WA-WQI 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.

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, biochemical oxygen demand, pH, ammonia+nitrate nitrogen, total phosphorus, total solids, and faecal coliform). 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

$$\boldsymbol{OWQI} = \sqrt{\frac{\boldsymbol{n}}{\sum_{\boldsymbol{i}=1}^{\boldsymbol{n}} \frac{1}{\boldsymbol{S}_{\boldsymbol{i}}^{2}}}} \tag{1.4}$$

where, S_i= Standard permissible value of n^{th} parameter.

1.4.6 Overall Index of Pollution (OIP)

Overall Index of Pollution (OIP) is estimated as the average of all the pollution indices (P_i) for individual water quality parameter. It was developed by Sargaonker and Deshpande (2003) 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. (1971) a general classification scheme has been formulated. OIP developed by Sargaonkar and Deshpande (2003) for the Indian rivers is based on measurements and subsequent classification of hardness, TDS, pH, dissolved oxygen, BOD, turbidity, arsenic, fluoride, and total coliforms. According to BIS, WHO (2006), 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

$$OIP = \frac{\sum_{i=1}^{n} P_i}{n} \tag{1.5}$$

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 (1987) for six categories of water uses public water supply, recreation, fish, shellfish, agriculture, and industry. It is observed in 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

$$IWQ = \prod_{i=1}^{n} I_i^{W_i} \quad 1.6$$

where IWQ is the Dinius water quality index whose value ranges from 0-100, I_i is the sub-index function of the pollutant parameter, W_i 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 (Zhao et al. 2012). 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 equation 1.7.

$$CPI = \frac{1}{n}\sum_{i=1}^{n}\frac{M_i}{S_i} \quad (1.7)$$

where *CPI* is a comprehensive water pollution index, M_i represents the measured concentration of each parameter; S_i 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	Sub 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 (NPI) is a powerful tool for assessing water quality. NPI denotes pollution computing which was developed by Nemerow and Sumitomo (1970). 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 analyzed, 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:

$$\boldsymbol{NPI} = \frac{\boldsymbol{C_i}}{\boldsymbol{L_i}} \tag{1.8}$$

where, C_i = observed concentration of the i^{th} parameter and 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. The L_i values for different water quality parameters are the permissible value of that 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 prior to use.

CHAPTER II

2.1 Literature Review

Chandra et al. (2017) conducted research in the city of Vijayawada in India with a population density of around 32320 per sq. km. They collected a total of 380 numbers of samples, 190 numbers each pre-monsoon and post-monsoon for the year 2014. They analysed 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 WQI was calculated using the WA-WQI method. The different physio-chemical parameters used were pH, total dissolved solids (TDS), chlorine (Cl), sodium (Na), sulfate (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.

Ewaid et al. (2017) studied the water of the Al-Gharraf river stretched across 230 km which 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 analysed as per the standard methods of the American Public Health Association (APHA 2005). The parameters considered for calculating the WQI are biological oxygen demand (BOD), TDS, dissolved oxygen (DO), turbidity (Tur), hydrogen ion concentration (pH), alkalinity, phosphate (PO_4), chloride (Cl), nitrate (NO_3), electrical conductivity (EC) and TH. The WA-WQI method was used to calculate the WQI. The weight age unit (W_i) of each parameter was inversely proportional to the standard of the World Health Organization (WHO) (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 to the Eraqi surface as per multiple previous researches. Dissolved oxygen range from 6,2 to 10 mg/l with an annual mean of 7.48 mg/l.The range and value both exceed the desired standard of < mg/l as per WHO. Similarly, the identified turbidity also exceeds the WHO standard of 5 NTU by a mean of 45 NTU. The observed value of electrical conductivity was always way above the WHO standard value of 250 ms/cm with a range of 928 to 1270 ms/cm. The alkalinity values of the sample range from 143 to 270 mg/l. Which was sometimes above the permissible drinking water limit of WHO 200 mg/l. It was concluded that the WQI value reduced long the downstream which confirmed the entry of the various pollutant into the river along the course depending upon the industrial and domestic wastewater following into the water body.

Datta et al. (2018) tried to determine the groundwater quality of various regions in and around Guwahati city. They wanted to compare the water quality of various sources and analyse 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 the month of 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. For calculating the WQI, the WA-WQI method proposed by Brown et al. (1972) has been used. The following 12 quality parameters had been selected for the calculation: pH, turbidity, TDS, bicarbonates, chlorides, sulphates, 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 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.

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 since 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 solids (TS), total suspended and dissolved solids (TSS and TDS), DO, phosphate (PO_4), sulfate (SO_4), potassium (K), nitrate (NO_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.

Mahagamage et al. (2016) 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 CCME-WQI method for identifying the WQI. The parameters are pH, TDS, dissolved oxygen, total phosphate, nitrate, nitrite, total hardness, electrical conductivity, BOD, COD, 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.

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 the 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 26th Regional Directorate from four different sites. The water quality of the Coruh 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.

Ahmed et al. (2019) researched the water quality of a shallow aquifer and its impact on irrigation in the Mathura district area using the CCME-WQI method. They collected a total of 65 water samples from the piezometer borehole by the Central Groundwater 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 NO^{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 was 94 in the year 2008 which is good to excellent water quality compared to the WQI value of 79 for 2009.

Al-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, 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.

Uddin et al. (2017) used the CCME-WQI method 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 (located between 24 03 and 24 15 north latitudes and between 89°00' and 89°11' east longitudes), 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-, SO_4^{2-}, N02-, 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, BOD, COD, 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 and Cr were highly positively correlated with WQI. Mn, As, Fe, Cd, and NO_2 are highly negatively correlated with WQI. The results highlight a strong correlation between all water quality parameters and WQI.

De et al. (2017) studied to evaluate the impact of leachate derived from uncontrolled municipal landfill on surrounding groundwater quality in Kolkata, India. Seasonal variation of twenty physio-chemical parameters in pre-monsoon and post-monsoon seasons were analysed in forty groundwater samples around the landfill site. Groundwater pollution was identified by the spatial distribution maps of TDS, Na^+, Cl^- Mn and Fe along with the heavy metals like Pb, Hg and Cr in both seasons. Hydrogeochemical characteristics of groundwater samples show that the area was brackish water. [Ca^{+2} - Cl^-][Mg^{+2}- Cl^-] and [Na^+ -Cl^-] type in PRM season whereas [Na^+-HCO_3^-] type dominated in POM season. Hierarchical cluster analysis (HCA) was also applied to identify the source of groundwater pollution. In the pre-monsoon season, groundwater samples closer to the active landfill site were physico–chemically different from upstream samples but more related to downstream samples. However, in the post-monsoon season, groundwater samples closer to the landfill site represented distinctly different physico-chemical characteristics from upstream and downstream samples as a result of the high influx of leachate pollutants. The major environmental concern in this study indicated the toxic effect of uncontrolled landfill leachate on the surrounding groundwater quality. The impact of leachate percolation on the surrounding groundwater was evidenced by the reducing environment along with higher concentrations of pollutants closer to the active landfill site. Based on WHO drinking water quality standards, groundwater in this area is not at all suitable for drinking and would be toxic to health. Nevertheless, based on irrigational water quality standards, RSC and Na% indicated that groundwater samples were suitable for irrigation only in the pre-monsoon season. The SAR values were found to be high in POM season. Therefore, the present study indicated the need for the pre-treatment process on landfill leachate before draining into surrounding jheels and bheries. Moreover, immediate attention is required towards the continuous monitoring and remediation of the groundwater around the Dhapa landfill site to prevent further deterioration of the water quality.

Sahu et al. (2016) attempted to demarcate the area in and around Rajarhat New Town into groundwater zones based on quality and to understand processes controlling the geochemical evolution of different groundwater types. The parameters analyzed in the laboratory were TDS, total hardness (TH), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), bicarbonate (HCO_3), sulphate (SO_4), chloride (Cl), phosphate (PO_4), nitrate (NO_3), fluoride (F), iodide (I), iron (Fe), manganese (Mn), zinc (Zn), lead (Pb) and cadmium (Cd). For assessment of WQI, 16 parameters were selected which include pH, TDS, TH, HCO_3, Cl, SO_4, NO_3, F, Ca, Mg, Fe, Mn, As, Zn, Pb, and Cd. The computed WQI values ranged from 40 to 194 and can be categorized into three types, 'excellent water', 'good water' and 'poor water'. The majority of the samples, about 60%, fell in the category of 'good water'. 'Excellent water' was about 27% and the rest was 'poor water'. The spatial distribution of the water types. The spatial variation in the WQI is mostly due to the concentration variation of Fe, As and Cl in groundwater. High loading on TDS indicates dissolved solids in groundwater are also moderately dominated by Mg, K and Mn.

Sukumaran et al. (2015) focused on the trend of the drinking water quality of one of the heritage cities of India, Howrah. The groundwater from ten stations was analysed for two consecutive years. The samples were collected during winter. The samples were analysed as per Standard methods for the examination of water and wastewater (APHA 2005). The results obtained were compared with the drinking water standards as specified by WHO (2006) and the Bureau of Indian Standards (IS 10500: 2012). For computing WQI three steps were followed. In the first step, each of the nine parameters was assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight of 5 was assigned to the parameter nitrate due to its major importance in water quality assessment. Magnesium which was given weightage of 2 as magnesium by itself may not be that harmful. Second step, relative weight (W_i) was computed. In the third step, a quality rating scale (q_i) for each parameter was assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result is multiplied by 100. The WQI of Howrah in 2012 is 96.9 and in 2013 was estimated 42.6. This showed the trend in water quality. In 2012 the drinking water of Howrah was nearing the "poor water" category but recouped to "excellent water" in terms of physicochemical parameters as per the water quality classification based on WQI value. But in both years total and faecal coliform count in water is very high. Interestingly it was high in 2013 than in 2012.

Das et al. (2021) undertaken to compute the WQI to study the suitability of groundwater considering the drinking water perspective in twelve wards of Borough X of KMC in the state of West Bengal. In this paper, an attempt was made to develop WQI of groundwater in the KMC area of West Bengal considering the seasonal variation of data and to devise a simple mechanism for the common people to understand the quality of water, instead of a complex set of data to determine the quality of groundwater. Four hundred groundwater samples were collected from existing tube wells of eighty different locations situated in Borough: X of KMC area in two different seasons and were analysed in the School of Water Resources Engineering, laboratory as per standard procedure recommended by APHA (2012). The first set of water sample collection was started in July 2013 and ended on the first week of December 2013, i.e., during the monsoon period and the second set of water sample collection was started in January 2014 and ended on April 2014, i.e., post-monsoon period. Selected ten water quality parameters, namely, pH, Turbidity, TDS, Chloride, Total Alkalinity, Total Hardness, Nitrate, Iron (Fe), Arsenic (As), and Fluoride (F) were considered in this study for calculating the WQI. WQI was classified based on four scales, namely: Extremely poor, Poor, Good, and Excellent. The selected range is between 0 and 70 for Very poor, 71–80 for Poor, 81–90 for Good, and >90 for Excellent. WQI for these samples revealed that about 34% of collected groundwater samples were categorized as "excellent" and 46% as "good" during the monsoon period, whereas 32% of groundwater samples were revealed as "excellent" and 55% of these as "good" during the post-monsoon period. Whereas about 01% of collected groundwater samples were categorized as "Extremely Poor" and 19% as "Poor" during the monsoon period, and 01% of groundwater samples were revealed as "Extremely Poor" and 12% of these as "Poor" during post-monsoon period.

John et al. (2021) attempted to study the relationship between groundwater quality and groundwater level, if any, for the city of Kolkata. The water quality data for this study were collected from the West Bengal Pollution Control Board. The parameters were then linked to groundwater level (pre-monsoon) which was accumulated from Central Ground Water-Board, to investigate the relationship between the same. The parameters were assessed for the years 2010, 2012, 2014, 2016 and 2018. The following parameters taken into account are electrical conductivity, total hardness, alkalinity, TDS, pH, chloride and nitrate as these were considered important for the study area. The water quality index was calculated following the WA-WQI method. The WQI for each year at all eight station points were calculated and the results indicated a singular coefficient for determining an easy appreciative value for the water quality parameter of the underlying aquifer. The data likewise depicted that although the pH is stable and suitable for drinking water purposes, the TDS, EC, chloride and nitrate contents of the aquifer were majorly distressed in the Dhapa, Tangra and Topsia regions.

From the above literature review, it is clear that very little work has been done on assessing the water quality index of groundwater in Kolkata City. Therefore, as a case study Garia and Cossipore areas of Kolkata have been chosen for the present study.

The main objectives of the study are (i) to evaluate the physicochemical behaviour of groundwater for drinking suitability and their influencing factors, (ii) to develop CCME-WQI and WA-WQIs model to evaluate the drinking suitability of groundwater of the Garia in south Kolkata and Cossipore in north Kolkata, (iii) the main objective of the study to determine the water quality in a single index value and (iv) The importance of groundwater for the people residing in the city.

CHAPTER-III

3.1 Study Area

Some 315 years ago, British merchants had dropped anchor at the small hamlet of Kolkata on the eastern corner of the Indian sub-continent. Soon after, they were granted trading rights and the area saw spectacular growth - the merger of the three hamlets of Kolkata, Sutanuti, and Govindpur led to the creation of a hub for British commercial and business interests and activities in the sub-continent: the city of Calcutta and it 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 and 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 an underground reservoir under the Kolkata Municipal Corporation.

Garia and Cossipore areas are located in the South & North portions of the city of Kolkata. Garia and Cossipore both are the water quality monitoring stations of WBPCB in south & north Kolkata. Groundwater in Garia and Cossipore that is collected as a sample by the PCB fortnightly from those monitoring stations. From the test report of different parameters, it can be assessed the water quality of groundwater in those areas.

People in different areas of South and North Kolkata like Garia and Cossipore are being used groundwater from that area. 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 important parts of old Kolkata, population density is very high in this area.

Figure 3.1 shows (1) water body Kolkata (2) Ground water sampled points and Fig.3.2 shows different water quality index (WQI) in K.M.C areas.

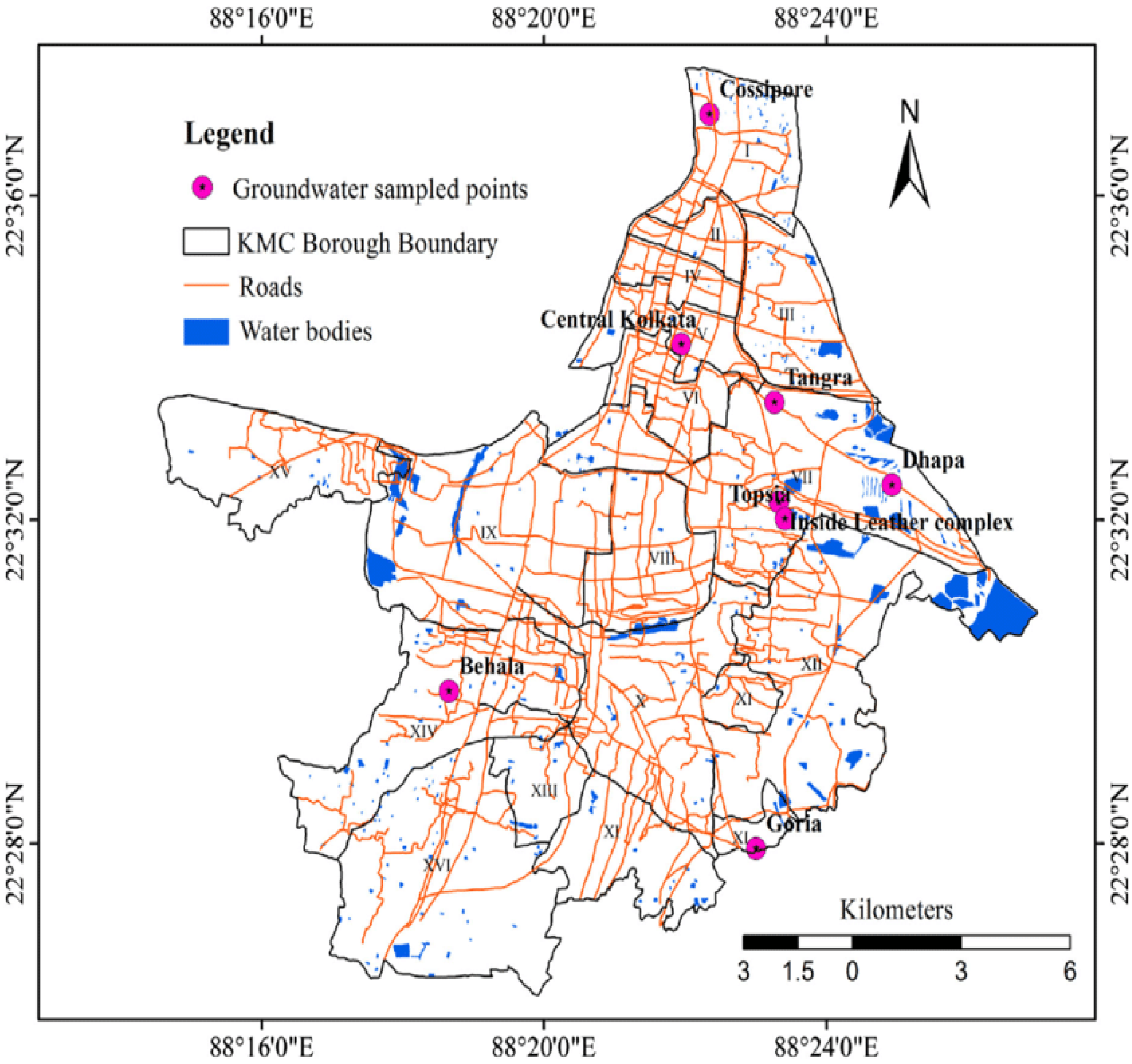

Fig. 3.1 Location of groundwater monitoring stations at Garia and Cossiporeselected by WBPCB (Ali and Ahmad 2020).

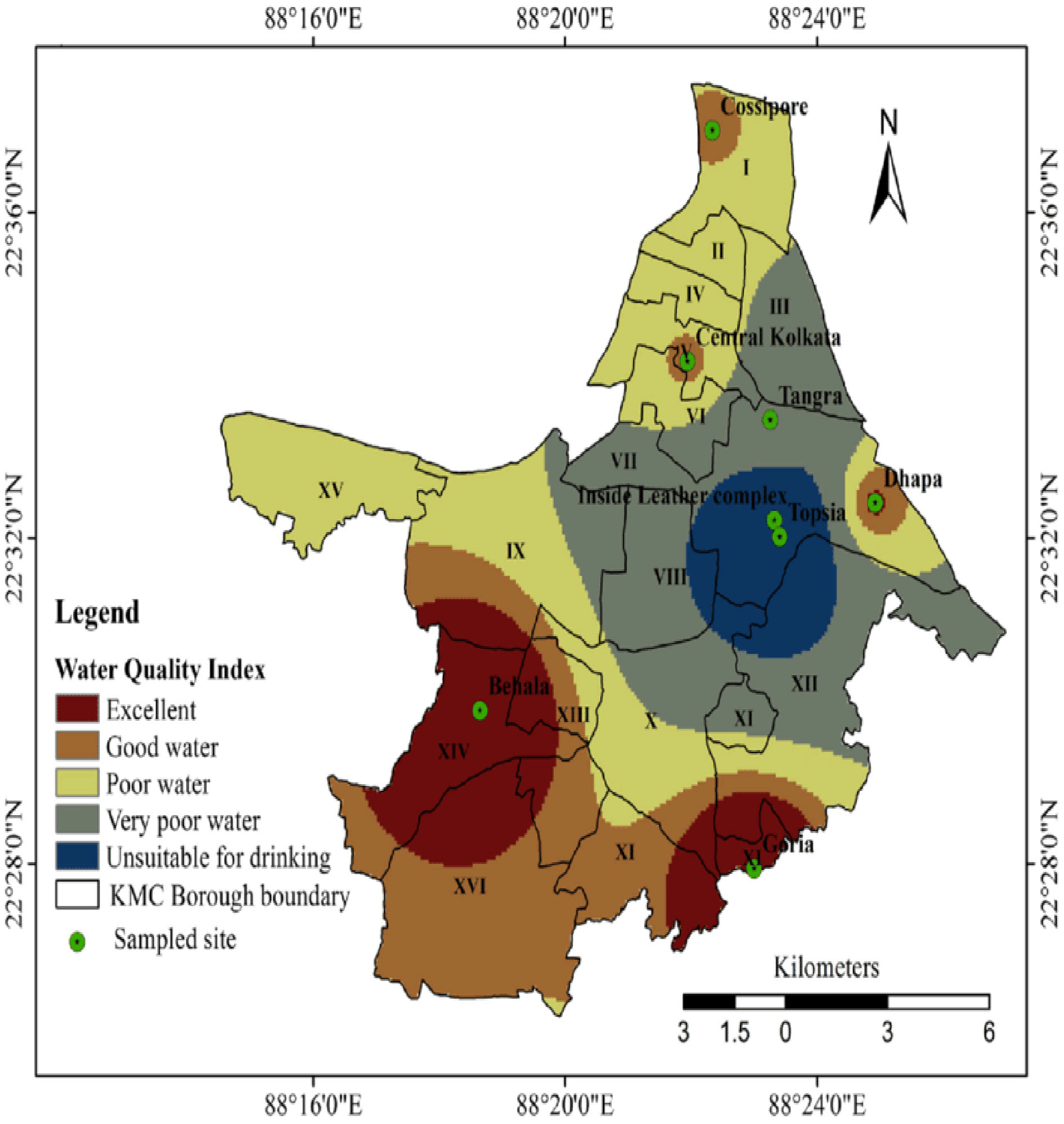

Fig. 3.2 Location of groundwater monitoring stations at Garia and Cossipore selected by WBPCB (Ali and Ahmad 2020).

CHAPTER IV

4.1 Objective

The aim of the study is to determine the ground water quality of the various regions in and around Kolkata city and to analyze and compare the quality of water. the study also includes organizing proper surveys to determine how the ground water quality affects the people as they use it for domestic purposes. So the main objective of the study are: -

1) To determine the water quality of Kolkata in a single index value
2) The importance of ground water for the people residing in the city.
3) To carry out water quality tests on the water sample taken from different parts.
4) To compare the ground water quality of the different regions.
5) To carry out surveys regarding the use of ground water.

4.2 Methodology

To calculate the WQI value of the groundwater of the Garia and Cossipore, both CCME-WQI and WA-WQI 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 eleven years, physico-chemical taken two months of each year of the 11 consecutive years from 2011 to 2021. These samples were collected from hand pumps and dug wells used for domestic purposes. The samples were also collected in high-density polyethylene (HDPE) bottle (one-litre capacity) and were stored at 4^{o}C until the analysis was completed by comparing their values with the Bureau of Indian Standards (BIS).

4.2.1 Computation Method of Canadian Council of Ministers of theEnvironment Water Quality Index (CCME-WQI):

The following six stages indicate the method for computing the Canadian Council Ministry of the Environment (CCME) WQI.
Calculation of the index is based on three terms:

Scope (F1) - number of parameters that are not compliant with the water quality guidelines,

Frequency (F2) - number of times that the guidelines are not respected and

Amplitude (F3) - the difference between non-compliant measurements and the corresponding guidelines.
First of all, the term F1 (scope) expresses the percentage of parameters for which at least one measurement did not comply with the corresponding guideline during the period under study

$$F_1 = \left(\frac{Number of failed parameters}{Total number of parameters}\right) \times 100 \qquad \textit{Eq.4.1}$$

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

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

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

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

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).

$$\boldsymbol{nse} = \left(\frac{\sum_i \boldsymbol{excursion_i}}{\boldsymbol{Total number of results}}\right) \quad \textit{Eq. 4.4}$$

There are three possible ways of determining the excursion:

• If the finding must not exceed the guideline:

$$\textbf{Excursion} = \left(\frac{\boldsymbol{Failed test result_i}}{\boldsymbol{Guideline_i}}\right) - \mathbf{1} \quad \textit{Eq. 4.5}$$

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

$$\textbf{Excursion} = \left(\frac{\boldsymbol{Guideline_i}}{\boldsymbol{Failed test result_i}}\right) - \mathbf{1} \quad \textit{Eq. 4.6}$$

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

Excursioni=Failed test result *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:

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

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

$$\textbf{CCME-WQI = 100 -} \left(\sqrt{\frac{\boldsymbol{F_1^2 + F_2^2 + F_3^2}}{\mathbf{1.732}}} \right) \quad \textit{Eq. 4.9}$$

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 categorization.

Table. 4.1 Water Quality Characteristics according to CCME-WQI.

CCME-WQI	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 CCME-WQI:

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

4.2.4 Demerits of CCME-WQI:

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).

4.2.5 Computation Method of Weighted Arithmetic Water Quality Index (WA-WQI):

WA-WQI 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 is used to determine the effect of waste dumping on the immediate ground and surface water- bodies to the dumpsite, as it is deemed the most appropriate, based on the prevailing conditions. The WQI is given as:

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

where, q_i= quality rating (sub-index) of i^{th} water quality parameter
w_i= unit weight of i^{th} water quality parameter = 1
Also, q_i, which relates the value of the parameter in polluted water to the standard permissible value, is obtained as follows:

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

where,
V_i= estimated value of the *n* parameter
V_{io}= ideal value of the n^{th} parameter
S_i= standard permissible value of the n^{th} parameter
In most cases, V_{io}=0 except for pH and DO (in mg/1)
For pH, V_{io}= 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:

$$\mathbf{W_i = \frac{K}{Si}} \quad \textit{Eq. 4.12}$$

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

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 WA-WQI (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	Turbidity	1	5
03	Magnesium	30	100
04	Total Alkalinity	200	600
05	Chloride	250	1000
06	Calcium	75	200
07	Total Hardness	200	600

4.2.6 Merit of WA-WQI:

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.

4.2.7 Demerit of WA-WQI:

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.

CHAPTER - V

5.1 Results and Discussion

5.1.1 Groundwater quality parameters for Garia sampling point

Below are the tables of data collected as per availability with the WBPCB for Garia Groundwater Monitoring Station for the years 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020 and 2021. The collected data are given in ranges for all eleven years.

Table 5.1 Yearly ranges of physicochemical parameters of groundwater for Garia monitoring station for the years 2011 to 2021.

Parameter	pH	Turbidity	Mg.	Total Alkalinity	Chloride	Calcium	Total Hardness
Unit	--	NTU	mg/l	mg/l	mg/l	mg/l	mg/l
04.04.11	7.9	2.39	26.73	470	131.13	120	410
19.04.12	7.35	41.6	29.16	320	107.63	84	330
04.04.13	7.31	0.83	26.73	460	100	100	360
02.04.14	7.47	4.96	53.46	340	119.82	80	420
01.04.15	7.25	4.38	36.45	490	148.04	112	430
19.04.16	7.37	234	38.5	340	139.96	31.68	237.62
07.04.17	0.08	463	38.88	360	159.95	40	260
17.10.17	7.84	119	34.02	320	169.95	64	300
11.04.18	7.37	4.18	43.74	320	119.96	64	340
04.10.18	7.74	1.82	38.88	340	27.99	56	300
11.04.19	7.68	2.29	37.38	330	125.96	30.77	230.77
16.10.19	7.81	6.82	3.84	380	39.2	35.2	104
05.10.20	7.16	2.15	28.9	450	84.97	50.98	245
05.04.21	7.52	7.37	21.87	290	83.59	24	150
27.10.21	7.68	30.3	21.87	300	99.97	12	120

5.1.3 Evaluation of WA-WQI

5.1.3.1 Weighted Arithmetic WQI for Garia in 2011

WA-WQI = 63.7882

Table – 5.2Experiment date 04.04.2011 (Garia Groundwater)-W.A- WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	60	18.6586
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	47.8	25.2700
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	235	3.1058
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	205	2.7093
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	160	5.6390
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	89.1	7.8506
Chloride	250	0.004	0.3783	2.6433	0.0105	0	52.452	0.5545
								63.7882

Say, WA-WQI = 64

From Table – 5.2, we can observe that the WA-WQI value for the year 2011dated 04.04.2011 is less than 75. So the quality of water can be classified as “Poor”.

5.1.3.2 Weighted Arithmetic WQI for 2012

Table – 5.3 Experiment date 19.04.2012 (Garia Groundwater) - W.A- WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	23.3333	7.2561
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	832	439.8465
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	160	2.1146
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	165	2.1807
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	112	3.9473
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	97.2	8.5643
Chloride	250	0.004	0.3783	2.6433	0.0105	0	43.052	0.4551
								464.3649

WA-WQI = 464.3649
Say, WA-WQI = 464

From Table – 5.3, we can observe that the WA-WQI value for the year 2012 dated19.04.2012 is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.3.3Weighted Arithmetic WQI for 2013 :

Table – 5.4 Experiment date 04.04.2013 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	20.6666	6.4268
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	16.6	8.7757
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	230	3.0398
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	180	2.3789
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	133.3333	4.6992
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	89.1	7.8506
Chloride	250	0.004	0.3783	2.6433	0.0105	0	40	0.4229
								33.5942

WA-WQI = 33.5942
Say, WA-WQI = 34

From Table 5.4, we can observe the WA-WQI value for the year 2013 dated (04.04.2013) is less than 50. So the quality of water can be classified as "Good"

5.1.3.4Weighted Arithmetic WQI for 2014 :

Table – 5.5Experiment date 02.04.2014 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	31.3333	9.7439
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	99.2	52.4432
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	170	2.2468
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	210	2.7754
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	106.6666	3.7593
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	178.2	15.7012
Chloride	250	0.004	0.3783	2.6433	0.0105	0	47.928	0.5067
								87.1768

WA-WQI = 87.1768
Say, WA-WQI = 87

From Table 5.5, we can observe that the WA-WQI value for the year 2014 dated 02.04.2014 is less than 100. So the quality of water can be classified as "Very Poor".

5.1.3.5Weighted Arithmetic WQI for 2015 :

Table – 5.6Experiment date 01.04.2015 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	16.6666	5.1829
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	87.6	46.3107
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	245	3.2380
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	215	2.8415
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	149.3333	5.2631
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	121.5	10.7054
Chloride	250	0.004	0.3783	2.6433	0.0105	0	59.216	0.62610
								74.1679

WA-WQI = 74.1679
Say, WA-WQI = 74

From Table 5.6, we can observe that the WA-WQI value for the year 2015 dated (01.04.2015) is less than 75. So the quality of water can be classified as “Poor”.

5.1.3.6 Weighted Arithmetic WQI for2016 :

Table – 5.7Experiment date 19.04.2016 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	24.6666	7.6707
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	4680	2474.1370
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	170	2.2468
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	118.81	1.5702
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	42.24	1.4887
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	128.3333	11.3074
Chloride	250	0.004	0.3783	2.6433	0.0105	0	55.984	0.5919
								2499.0130

WA-WQI = 2499.0130
Say, WA-WQI = 2499

From Table 5.7, we can observe the WA-WQI value for the year 2016 dated 19.04.2016 is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.3.7 Weighted Arithmetic WQI for 2017 :

Table – 5.8Experiment date 07.04.2017 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	Σ $1/s_i$	K = 1/Σ $1/s_i$	w_i = K/s_i	Ideal Value (V_{io})	q_i = 100[(v_i-v_{io})/(s_i-v_{io})]	$q_i\times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	-461.3333	-143.4642
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	9260	4895.4078
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	180	2.37897
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	130	1.7181
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	53.3333	1.8796
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	129.6	11.4190
Chloride	250	0.004	0.3783	2.6433	0.0105	0	63.98	0.6764
								4770.0159

WA-WQI = 4770.0159
Say, WA-WQI = 4770

From Table 5.8, we can observe that the WA-WQI value for the year 2017 dated (07.04.2017) is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.3.8 Weighted Arithmetic WQI for 2017 :

Table – 5.9Experiment date 17.10.2017 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	Σ $1/s_i$	K = 1/Σ $1/s_i$	w_i = K/s_i	Ideal Value (V_{io})	q_i = 100[(v_i-v_{io})/(s_i-v_{io})]	$q_i\times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	56	17.4147
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	2380	1258.2149
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	160	2.1146
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	150	1.9824
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	85.3333	3.0074
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	113.4	9.9917
Chloride	250	0.004	0.3783	2.6433	0.0105	0	67.98	0.7187
								1293.4448

WA-WQI = 1293.4448
Say, WA-WQI = 1293

From Table 5.9, we can observe that the WA-WQI value for the year 2017 dated (17.10.2017) is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.3.9 Weighted Arithmetic WQI for 2018 :

Table – 5.10Experiment date 11.04.2018 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	24.6666	7.6707
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	83.6	44.1961
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	160	2.1146
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	170	2.2468
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	85.3333	3.0074
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	145.8	12.8464
Chloride	250	0.004	0.3783	2.6433	0.0105	0	47.984	0.5073
								72.5896

WA-WQI = 72.5896
Say, WA-WQI = 73

From Table 5.10, we can observe that the WA-WQI value for the year of 2018 dated (11.04.2018) is less than 75. So the quality of water can be classified as “Poor”.

5.1.3.10 Weighted Arithmetic WQI for 2018 :

Table – 5.11Experiment date 04.10.2018 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	49.3333	15.3415
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	36.4	19.2432
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	170	2.2468
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	150	1.9824
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	74.6666	2.6315
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	129.6	11.4190
Chloride	250	0.004	0.3783	2.6433	0.0105	0	11.196	0.1183
								52.9831

WA-WQI = 52.9831
Say, WA-WQI = 53

From Table 5.11, we can observe that the WA-WQI value for the year of 2018 dated (04.10.2018) is less than 75. So the quality of water can be classified as “Poor”.

5.1.3.11 Weighted Arithmetic WQI for 2019:

Table – 5.12Experiment date 11.04.2019 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	45.3333	14.0976
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	45.8	24.2127
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	165	2.1807
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	115.385	1.5249
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	41.0266	1.4459
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	124.6	10.978
Chloride	250	0.004	0.3783	2.6433	0.0105	0	50.384	0.5327
								54.9732

WA-WQI = 54.9732
Say, WA-WQI = 55

From Table 5.12, we can observe that the WA-WQI value for the year of 2019 dated (11.04.2019) is less than 75. So the quality of water can be classified as “Poor”.

5.1.3.12 Weighted Arithmetic WQI for 2019 :

Table – 5.13Experiment date 16.10.2019 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	54	16.7927
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	136.4	72.1094
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	190	2.5111
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	52	0.6872
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	46.9333	1.6541
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	12.8	1.1278
Chloride	250	0.004	0.3783	2.6433	0.0105	0	15.68	0.1657
								95.0483

WA-WQI = 95.0483
Say, WA-WQI = 95

From Table – 5.13, we can observe that the WA-WQI value for the year of 2019 dated (16.10.2019) is less than 100. So the quality of water can be classified as “Very Poor”.

5.1.3.13 Weighted Arithmetic WQI for 2020 :

Table – 5.14Experiment date 05.10.2020 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	10.6666	3.3170
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	43	22.7324
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	225	2.9737
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	122.5	1.6190
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	67.9733	2.3956
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	96.3333	8.4879
Chloride	250	0.004	0.3783	2.6433	0.0105	0	33.988	0.3593
								41.8852

WA-WQI = 41.8852
Say, WA-WQI = 42

From Table – 5.14, we can observe that the WA-WQI value for the year of 2020 dated (05.10.2020) is less than 50. So the quality of water can be classified as “Good”.

5.1.3.14 Weighted Arithmetic WQI for 2021:

Table – 5.15Experiment date 05.04.2021 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	34.6666	10.7805
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	147.4	77.9247
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	145	1.9163
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	75	0.9912
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	32	1.1278
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	72.9	6.4232
Chloride	250	0.004	0.3783	2.6433	0.0105	0	33.436	0.3535
								99.5175

WA-WQI = 99.5175
Say, WA-WQI = 100

From Table – 5.15, we can observe that the WA-WQI value for the year 2021 dated (05.04.2021) is equal to 100. So the quality of water can be classified as “Very Poor”.

5.1.3.15 Weighted Arithmetic WQI for 2021:

Table – 5.16Experiment date 27.10.2021 (Garia Groundwater) - WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	45.3333	14.0976
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	606	320.3690
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	150	1.9824
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	60	0.7929
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	16	0.5639
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	72.9	6.4232
Chloride	250	0.004	0.3783	2.6433	0.0105	0	39.988	0.4228
								344.6520

WA-WQI = 344.6520
Say, WA-WQI = 345

From Table 5.16, we can observe that the WA-WQI value for the year 2021 dated (27.10.2021) is greater than 100. So the quality of water can be classified as "Unfit for consumption" without treatment of groundwater.

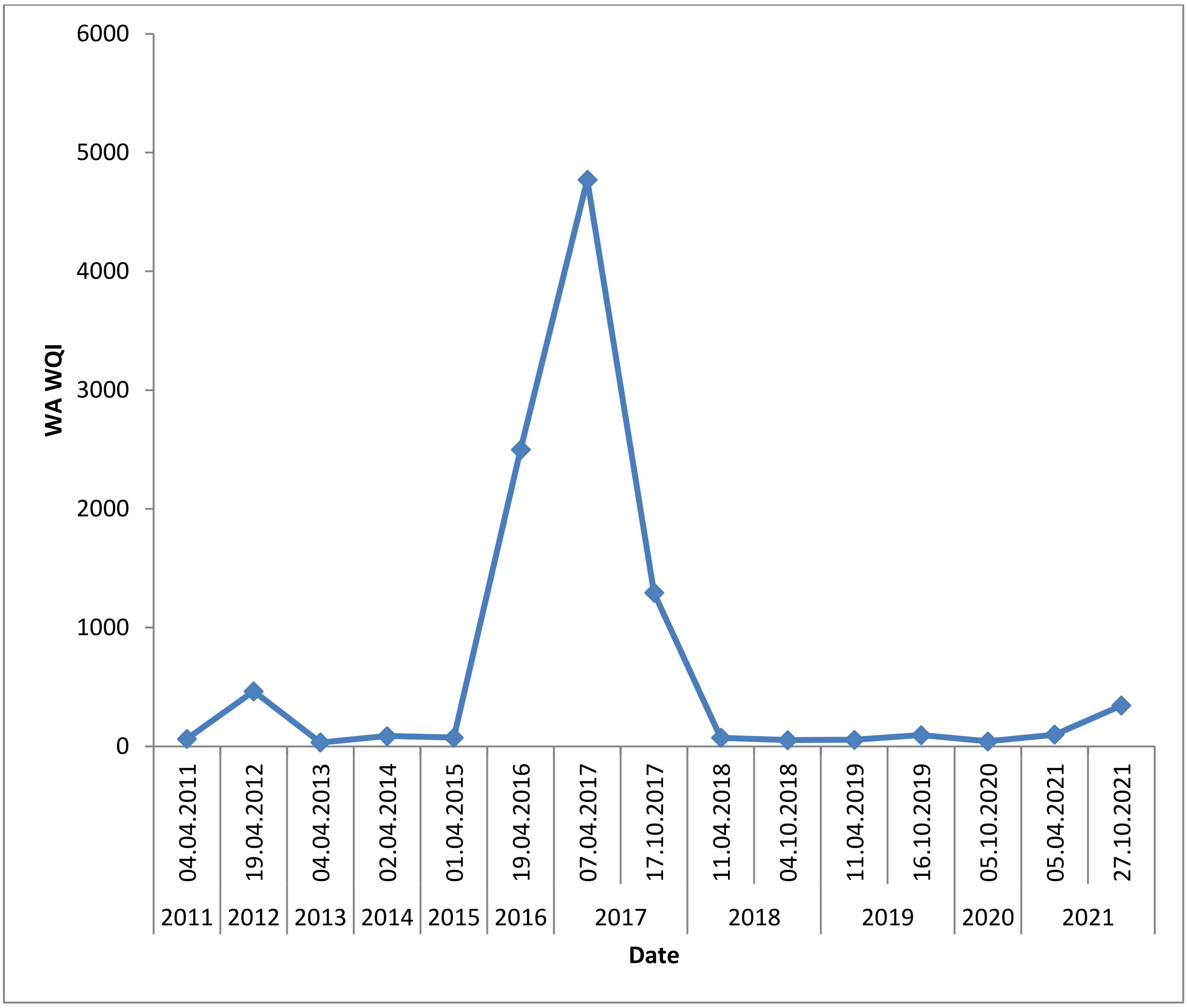

Fig. 5.1 Date-wise change of groundwater WA-WQI for Garia.

5.1.2 Groundwater quality parameters for Cossipore sampling point

Below are the tables of data collected as per availability with the WBPCB for the Cossipore Groundwater Monitoring Station for the years 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020 and 2021. The collected data are given in ranges for all eleven years.

Table: 5.1(a) Yearly ranges of physico-chemical parameters of raw groundwater of Cossipore station for the years 2011 to 2021.

Parameter	pH	Turbidity	Mg.	Total Alkalinity	Chloride	Calcium	Total Hardness
Unit	--	NTU	mg/l	mg/l	mg/l	mg/l	mg/l
06.04.11	7.36	30.9	82.62	330	592.51	128	660
10.04.12	7.32	35.3	21.87	300	733.82	236	680
01.04.13	7.23	77.1	63.18	270	404.6	164	670
04.04.14	7.3	36.1	72.9	340	488.5	200	800
17.04.15	7.86	44.1	10.69	220	51.05	62.4	200
15.04.16	7.67	7.54	81.8	210	210	126.73	653.47
20.04.17	7.64	7.58	80.19	200	599.81	124	640
09.10.17	7.55	1.34	75.33	180	499.85	116	600
10.04.18	8.19	4.93	75.33	170	649.8	116	600
01.10.18	7.41	15.9	72	155	599.81	112	580
04.04.19	7.4	217	88.79	368	549.83	169.23	788.46
18.10.19	7.38	50.9	51.77	400	584.9	196.08	705
06.10.20	7.43	13.4	30.97	420	699.78	168.63	549.02
05.04.21	7.49	4.84	58.32	350	743.03	496	730

5.1.4 Evaluation of WA-WQI (Cossipore)

5.1.4.1Weighted Arithmetic WQI for 2011:

Table: 5.17 Experiment date 06.04.2011 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	Σ $1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7.0000	24	7.4634
Turbidity	5	0.2	0.3783	2.6433	0.5286	0.0000	618	326.7129
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0.0000	165	2.1807
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0.0000	330	4.3614
Calcium	75	0.0133	0.3783	2.6433	0.0352	0.0000	170.6666	6.0149
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0.0000	275.4	24.2655
Chloride	250	0.004	0.3783	2.6433	0.0105	0.0000	237.004	2.5058
								373.5050

WA-WQI = 373.5050

Say, WA-WQI = 374

From Table – 5.17, we can observe that the WA-WQI value for the year of 2011 dated (06.04.2011) is greater than 100. So the quality of water can be classified as "Unfit for consumption" without treatment of groundwater.

5.1.4.2Weighted Arithmetic WQI for 2012 :

Table: 5.18 Experiment date 10.04.2012 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	Σ $1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	21.3333	6.6341
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	706	373.2352
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	150	1.9824
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	340	4.4936
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	314.6666	11.0901
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	72.9	6.4232
Chloride	250	0.004	0.3783	2.6433	0.0105	0	293.528	3.1035
								406.9624

WA-WQI = 406.9624

Say, WA-WQI = 407

From Table – 5.18, we can observe that the WA-WQI value for the year of 2012 dated (10.04.2012) is greater than 100. So the quality of water can be classified as "Unfit for consumption" without treatment of groundwater.

5.1.4.3Weighted Arithmetic WQI for 2013:

Table: 5.19 Experiment date 01.04.2013 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	Σ $1/s_i$	K = 1/Σ $1/s_i$	w_i = K/s_i	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	15.3333	4.7683
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	1542	815.1964
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	135	1.7842
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	335	4.4275
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	218.6666	7.7067
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	210.6	18.5560
Chloride	250	0.004	0.3783	2.6433	0.0105	0	161.84	1.7111
								854.1504

WA-WQI = 854.1504
Say, WA-WQI = 854

From Table 5.19, we can observe that the WA-WQI value for the year 2013 dated (01.04.2013) is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.4.4Weighted Arithmetic WQI for 2014 :

Table: 5.20 Experiment date 04.04.2014 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	Σ $1/s_i$	K = 1/Σ $1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	20	6.2195
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	722	381.6937
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	170	2.2468
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	400	5.2866
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	266.6666	9.3984
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	243	21.4108
Chloride	250	0.004	0.3783	2.6433	0.0105	0	195.4	2.0660
								428.3220

WA-WQI = 428.3220
Say, WA-WQI = 428

From Table 5.20, we can observe that the WA-WQI value for the year of 2014 dated (04.04.2014) is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.4.5Weighted Arithmetic WQI for 2015 :

Table: 5.21 Experiment date 17.04.2015 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	57.3333	17.8293
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	882	466.2796
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	110	1.4538
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	100	1.3216
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	83.2	2.9323
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	35.6333	3.1396
Chloride	250	0.004	0.3783	2.6433	0.0105	0	20.42	0.2159
								493.1724

WA-WQI = 493.1724
Say, WA-WQI = 493

From Table 5.21, we can observe that the WA-WQI value for the year of 2015 dated (17.04.2015) is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.4.6Weighted Arithmetic WQI for 2016:

Table: 5.22 Experiment date 15.04.2016 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	44.6666	13.8903
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	150.8	79.7221
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	105	1.3877
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	326.735	4.3183
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	168.9733	5.9553
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	272.6666	24.0247
Chloride	250	0.004	0.3783	2.6433	0.0105	0	259.92	2.7481
								132.0468

WA-WQI = 132.0468
Say, WA-WQI = 132

From Table 5.22, we can observe that the WA-WQI value for the year of 2016 dated (15.04.2016) is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.4.7 Weighted Arithmetic WQI for 2017:

Table: 5.23 Experiment date 20.04.2017 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i\times w_i$
PH	8.5	0.1176	0.37831	2.6433	0.3109	7	42.6666	13.2683
Turbidity	5	0.2	0.37831	2.6433	0.5286	0	151.6	80.1451
Total Alkalinity	200	0.005	0.37831	2.6433	0.0132	0	100	1.3216
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	320	4.2292
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	165.3333	5.8270
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	267.3	23.5518
Chloride	250	0.004	0.3783	2.6433	0.0105	0	239.924	2.5367
								130.8801

WA-WQI = 130.8801
Say, WA-WQI = 131

From Table 5.23, we can observe that the WA-WQI value for the year 2017 dated (20.04.2017) is greater than 100. So the quality of water can be classified as "Unfit for consumption" without treatment of groundwater.

5.1.4.8Weighted Arithmetic WQI for 2017 :

Table: 5.24 Experiment date 09.10.2017 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i\times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	36.6666	11.4025
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	26.8	14.1681
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	90	1.1894
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	300	3.9649
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	154.6666	5.4510
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	251.1	22.1244
Chloride	250	0.004	0.3783	2.6433	0.0105	0	199.94	2.1140
								60.4146

WA-WQI = 60.4146
Say, WA-WQI = 60

From Table 5.24, we can observe that the WA-WQI value for the year 2017 dated (09.10.2017) is less than 75. So the quality of water can be classified as “Poor”.

5.1.4.9 Weighted Arithmetic WQI for 2018 :

Table: 5.25 Experiment date 10.04.2018 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	79.3333	24.6708
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	98.6	52.1260
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	85	1.1234
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	300	3.9649
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	154.6666	5.4510
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	251.1	22.1244
Chloride	250	0.004	0.3783	2.6433	0.0105	0	259.92	2.7481
								112.2090

WA-WQI = 112.2090
Say, WA-WQI = 112

From Table 5.25, we can observe that the WA-WQI value for the year of 2018 dated (10.04.2018) is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.4.10Weighted Arithmetic WQI for 2018:

Table: 5.26 Experiment date 01.10.2018 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i - v_{io})/(s_i - v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	27.3333	8.5000
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	318	168.1144
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	77.5	1.0242
Total Hardness	200	0.005	0.3783	2.6433	0.01321	0	290	3.8327
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	149.3333	5.2631
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	240	21.1464
Chloride	250	0.004	0.3783	2.6433	0.0105	0	239.924	2.5367
								210.4179

WA-WQI = 210.4179
Say, WA-WQI = 210

From Table 5.26, we can observe that the WA-WQI value for the year of 2018 dated (01.10.2018) is greater than 100. So the quality of water can be classified as "Unfit for consumption" without treatment of groundwater.

5.1.4.11 Weighted Arithmetic WQI for 2019:

Table: 5.27 Experiment date 04.04.2019 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.31097	7	26.6666	8.2927
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	4340	2294.3920
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	184	2.4318
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	394.23	5.2103
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	225.64	7.9524
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	295.9666	26.0777
Chloride	250	0.004	0.3783	2.6433	0.0105	0	219.932	2.3253
								2346.6825

WA-WQI = 2346.6825
Say, WA-WQI = 2347

From Table – 5.27, we can observe that the WA-WQI value for the year of 2019 dated (04.04.2019) is greater than 100. So the quality of water can be classified as "Unfit for consumption" without treatment of groundwater.

5.1.4.12Weighted Arithmetic WQI for 2019:

Table : 5.28 Experiment date 18.10.2019 (Cossipore Groundwater)) W.A- WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.31097	7	25.3333	7.8780
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	1004	530.7764
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	200	2.6433
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	352.5	4.6588
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	261.44	9.2142
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	172.5666	15.2048
Chloride	250	0.004	0.3783	2.6433	0.0105	0	233.96	2.4737
								572.8494

WA-WQI = 572.8494
Say, WA-WQI = 573

From Table 5.28, we can observe that the WA-WQI value for the year of 2019 dated (18.10.2019) is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.4.13Weighted Arithmetic WQI for 2020 :

Table: 5.29 Experiment date 06.10.2020 (Cossipore Groundwater)) W.A- WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	28.6666	8.9146
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	268	141.6813
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	210	2.7754
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	274.51	3.6280
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	224.84	7.9242
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	103.2333	9.0959
Chloride	250	0.004	0.3783	2.6433	0.0105	0	279.912	2.9595
								176.9797

WA-WQI = 176.9797
Say, WA-WQI = 177

From Table 5.29, we can observe that the WA-WQI value for the year of 2020 dated (06.10.2020) is greater than 100. So the quality of water can be classified as “Unfit for consumption” without treatment of groundwater.

5.1.4.14Weighted Arithmetic WQI for 2021 :

Table: 5.30 Experiment date 05.04.2021 (Cossipore Groundwater) WA-WQI Method

Parameter	s_i	$1/s_i$	$\Sigma\ 1/s_i$	$K = 1/\Sigma\ 1/s_i$	$w_i = K/s_i$	Ideal Value (V_{io})	$q_i = 100[(v_i-v_{io})/(s_i-v_{io})]$	$q_i \times w_i$
PH	8.5	0.1176	0.3783	2.6433	0.3109	7	32.6666	10.1585
Turbidity	5	0.2	0.3783	2.6433	0.5286	0	96.8	51.1744
Total Alkalinity	200	0.005	0.3783	2.6433	0.0132	0	175	2.3128
Total Hardness	200	0.005	0.3783	2.6433	0.0132	0	365	4.8240
Calcium	75	0.0133	0.3783	2.6433	0.0352	0	261.3333	9.2104
Magnesium	30	0.0333	0.3783	2.6433	0.0881	0	194.4	17.1286
Chloride	250	0.004	0.3783	2.6433	0.0105	0	297.212	3.1424
								97.9515

WA-WQI = 97.9515
Say, WA-WQI = 98

From Table 5.30, we can observe that the WA-WQI value for the year 2021 dated (05.04.2021) is equal to 100. So the quality of water can be classified as “Very Poor”.

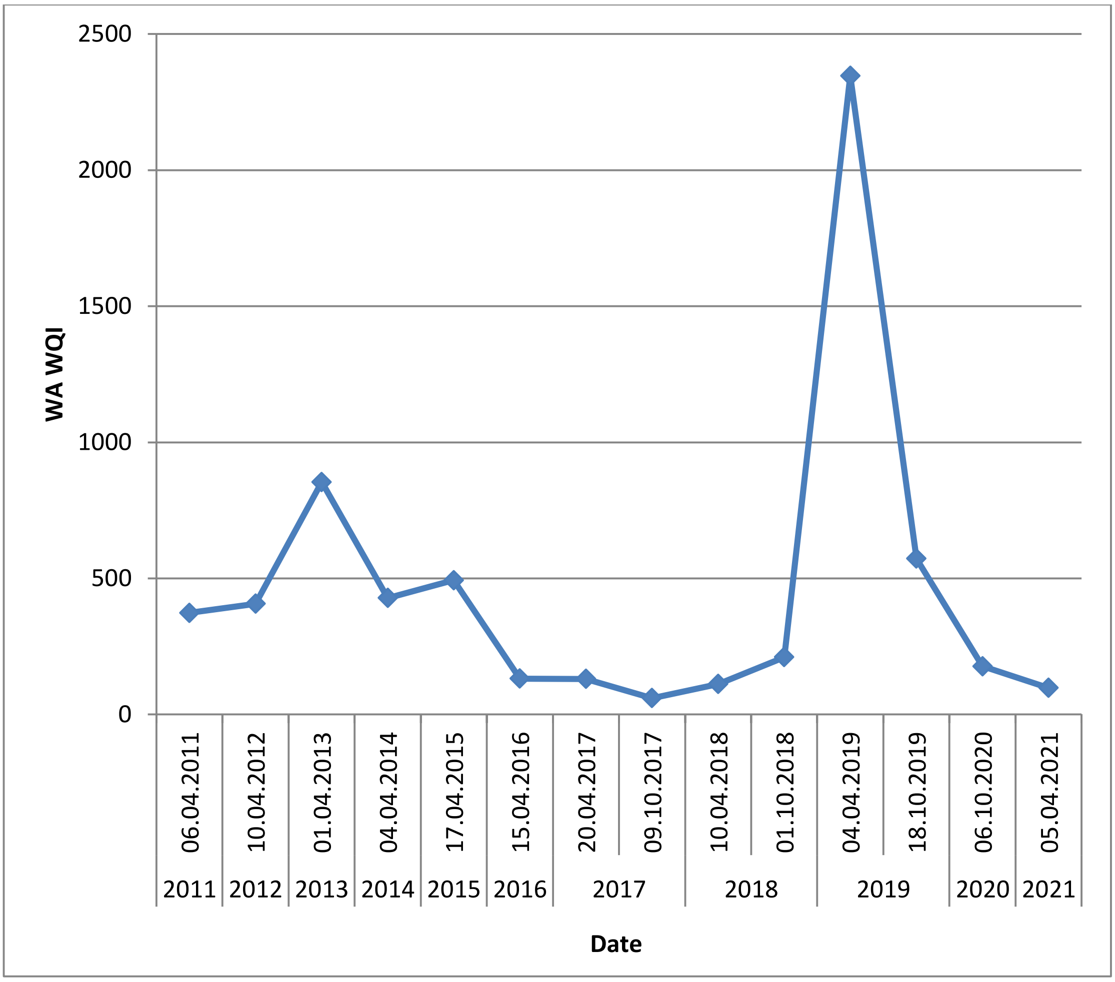

Fig. 5.2 Date-wise change of groundwater WA-WQI for Cossipore.

5.1.5 Evaluation of CCME-WQI (Garia)

5.1.5.1CCME-WQI for 2011:

Table: 5.31 Experiment date 04.04.2011 (Garia Groundwater) CCME-WQI Method

CCME Method (Garia Groundwater) - 04.04.2011			
	Total Alkalinity	Calcium	Total hardness
A	470	120	410
B	200	75	200
A/B	2.35	1.6	2.05
C=(A/B-1)	1.35	0.6	1.05
Σ C	3		
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	42.86		
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76		
nse = Σ C/Z	0.02857		
F3 = nse/(nse X .01 + .01)	2.77778		
CCME-WQI = [100 - √(F1^2 + F2^2 + F3^2) / 1.732]	64.1850		

CCME-WQI = 64.1850

Say, CCME-WQI = 64

As per Table 5.31, we can see that the CCME-WQI value in the year of 2011 dated 04.04.2011 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.2CCME-WQI for 2012:

Table: 5.32 Experiment date 19.04.2012 (Garia Groundwater) CCME-WQI Method

CCME Method (Garia Groundwater) - 19.04.2012				
	Turbidity	Total Alkalinity	Calcium	Total Hardness
A	41.6	320	84	330
B	5	200	75	200
A/B	8.32	1.6	1.12	1.65
C=(A/B-1)	7.32	0.6	0.12	0.65
Σ C	8.69			
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	57.1429			
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76			
nse = Σ C/Z	0.0828			
F3 = nse/nse X .01 + .01	7.6436			
CCME-WQI = [100 - √(F1^2 + F2^2 + F3^2) / 1.732]	57.8594			

CCME-WQI = 57.8594

Say, CCME-WQI = 58

As per table no. 5.32, we can see that the CCME-WQI value in the year of 2011 dated 04.04.2011 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.3 CCME-WQI for 2013:

Table: 5.33 Experiment date 04.04.2013 (Garia Groundwater) CCME-WQI Method

CCME Method (Garia Groundwater) - 04.04.2013			
	Total Alkalinity	Calcium	Total hardness
A	460	100	360
B	200	75	200
A/B	2.3	1.3333	1.8
C=(A/B-1)	1.3	0.3333	0.8
Σ C	2.4333		
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	42.8571		
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76		
nse = Σ C/Z	0.0232		
F3 = nse/(nse X .01 + .01)	2.2650		
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	64.1971		

CCME-WQI = 64.1971

Say, CCME-WQI = 64

As per Table 5.33, we can see that the CCME-WQI value in the year 2013 dated 04.04.2013 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.4 CCME-WQI for2014 :

Table: 5.34 Experiment date 02.04.2014 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 02.04.2014				
	Mg	Total Alkalinity	Calcium	Total Hardnes s
A	53.46	340	80	420
B	30	200	75	200
A/B	1.782	1.7	1.0667	2.1
C=(A/B-1)	0.782	0.7	0.0667	1.1
Σ C	2.6487			
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	57.1429			
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76			
nse = Σ C/Z	0.0252			
F3 = nse/nse X .01 + .01	2.4605			
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	58.0670			

CCME-WQI = 58.0670

Say, CCME-WQI = 58

As per table no. 5.34, we can see that the CCME-WQI value in the year of 2014 dated 02.04.2014 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.5 CCME-WQI for 2015 :

Table: 5.35 Experiment date 01.04.2015 (Garia Groundwater) CCME-WQI Method

CCME Method (Garia Groundwater) - 01.04.2015				
	Mg	Total Alkalinity	Calcium	Total Hardness
A	36.45	490	112	430
B	30	200	75	200
A/B	1.215	2.45	1.4933	2.15
C=(A/B-1)	0.215	1.45	0.4933	1.15
Σ C	3.3083			
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	57.1429			
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76			
nse = Σ C/Z	0.0315			
F3 = nse/nse X .01 + .01	3.0546			
CCME-WQI = [100 - √(F1^2 + F2^2 + F3^2) / 1.732]	58.0540			

CCME-WQI = 58.0540

Say, CCME-WQI = 58

As per Table 5.35, we can see that the CCME-WQI value in the year of 2015 dated 01.04.2015 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.6 CCME-WQI for2016:

Table: 5.36 Experiment date 19.04.2016 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 19.04.2016				
	Mg	Total Alkalinity	Turbidity	Total Hardness
A	38.5	340	234	237.62
B	30	200	5	200
A/B	1.2833	1.7	46.8	1.1881
C=(A/B-1)	0.2833	0.7	45.8	0.1881
Σ C	46.9714			
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	57.1429			
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76			
nse = Σ C/Z	0.4473			
F3 = nse/nse X .01 + .01	30.9081			
CCME-WQI = [100 - √(F1^2 + F2^2 + F3^2) / 1.732]	54.4499			

CCME-WQI = 54.4499

Say, CCME-WQI = 54

As per Table 5.36, we can see that the CCME-WQI value in the year of 2016 dated 19.04.2016 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.7 CCME-WQI for2016 :

Table: 5.37Experiment date 19.04.2016 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 07.04.2017				
	Mg	Total Alkalinity	Turbidity	Total Hardness
A	38.88	360	463	260
B	30	200	5	200
A/B	1.296	1.8	92.6	1.3
C=(A/B-1)	0.296	0.8	91.6	0.3
Σ C	92.996			
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	57.1429			
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76			
nse = Σ C/Z	0.8857			
F3 = nse/nse X .01 + .01	46.9686			
CCME-WQI = [100 - $\sqrt{}$(F1^2 + F2^2 + F3^2) / 1.732]	50.0826			

CCME-WQI = 50.0826

Say, CCME-WQI = 50

As per Table 5.37, we can see that the CCME-WQI value in the year 2017 dated 07.04.2017 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.8 CCME-WQI for2017 :

Table: 5.38 Experiment date 17.10.2017 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 17.10.2017				
	Mg	Total Alkalinity	Turbidity	Total Hardness
A	34.02	320	119	300
B	30	200	5	200
A/B	1.134	1.6	23.8	1.5
C=(A/B-1)	0.134	0.6	22.8	0.5
Σ C	24.034			
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	57.1429			
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76			
nse = Σ C/Z	0.2289			
F3 = nse/nse X .01 + .01	18.6261			
CCME-WQI = [100 - $\sqrt{}$(F1^2 + F2^2 + F3^2) / 1.732]	56.7333			

CCME-WQI = 56.7333

Say, CCME-WQI = 57

As per Table 5.38, we can see that the CCME-WQI value in the year 2017 dated 17.10.2017 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.9 CCME-WQI for 2018:

Table: 5.39 Experiment date 11.04.2018 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 11.04.2018			
	Total Alkalinity	Mg.	Total hardness
A	320	43.74	340
B	200	30	200
A/B	1.6	1.458	1.7
C=(A/B-1)	0.6	0.458	0.7
Σ C	1.758		
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	42.8571		
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76		
nse = Σ C/Z	0.0167		
F3 = nse/(nse X .01 + .01)	1.6467		
CCME-WQI = $[100 - \sqrt{(F1^2 + F2^2 + F3^2)} / 1.732]$	64.2083		

CCME-WQI = 64.2083

Say, CCME-WQI = 64

As per Table 5.39, we can see that the CCME-WQI value in the year of 2018 dated 11.04.2018 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.10 CCME-WQI for 2018 :

Table: 5.40 Experiment date 04.10.2018 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 04.10.2018			
	Total Alkalinity	Mg.	Total hardness
A	340	38.88	300
B	200	30	200
A/B	1.7	1.296	1.5
C=(A/B-1)	0.7	0.296	0.5
Σ C	1.496		
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	42.8571		
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76		
nse = Σ C/Z	0.0142		
F3 = nse/(nse X .01 + .01)	1.4047		
CCME-WQI = $[100 - \sqrt{(F1^2 + F2^2 + F3^2)} / 1.732]$	64.2118		

CCME-WQI = 64.2118

Say, CCME-WQI = 64

As per Table 5.40, we can see that the CCME-WQI value in the year of 2018 dated 04.10.2018 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.11 CCME-WQI for2019 :

Table: 5.41 Experiment date 11.04.2019 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 11.04.2019			
	Total Alkalinity	Mg.	Total hardness
A	330	37.38	230.77
B	200	30	200
A/B	1.65	1.246	1.15385
C=(A/B-1)	0.65	0.246	0.15385
Σ C	1.0498		
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	42.8571		
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76		
nse = Σ C/Z	0.0100		
F3 = nse/(nse X .01 + .01)	0.9900		
CCME-WQI = [100 - √($F1^2 + F2^2 + F3^2$) / 1.732]	64.2164		

CCME-WQI = 64.2164

Say, CCME-WQI = 64

As per Table 5.41, we can see that the CCME-WQI value in the year of 2019 dated 11.04.2019 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.5.12 CCME-WQI for2019 :

Table: 5.42 Experiment date 16.10.2019 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 16.10.2019		
	Turbidity	Total Alkalinity
A	6.82	380
B	5	200
A/B	1.364	1.9
C=(A/B-1)	0.364	0.9
Σ C	1.264	
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	28.5714	
F2 = Total No. of failed Test/Total No. of Test (Z)	44.7619	
nse = Σ C/Z	0.0120	
F3 = nse/nse X .01 + .01	1.1894	
CCME-WQI = [100 - √($F1^2 + F2^2 + F3^2$) / 1.732]	69.3322	

CCME-WQI = 69.3322

Say, CCME-WQI = 69

As per Table 5.42, we can see that the CCME-WQI value in the year of 2019 dated 16.10.2019 is in the range of 65-79 and the quality of water is classified as “Fair”. So, it is observed from the result that the quality of water is usually but occasionally threatened or impaired; conditions sometimes depart from desirable levels.

5.1.5.13 CCME-WQI for2020 :

Table: 5.43 Experiment date 05.10.2020 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 05.10.2020		
	Total Hardness	Total Alkalinity
A	245	450
B	200	200
A/B	1.225	2.25
C=(A/B-1)	0.225	1.25
Σ C	1.475	
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	28.5714	
F2 = Total No. of failed Test/Total No. of Test (Z)	44.7619	
nse = Σ C/Z	0.0140	
F3 = nse/nse X .01 + .01	1.3853	
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	69.3294	

CCME-WQI = 69.3294

Say, CCME-WQI = 69

As per Table 5.43, we can see that the CCME-WQI value in the year of 2020 dated 05.10.2020 is in the range of 65-79 and the quality of water is classified as “Fair”. So, it is observed from the result that the quality of water is usually but occasionally threatened or impaired; conditions sometimes depart from desirable levels.

5.1.5.14 CCME-WQI for2021 :

Table: 5.44 Experiment date 05.04.2021 (Garia Groundwater) CCME-WQI Method

CCME Method (Garia Groundwater) - 05.04.2021		
	Turbidity	Total Alkalinity
A	7.37	290
B	5	200
A/B	1.474	1.45
C=(A/B-1)	0.474	0.45
Σ C	0.924	
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	28.5714	
F2 = Total No. of failed Test/Total No. of Test (Z)	44.7619	
nse = Σ C/Z	0.0088	
F3 = nse/nse X .01 + .01	0.8723	
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	69.3357	

CCME-WQI = 69.3357

Say, CCME-WQI = 69

As per Table 5.44, we can see that the CCME-WQI value in the year 2021 dated 05.04.2021 is in the range of 65-79 and the quality of water is classified as “Fair”. So, it is observed from the result that the quality of water is usually but occasionally threatened or impaired; conditions sometimes depart from desirable levels.

5.1.5.15 CCME-WQI for2021 :

Table: 5.45 Experiment date 27.10.2021 (Garia Groundwater) CCME- WQI Method

CCME Method (Garia Groundwater) - 27.10.2021		
	Turbidity	Total Alkalinity
A	30.3	300
B	5	200
A/B	6.06	1.5
C=(A/B-1)	5.06	0.5
Σ C	5.56	
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	28.5714	
F2 = Total No. of failed Test/Total No. of Test (Z)	44.7619	
nse = Σ C/Z	0.0529	
F3 = nse/nse X .01 + .01	5.0289	
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	69.2027	

CCME-WQI = 69.2027

Say, CCME-WQI = 69

As per Table 5.45, we can see that the CCME-WQI value in the year 2021 dated 27.10.2021 is in the range of 65-79 and the quality of water is classified as “Fair”. So, it is observed from the result that the quality of water is usually but occasionally threatened or impaired; conditions sometimes depart from desirable levels.

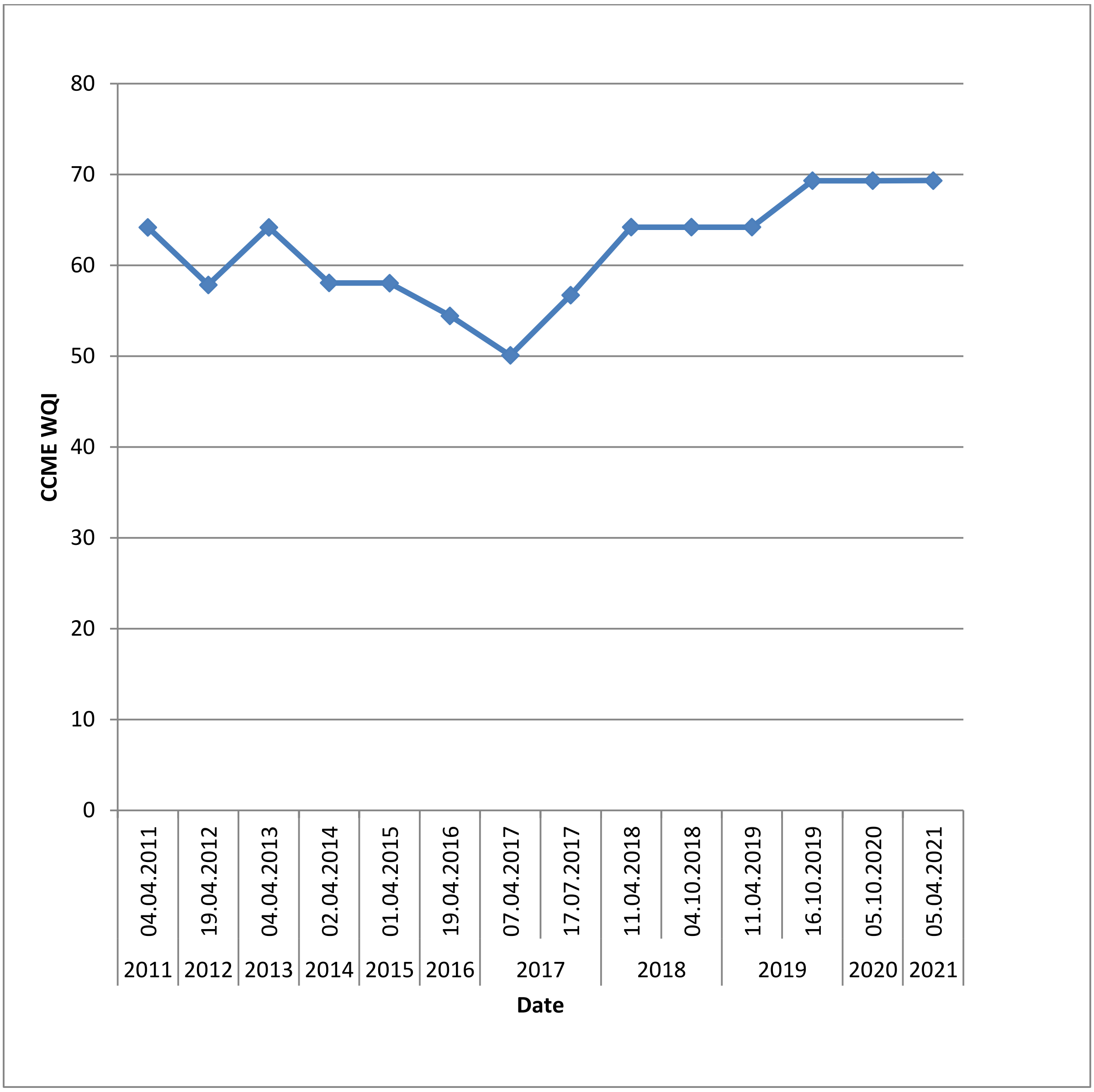

Fig. 5.3. Date-wise change of groundwater CCME-WQI for Garia.

5.1.6 Evaluation of CCME-WQI (Cossipore)

5.1.6.1 CCME-WQI for 2011:

Table: 5.46 Experiment date 06.04.2011 (Cossipore Groundwater) CCME-WQI Method

CCME Method (Cossipore Groundwater) - 06.04.2011						
	Turbidity	Mg.	Total Alkalinity	Cl	Cal	Total Hardness
A	30.9	82.62	330	592.51	128	660
B	5	30	200	250	75	200
A/B	6.18	2.754	1.65	2.3700	1.7067	3.3
C=(A/B-1)	5.18	1.754	0.65	1.3700	0.7067	2.3
Σ C	11.9607					
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	85.7143					
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694					
nse = Σ C/Z	0.1220					
F3 = nse/nse × .01 + .01	10.8773					
CCME-WQI = $[100 - \sqrt{(F1^2 + F2^2 + F3^2)} / 1.732]$	34.5178					

CCME-WQI = 34.5178

Say, CCME-WQI = 35

As per table 5.46, we can see that the CCME-WQI value in the year of 2011 dated 06.04.2011 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.2 CCME-WQI for 2012:

Table: 5.47 Experiment date 10.04.2012 (Cossipore Groundwater) CCME-WQI Method

CCME Method (Cossipore Groundwater) - 10.04.2012					
	Turbidity	Total Alkalinity	Chloride	Calcium	Total Hardness
A	35.3	300	733.82	236	680
B	5	200	250	75	200
A/B	7.06	1.5	2.9353	3.1467	3.4
C=(A/B-1)	6.06	0.5	1.9353	2.1467	2.4
Σ C	13.0419				
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	71.4286				
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694				
nse = Σ C/Z	0.1331				
F3 = nse/nse X .01 + .01	11.7451				
CCME-WQI = $[100 - \sqrt{(F1^2 + F2^2 + F3^2)} / 1.732]$	40.4507				

CCME-WQI = 40.4507

Say, CCME-WQI = 40

As per Table 5.47, we can see that the CCME-WQI value in the year of 2012 dated 10.04.2012 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.3 CCME-WQI for 2013 :

Table: 5.48 Experiment date 01.04.2013 (Cossipore Groundwater) CCME-WQI Method

CCME Method (Cossipore Groundwater) - 01.04.2013						
	Turbidity	Mg.	Total Alkalinity	Cl	Cal	Total Hardness
A	77.1	63.18	270	404.6	164	670
B	5	30	200	250	75	200
A/B	15.42	2.106	1.35	1.6184	2.1867	3.35
C=(A/B-1)	14.42	1.106	0.35	0.6184	1.1867	2.35
Σ C	20.0311					
F1 (Scope) = No. of failed variables/ Total No. of Variables X 100	85.7143					
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694					
nse = Σ C/Z	0.2044					
F3 = nse/nse X .01 + .01	16.9710					
CCME-WQI = $[100 - \sqrt{(F1^2 + F2^2 + F3^2)} / 1.732]$	34.0873					

CCME-WQI = 34.0873

Say, CCME-WQI = 34

As per Table 5.48, we can see that the CCME-WQI value in the year 2013 dated 01.04.2013 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.4 CCME-WQI for2014 :

Table: 5.49 Experiment date 04.04.2014 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 04.04.2014						
	Turbidity	Mg.	Total Alkalinity	Cl	Cal	Total Hardness
A	36.1	72.9	340	488.5	200	800
B	5	30	200	250	75	200
A/B	7.2200	2.43	1.7	1.954	2.6667	4
C=(A/B-1)	6.2200	1.43	0.7	0.954	1.6667	3
Σ C	13.9707					
F1 (Scope) = No. of failed variables/ Total No. of Variables X 100	85.7143					
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694					
nse = Σ C/Z	0.1426					
F3 = nse/nse X .01 + .01	12.4771					
CCME-WQI = $[100 - \sqrt{(F1^2 + F2^2 + F3^2)} / 1.732]$	34.4228					

CCME-WQI = 34.4228

Say, CCME-WQI = 34

As per Table 5.49, we can see that the CCME-WQI value in the year of 2014 dated 04.04.2014 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.5 CCME-WQI for2015 :

Table: 5.50 Experiment date 17.04.2015 (Cossipore Groundwater) CCME-WQI Method

CCME Method (COSSIPORE Groundwater) - 17.04.2015		
	Turbidity	Total Alkalinity
A	44.1	220
B	5	200
A/B	8.82	1.1
C=(A/B-1)	7.82	0.1
Σ C	7.92	
F1 (Scope) = No. of failed variables/ Total No. of Variables X 100	28.5714	
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76	
nse = Σ C/Z	0.0754	
F3 = nse/nse X .01 + .01	7.0138	
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	69.0746	

CCME-WQI = 69.0746

Say, CCME-WQI = 69

As per Table 5.50, we can see that the CCME-WQI value in the year of 2015 dated 17.04.2015 is in the range of 65-79 and the quality of water is classified as “Fair”. So, it is observed from the result that the quality of water is usually but occasionally threatened or impaired; conditions sometimes depart from desirable levels.

5.1.6.6 CCME-WQI for2016 :

Table: 5.51 Experiment date 15.04.2016 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 15.04.2016						
	Turbidity	Mg.	Total Alkalinity	Cl	Cal	T H
A	7.54	81.8	210	649.8	126.73	653.47
B	5	30	200	250	75	200
A/B	1.508	2.7267	1.05	2.5992	1.6897	3.2674
C=(A/B-1)	0.508	1.7267	0.05	1.5992	0.6897	2.2674
Σ C	6.8410					
F1 (Scope) = No. of failed variables/ Total No. of Variables X 100	85.7143					
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694					
nse = Σ C/Z	0.0698					
F3 = nse/nse X .01 + .01	6.5251					
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	34.7109					

CCME-WQI = 34.7109

Say, CCME-WQI = 35

As per Table 5.51, we can see that the CCME-WQI value in the year of 2016 dated 15.04.2016 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.7 CCME-WQI for 2017 :

Table: 5.52 Experiment date 20.04.2017 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 20.04.2017					
	Turbidity	Mg.	Cl	Cal	T H
A	7.58	80.19	599.81	124	640
B	5	30	250	75	200
A/B	1.516	2.673	2.3992	1.6533	3.2
C=(A/B-1)	0.516	1.673	1.3992	0.6533	2.2
Σ C	6.4416				
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	71.4286				
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694				
nse = Σ C/Z	0.0657				
F3 = nse/nse X .01 + .01	6.1676				
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	40.7310				

CCME-WQI = 40.7310

Say, CCME-WQI = 41

As per Table 5.52, we can see that the CCME-WQI value in the year 2017 dated 20.04.2017 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.8 CCME-WQI for 2017 :

Table 5.53 Experiment date 09.10.2017 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 09.10.2017				
	Mg.	Cl	Cal	T H
A	75.33	499.85	116	600
B	30	250	75	200
A/B	2.511	1.9994	1.5467	3
C=(A/B-1)	1.511	0.9994	0.5467	2
Σ C	5.0571			
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	57.1429			
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76			
nse = Σ C/Z	0.0482			
F3 = nse/nse X .01 + .01	4.5949			
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	58.0072			

CCME-WQI = 58.0072

Say, CCME-WQI = 58

As per Table 5.53, we can see that the CCME-WQI value in the year 2017 dated 09.10.2017 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.6.9 CCME-WQI for 2018:

Table: 5.54 Experiment date 10.04.2018 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 10.04.2018				
	Mg.	Cl	Cal	T H
A	75.33	649.8	116	600
B	30	250	75	200
A/B	2.511	2.5992	1.5467	3
C=(A/B-1)	1.511	1.5992	0.5467	2
Σ C	5.6569			
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	57.1429			
F2 = Total No. of failed Test/Total No. of Test (Z)	44.76			
nse = Σ C/Z	0.0539			
F3 = nse/nse X .01 + .01	5.1121			
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	57.9873			

CCME-WQI = 57.9873

Say, CCME-WQI = 58

As per Table 5.54, we can see that the CCME-WQI value in the year of 2018 dated 10.04.2018 is in the range of 45-64 and the quality of water is classified as “Marginal”. So, it is observed from the result that the quality of water is frequently endangered or deteriorated and deviated from the natural or desirable levels.

5.1.6.10 CCME-WQI for 2018 :

Table: 5.55 Experiment date 01.10.2018 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 01.10.2018					
	Turbidity	Mg.	Cl	Cal	T H
A	15.9	72	599.81	112	580
B	5	30	250	75	200
A/B	3.1800	2.4	2.3992	1.4933	2.9
C=(A/B-1)	2.1800	1.4	1.3992	0.4933	1.9
Σ C	7.3726				
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	71.4286				
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694				
nse = Σ C/Z	0.0752				
F3 = nse/nse X .01 + .01	6.9967				
CCME-WQI = [100 - $\sqrt{}$($F1^2 + F2^2 + F3^2$) / 1.732]	40.7003				

CCME-WQI = 40.7003

Say, CCME-WQI = 41

As per Table 5.55, we can see that the CCME-WQI value in the year of 2018 dated 01.10.2018 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.11 CCME-WQI for 2019 :

Table: 5.56 Experiment date 04.04.2019 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 04.04.2019						
	Turbidity	Mg.	Total Alkalinity	Cl	Cal	T H
A	217	88.79	368	549.83	169.23	788.46
B	5	30	200	250	75	200
A/B	43.4	2.9597	1.84	2.1993	2.2564	3.9423
C=(A/B-1)	42.4	1.9597	0.84	1.1993	1.2564	2.9423
Σ C	50.5977					
F1 (Scope) = No. of failed variables/ Total No. of Variables X 100	85.7143					
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694					
nse = Σ C/Z	0.5163					
F3 = nse/nse X .01 + .01	34.0501					
CCME-WQI = [100 - $\sqrt{}$(F1^2 + F2^2 + F3^2) / 1.732]	31.9194					

CCME-WQI = 31.9194

Say, CCME-WQI = 32

As per Table 5.56, we can see that the CCME-WQI value in the year of 2019 dated 04.04.2019 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.12 CCME-WQI for2019 :

Table: 5.57 Experiment date 18.10.2019 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 18.10.2019						
	Turbidity	Mg.	Total Alkalinity	Cl	Cal	T H
A	50.2	51.77	400	584.9	196.08	705
B	5	30	200	250	75	200
A/B	10.04	1.7257	2	2.3396	2.6144	3.525
C=(A/B-1)	9.04	0.7257	1	1.3396	1.6144	2.525
Σ C	16.2447					
F1 (Scope) = No. of failed variables/ Total No. of Variables X 100	85.7143					
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694					
nse = Σ C/Z	0.1658					
F3 = nse/nse X .01 + .01	14.2192					
CCME-WQI = [100 - $\sqrt{}$(F1^2 + F2^2 + F3^2) / 1.732]	34.3047					

CCME-WQI = 34.3047

Say, CCME-WQI = 34

As per Table 5.57, we can see that the CCME-WQI value in the year of 2019 dated 18.10.2019 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.13 CCME-WQI for2020 :

Table : 5.58 Experiment date 06.10.2020 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 06.10.2020						
	Turbidity	Mg.	Total Alkalinity	Cl	Cal	T H
A	13.4	30.97	420	699.78	168.63	549.02
B	5	30	200	250	75	200
A/B	2.68	1.0323	2.1	2.7991	2.2484	2.7451
C=(A/B-1)	1.68	0.0323	1.1	1.7991	1.2484	1.7451
Σ C	7.6050					
F1 (Scope) = No. of failed variables/ Total No. of Variables X 100	85.7143					
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694					
nse = Σ C/Z	0.0776					
F3 = nse/nse X .01 + .01	7.2013					
CCME-WQI = [100 - √($F1^2 + F2^2 + F3^2$) / 1.732]	34.6872					

CCME-WQI = 34.6872

Say, CCME-WQI = 35

As per Table 5.58, we can see that the CCME-WQI value in the year of 2020 dated 06.10.2020 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

5.1.6.14 CCME-WQI for2021 :

Table: 5.59 Experiment date 05.04.2021 (Cossipore Groundwater) CCME- WQI Method

CCME Method (Cossipore Groundwater) - 05.04.2021					
	Mg.	Total Alkalinity	Cl	Cal	T H
A	58.32	350	743.03	196	730
B	30	200	250	75	200
A/B	1.944	1.75	2.9721	2.6133	3.6500
C=(A/B-1)	0.944	0.75	1.9721	1.6133	2.6500
Σ C	7.9295				
F1 (Scope) = No. of failed variables/Total No. of Variables X 100	71.4286				
F2 = Total No. of failed Test/Total No. of Test (Z)	73.4694				
nse = Σ C/Z	0.0809				
F3 = nse/nse X .01 + .01	7.4856				
CCME-WQI = [100 - √($F1^2 + F2^2 + F3^2$) / 1.732]	40.6804				

CCME-WQI = 40.6804

Say, CCME-WQI = 41

As per Table 5.59, we can see that the CCME-WQI value in the year 2021 dated 05.04.2021 is in the range of 0-44 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; conditions usually depart from natural or desirable levels.

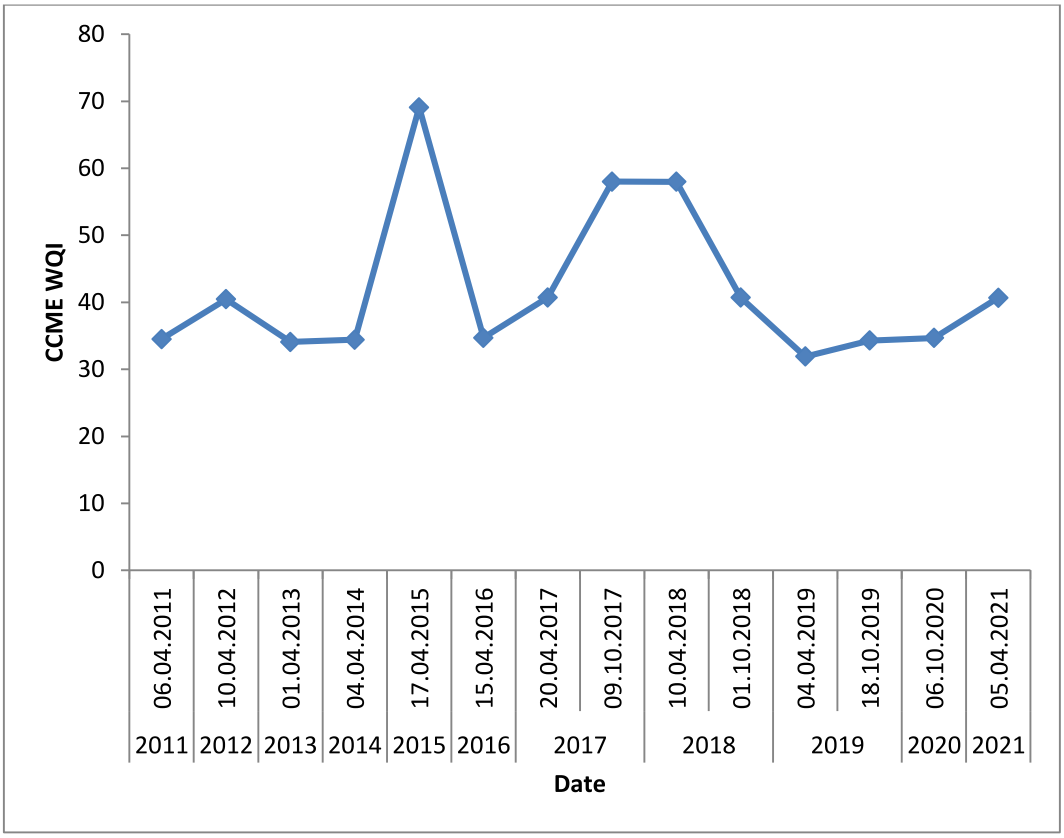

Fig. 5.4. Date-wise change of groundwater CCME-WQI for Cossipore.

CHAPTER VI

6.1 Conclusions

The quality of groundwater using physical, and chemical parameters are evaluated by this study. The groundwater collected by the West Bengal Pollution Control Board (WBPCB) from Garia and Cossipore in the month of April and October in eleven years in south and north Kolkata of West Bengal in India has been considered for this study. In this study, the groundwater quality data was collected from WBPCB two times each year, for eleven consecutive years (2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, and 2021). The Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI) and the Weighted Arithmetic Water Quality Index (WA-WQI) were applied in order to assess and compare the groundwater quality of the Garia and Cossipore. This study is also applicable to the water quality at the intake point of the Garia and Cossipore which are situated in the southern & northern parts of Kolkata.

➢Using the CCME-WQI method, the WQI values are estimated in the range of 0 to 44 ranking the groundwater quality as “Poor” and the range of 45 – 64 ranking the water quality as “Marginal”. As per the water quality characteristics given by CCME-WQI and thereby water quality is almost always threatened or impaired, and not suitable for drinking without treatment. For2011, the value is calculated as 64 on 04.04.2011 for Garia which is Marginal and 69 on 17.04.2015 for Cossipore which is “Fair” which is occasionally threatened or impaired; conditions sometimes depart from desirable levels.

➢The present study evaluated the groundwater quality for drinking and irrigation suitability by calculating the CCME-WQI. The Canadian WQI approach used for the development of site-specific objectives was chosen because of the limited amount of water quality data for each site. The seven physicochemical parameters were considered because these parameters define the ionic constituents present in water required for drinking and irrigation. The index scheme has been used to meet the requirements of the classification of groundwater according to BIS and FAO standards. The study confirms that groundwater quality is poor to fair and the majority of the samples fall in the marginal category for drinking in both seasons. From the irrigation point of view, quality is fair to good type however, 47 and 55% of samples are fair for irrigation in pre and post-monsoon season. The groundwater quality is significantly affected and found vulnerable in the pre-monsoon season due to intensive agriculture and anthropogenic inputs.

➢Applying the WA-WQI method, the value of WQI was observed in the range from ~344 to ~4770 for the years and for both monitoring stations mentioned. It indicates that the WA-WQI value of groundwater is always greater than 100 the water quality is indicated as Unfit for consumption. So, according to the WQI classes developed by Brown et al. (1972), the quality of groundwater can be categorised as "Unfit for consumption" and can only be consumed by humans after proper treatment. Although, there is a wide variation in lower and higher values of WA-WQI.

6.2 Future Scopes

Only eleven years of water quality parameters data have been considered for the above water quality study. If water quality parameters data for many more years will be considered, then the overall picture of the WQI values would be more prominent, and also changes in water quality and its parameters can be observed on a long-term basis.

➢Only seven parameters have been considered for this study. Many important data have not been considered during this water quality study. In the future, the target is to collect or analyze more water quality parameter data for evaluating the more accurate value of the water quality index. So, in the future, this study can portray a better picture if many more water quality parameters are considered during the study.

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