EVALUATION OF DRINKING WATER QUALITY IN RESTAURANTS OF GAZIPUR CITY USING WATER QUALITY INDICES AND MULTIVARIATE ANALYSIS

A THESIS WORK BY

RAKIBUL HASAN (160051010)

MD. SHAHRIAR HOSSAIN (160051012)

MD. RAHADUJJAMAN (160051080)

A THESIS SUBMITTED TO THE DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

ISLAMIC UNIVERSITY OF TECHNOLOGY, GAZIPUR.

EVALUATION OF DRINKING WATER QUALITY IN RESTAURANTS OF GAZIPUR CITY USING WATER QUALITY INDICES AND MULTIVARIATE ANALYSIS

A THESIS WORK BY

RAKIBUL HASAN (160051010)

MD. SHAHRIAR HOSSAIN (160051012)

MD. RAHADUJJAMAN (160051080)

A THESIS SUBMITTED TO THE DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

ISLAMIC UNIVERSITY OF TECHNOLOGY, GAZIPUR.

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE

OF

BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING

2021

PROJECT REPORT APPROVAL

It is hereby certified that the work presented in this thesis was carried out by the following final year students of session 2020-2021 under the direct supervision of Dr. Md. Rezaul Karim, Professor and Head of Department of Civil and Environmental Engineering (CEE), Islamic University of Technology, Gazipur, Dhaka.

Supervisor

Prof. Dr. Md. Rezaul Karim

Head of the Department

Department of Civil and Environmental Engineering

Islamic University of Technology, Gazipur, Dhaka.

DECLARATION

It is hereby declared that this entitled “Evaluation of drinking water quality in restaurants of Gazipur city using water quality indices and multivariate analysis” thesis/project report or any part of it has not been submitted elsewhere for the award of any Degree or Diploma (except for publication).

Rakibul Hasan	**Md. Shahriar Hossain**	**MD. Rahadujjaman**
Student ID: 160051010	Student ID: 160051012	Student ID: 160051080

Supervisor

Prof. Dr. Md. Rezaul Karim

Head of the Department

Department of Civil and Environmental Engineering

Islamic University of Technology, Gazipur, Dhaka

DEDICATION

WE WOULD LIKE TO DEDICATE THIS THESIS WORK TO OUR ***PARENTS AND FAMILY****.*
WE WANT TO SHOW OUR GRATITUDE FOR THEIR CONTINUOUS SUPPORT THROUGHOUT OUR LIFE.

WE ALSO WANT TO EXPRESS UTMOST RESPECT FOR OUR THESIS SUPERVISOR PROFESSOR DR. MD. REZAUL KARIM.

ACKNOWLEDGEMENTS

"In the name of Allah, Most Gracious, Most Merciful"

At first authors acknowledges the blessings of The Almighty, The Beneficent, and The Merciful for enabling him to complete the study successfully. This dissertation would not have been possible without the guidance and help of several individuals who, in one way or another, contributed and extended their valuable assistance in the preparation and completion of this study.

Authors owes his deepest and sincerest gratitude to Dr. Md. Rezaul Karim, Professor and Head of Department of Civil and Environmental Engineering, for his continuous encouragement, guidance and heartfelt efforts in explaining things articulately and his inspiration at every stage of this work.

Authors expresses his profound gratefulness to all the departmental faculty members for their assistance and support they have shown from the beginning.

Authors also like express their gratitude for their batchmates, especially Md. Tanvirul Islam for his continuous support and help to generating ArcMap.

Authors finally must express his gratitude to his parents who supported and encouraged him throughout his life and have given him the opportunity of receiving the finest education from one of the most renowned institutions in the country.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

Abstract

Groundwater is a vital source for drinking purposes in Gazipur area. In this present study, 173 samples are collected from different restaurants divided into 18 zones across Gazipur city area. Thirteen physicochemical parameters like pH, Color, Turbidity, DO, TDS, Cl(residual), F, Hardness as CaCO3, Fe, Mn, NO3, SO42-, NH3 are used for analysis. From these parameters DO, TDS, Mn, Hardness, pH value exceed the standard limit. These eighteen zones of Gazipur city are divided into three clusters as cluster I (8 zones), cluster II (2 zones), and cluster III (8 zones) by the homogeneity of samples. The dominant water types in Cluster, I is (Color-Iron-Nitrate-Ammonia) type of water, cluster II (Chlorine-Fluoride-Sulfate) type of water, and cluster III (Hardness-pH-TDS-DO-Turbidity) type of water. Three water quality Index models like Integrated Water Quality Index, Assigned Weight Water Quality Index, and Weighted Arithmetic Water Quality Index are used to evaluate Water quality. The IWQI and Weighted Arithmetic Water Quality Index reveal that 31% and 49% of the total sample mostly fall into the unsuitable category. But Assigned Weight Water Quality Index model categorized 2% of total samples as unsuitable. Pearson correlation matrix shows strong positive correlation between TDS-EC (0.987) has strong positive correlation and Color-Manganese (0.292) has moderate positive correlation in cluster I. In cluster II TDS-EC (0.994), Color-Manganese (0.704) show a strong positive correlation, but PH-color (-0.769), Fluoride-Nitrate (-0.828) shows negative correlation & there is no strong correlation in cluster III. In Cluster, I, Cluster II, Cluster III total cumulative variance can be explained 73.095%, 91.335% & 68.013% respectively by the result of factor analysis. Three Clusters' components eigenvalue is greater than 1 are respectively Cluster I (six factors), Cluster II (five factors) and Cluster III (six factors). The strong factor loadings in three Clusters are TDS, EC, Hardness, Color, Nitrate, Turbidity, Mn, Fluoride, Ammonia, Iron to contaminate the environment. Factor analysis predicts the source of groundwater pollution which consist of effluent from textile industries, combine mill, pharmaceutical industries, nitrogenous fertilizer in agricultural area, rock and water interaction in the study area. In future, Gazipur city will become more densely populated that will create more contamination in water. A high number of industries containing much population damaging surface water as well as ground water. It damages human health with the environment while drinking regularly. That's why we have tried to analyze the present scenario of drinking water of Gazipur region. Management and investigation of groundwater quality in a proper way helps to supply good quality of drinking water in the restaurants of Gazipur City.

CHAPTER ONE: INTRODUCTION

1.1 Background and Present scenario of the proposed topic:

In Bangladesh, the drinking water quality is at high risk and problems are even more severe in the urban areas (Sarker A., et. al., 2016). Gazipur is a major city which is full of industries in Bangladesh. It has an area of 1741.53 km^2. Gazipur (town) has 9 Wards and 31 Mahallas. The area of the town is 49.32 km^2. The town's population is 123,531; male 52.52%, female 47.48%; density is 2,505 per km^2. The environment is deteriorating day by day due to its high population. Water is a vital material not only for drinking but also for other activities. But, most of the people are not getting these facilities. Both households and restaurants in this region are lake of safe drinking water. The restaurants do not purify the water properly. They used to supply the ground water directly without purification. The tendency of industrialization and urbanization may contribute greatly to the poor quality of water through indiscriminate disposal of solid waste, industrial effluents and other toxic wastes which are the major environmental issues posing threats to the existence of human being (Islam, Tusher, Mustafa & Mahmud, 2013). Chemical contaminants pose a great public health risk which may have immediate health consequences (Akter et al., 2016). Therefore, the people who are living in this region facing an unhygienic situation.

That's why it is become a burning issue to analyze, judge & find the solution of water related problem. It is not only damaging human health but also destroying our ecosystem as well as environment.

1.2 Objectives of the study:

We tried to analyze drinking water in Gazipur city restaurant. It will help us to minimize the damage of human & environment in Gazipur region. The objective of our study is to find some goals. That is:

- To know the present condition of drinking water in Gazipur city by using different methods.
- Comparison among the weighted arithmetic WQI method, Integrated Water Quality Index Method & Assigned Weight Water Quality Index Method.
- Principle component analysis (PCA) to predict the sources of groundwater pollution happening in Gazipur region.

- To know the dominant parameters showing similarities in some region cluster analysis is applicable.
- To perform Pearson correlation so that we can understand the relationships among the regions in different clusters. It will help us in finding solution.

1.3 Significance of the Study:

The study will help us to know the present scenario of Gazipur city restaurant. The actual reason of health hazard in this region due to having contaminated water will be known. The variation of physical, chemical properties among different locations water will be understood. It will help us to know the basic ecological scenario of Gazipur city. Variation and changes around zones with proper reasoning will provide a clear idea about drinking water quality as well as ground water quality. Ground water plays a vital role in water demand & use cycle. If Ground water become contaminated, the water related diseases will increase tremendously. So, we need to know the reasons, victims & possible ways of contamination. Water Quality Index (WQI) analysis will help us to provide a clear knowledge about present condition of SW & GW. Cluster analysis will help us to the possible similarities among the regions regarding physical & chemical properties. It will help us to find the solution. It will also create a scope to use a particular mechanism to solve the problem segmentally. Pearson correlation will show the linkage & similarities among clusters. PCA analysis will help us to understand the situation clearly. Therefore, our analysis will give an overview & a solution to solve the problem related to drinking water in Gazipur city.

1.4 Limitations:

Though we have done the research in the best possible way, there are some limitations. It happens due to pandemic situation of COVID19. We have tried to minimize it taking various steps. But there are some limitations still remaining. They are:

- We have done the research during COVID19 period. Due to this we got less time to visit the locations physically.
- We haven't taken the data across whole restaurant in Gazipur region due to pandemic situation.
- A higher value of differences has found out in data set among three methods of WQI (the weighted arithmetic WQI method, Integrated Water Quality Index Method & Assigned Weight Water Quality Index Method).
- Pearson correlation shows less similarities than the desired value.

CHAPTER TWO: LITERATURE REVIEW

2.1 Previous study

Evaluation of water quality using water quality index (WQI)method and GIS in Aksu River (SW-Turkey).

The goal of this study is to determine the water quality of the Aksu River. The overall Water Quality Index defines the lake as good water quality. In the calculation of WQI they found that COD and Mg are the most important water quality parameters. In this analysis, 42 water samples were collected from 21 locations selected during the wet and dry period to evaluate the water quality of the Aksu River. In Pearson linear correlation matrix between Cl and SO4, Na, COD, and Cr; SO4 with COD, NO2, and Cr; Na with COD, NO2; COD with NO2, Cr. Chloride and sulfate indicates very strong positive correlations and the values are substantially associated with pollutant parameters by the correlation coefficient. They also found that effluent from leather industries, marble factories are the main pollutant source of Aksu river. In dry and wet period, the range of water quality index value are respectively 35.6133 to 337.5198 and 32.1063 to 304.3386. But the northern and southern part of river basin water quality is poor and very poor respectively. (Şener, Şener and Davraz, 2017).

An application of the Water Quality Index (WQI) and multivariate statistics to evaluate the water quality around Maddhapara Granite Mining Industrial Area, Dinajpur, Bangladesh.

The main purpose of this study is to assess the hydro-chemical properties to evaluate the water quality and also find the pollutant source of surface and ground water at Maddhapara Granite Mining Industrial Area. There are 31 samples that are grouped into three clusters. They found that the percentages of groups for three clusters respectively Cluster I (70.97%), Cluster II (22.58%), Cluster-III (6.45%) of the overall water sample. By the result of factor analysis five factors explained the total variance of 75.89%. The strong loading components predict that dissolution of ions, weathering rocks and anthropogenic activities are the main source for pollution. In the analysis of Water Quality Index found that 96.77 %of the water samples were of excellent quality and 3.23% of the water samples were of good quality. Cluster I was shown to be of the best quality water from the three clusters and then Cluster II and Cluster III sequentially. (Howladar, Al Numanbakth, and Faruque, 2017).

Water Quality Index for measuring drinking water quality in rural Bangladesh: a cross-sectional study.

In order to enhance public health, the study aims to raise awareness of the chemical content of drinking water at the household level. Water Quality Index (WQI) is considered as the most effective method of categorize water. A number of water quality parameters are included in a mathematical equation to rate water quality, determining the suitability of water for drinking. There are 542 samples are collected from 293 households for water quality index analysis. From the overall sample size, the majority (67%) had poor quality drinking water (WQI>100) and 33% of good quality drinking water (WQI<100). In that region, most of the people use poor quality drinking water. They found that higher values of arsenic, manganese, and iron are the reasons for decreasing water quality Approximately half of the households exceeded reasonable manganese exposure acceptable limit when considering Bangladeshi standards**.** (Akter et al., 2016).

Coupled multivariate statistical analysis and WQI approaches for groundwater quality assessment in Wadi El-Assiuty downstream area, Eastern Desert, Egypt.

The study aims to evaluate the pollutant sources and quality of Groundwater. They collected 48 groundwater samples for analysis the quality of groundwater by using 12 physicochemical parameters. They found that three factors define the quality of groundwater in the study area by using factor analysis and cluster analysis define two distinct clusters by the homogeneity of samples. In order to distinguish the source of the difference in water quality and evaluate the of groundwater deterioration, multivariate statistical analysis was used. The resulting WQI showed that about 54% of the groundwater samples collected were of good quality for human consumption. The degradation of water quality in most regions of the study area was oxidation, ion exchange, precipitation, and reduction process because of high concentration of Na+, Ca2+, TDS, and Cl-. (Masoud and Ali, 2020).

The water quality and pollution sources assessment of Surma river, Bangladesh using, hydro-chemical, multivariate statistical, and water quality index methods.

The purpose of the study is to assess 14 water quality parameters such as turbidity, TS, TSS, TDS, hardness, iron, DO, BOD, COD, alkalinity, water pH, conductivity, chloride, and CO2. They found that improper management of drainage system and solid waste are the main reason for degrading water quality of Surma river. Most of the water samples of BOD, COD, Turbidity, TSS, and CO2 were cross the standard limit. The most common statistical analysis that are widely used to identify the dominating components and sources that explain the variations in the water quality and their impacts on water environments are hierarchical cluster analysis, principal component analysis (PCA), correlation matrix analysis. The Water Quality Index (WQI) analysis has found that most of the water samples are of poor quality. In factor analysis, five factors explained the overall variance of 78.8 percent. TDS, DO, BOD, COD, pH, and turbidity are the highest factor loading values identified as a significant environmental contaminant. Analysis and observation show that human waste, sewage contamination, land runoff, organic pollutants, and agricultural practices mainly impact the quality of river water. (Howladar et al., 2021).

An assessment of groundwater quality for irrigation and drinking purposes around brick kilns in three districts of Balochistan province, Pakistan, through water quality index and multivariate statistical approaches.

The purpose of the study is to evaluate three districts of Balochistan ground water quality for drinking and irrigation purposes. The groundwater quality was assessed through twenty-two physiochemical parameters using standard protocols. The results of the study showed that analyzed physicochemical parameters were found above the permissible limits of WHO with few exceptions. They found that the study area of the water quality is poor by the calculation of water quality index (WQI). The dominance of the major cations and anions patterns are Na+ >Mg2+>Ca2+>K+ andHCO3 - >SO4 2- >Cl- >Fa. Correlation matrix shows there is strong positive and negative correlation between different parameters of sample. Factor analysis predicts the pollutant source in groundwater and cluster analysis define different distinct cluster by the homogeneity of parameters. The results of these statistical methods for multivariate analysis also showed the contribution of both natural and anthropogenic activities to the study's change the groundwater hydrochemistry. (Khanoranga and Khalid, 2019).

Development of new integrated water quality index (IWQI) model to evaluate the drinking suitability of water.

This study shows how Water Quality Index (WQI) can be found out more accurately having less limitations. Ordinary method considers either permissible limit or desirable limit. So, much confusion remains and gives less accurate result. To evaluate Water quality indices there are several methods which has their own weaknesses and limitations. There is a need to develop a universally accepted water quality index (WQI) which is flexible enough to represent drinking water suitability all over world. That’s why a new method has been developed named as Integrated Water quality Index (IWQI) considering both permissible limit & desirable limit. It is more accurate in result having less limitations. Based on this concept, IWQI has been classified into 5 categories viz. excellent (< 1), good (1–2), marginal (2–3), poor (3–5) and unsuitable (> 5); depends on the concentration of cations (Ca, Mg, Na and K), anions (Cl, SO4 and NO3) and other parameters (pH, TDS) present in groundwater samples. The result reveals that 2% samples excellent for drinking, 39% good, 43% marginal, 8% poor and 8% unsuitable for drinking. The results are obtained at 20% deficit of its maximum permissible limit and can be adjusted per user need to alert water managers of possible human health concerns with drinking water. The water quality is degrading day by day due industrial & agricultural input into the water aquifer system and ground water contamination. Therefore, IWQI method is more accurate and unbiased than other types**.** (Mukate et al., 2019).

Development of a water quality index (WQI) for the Loktak Lake in India.

This paper examined the water quality index (WQI) of the Loktak river. This wetland has been under pressure due to increasing anthropogenic activities. Some physiochemical parameters are temperature (Tem), potential hydrogen (pH), electrical conductivity (EC), turbidity (T), dissolved oxygen (DO), total hardness (TH), calcium (Ca), chloride (Cl), fluoride (F), sulphate (SO2_4), magnesium (Mg), phosphate (PO3_ 4), sodium (Na), potassium (K), nitrite (NO2) nitrate (NO3), total dissolved solids (TDS), total carbon (TC), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) taken to calculate the WQI. The result is compared with WHO standard and Bureau of Indian standards for understanding its validity. It is seen that the concentration of nitrite is higher and it crosses permissible limit. The WQI value was found around 64 to 77 which indicates that this lake water is not fit for human & animal in case of drinking. Physiochemical parameters like DO, EC, nitrite, and COD are the main reason for high value of water quality index. But people living in this region uses this water for drinking and other purposes. That's WQI analysis of this region is too important to detect, mitigate & control the problem of this region regarding water uses. This method uses weightage value for different parameters according to its importance. It is from 1.46 to 4.09. That's why WQI value using this method gives a satisfactory result. (Das Kangabam, Bhoominathan, Kanagaraj and Govindaraju, 2017).

Assessment of drinking water quality characteristics and quality index of Rajshahi city, Bangladesh

The aim of the study is to analyzed 116 ground water sample collected in pre & post monsoon period in 2014 & 2015 in the drought-prone Rajshahi City Corporation area, Bangladesh. It is done to judge the drinking suitability from management perspective. According to the Bangladesh Drinking. Water Standards (2005), parameters like pH, Ca2+, Mg2+, Cl−, Fe(total) and Mn2+exceed the desirable limit, but within permissible limit without adverse effect except Mg2+ concentration, which accounts for 45% in pre-monsoon period and makes groundwater unsafe for drinking purposes. The ground water contains alkaline earth elements (Ca^{2+}+ Mg^{2+}) and exceed alkali elements (Na^{+}+K^{+}). Again, weak acids ($HCO3^{-}$) exceed the strong acids ($SO4^{2-}$) where Ca^{2+} and $HCO3^{-}$ are dominant ions, and attribute to temporary hardness of groundwater. The groundwater of the aquifer is of (Ca^{2+}, Mg^{2+}, $HCO3^{-}$) type. Cluster analysis define three types of water Fe, Mn, K and NO3 or iron-type water (Type I), Na, Mg and SO4 or sodium-type water (Type II) and Ca and Cl or calcium-type water (Type III). Most of the ground water of this region falls into good category. But with change of time and increasing rate of population can change the quality of water in a negative way. That's why we need take mitigation measure and long-term plan to control it. (Rahaman et al., 2019)

Evaluation of the groundwater quality with WQI (Water Quality Index) and multivariate analysis: a case study of the Tefenni plain (Burdur/Turkey)

This study examined groundwater quality, seasonal variations and its suitability for drinking, irrigation and industrial usage. Mostly the agricultural & domestic use of water depends on ground water in Tefenni plain. That's why 56 samples were taken from wells, lakes, springs to examine. From the result of water quality index, they found that during dry and wet season 89.28% of groundwater samples are excellent. Factor analysis predicts that water-rock interaction and non-point pollution source are the main reason for groundwater pollution. From the water quality index, they found that Ca–Mg–HCO3, Mg–Ca–HCO3, Na–CO3–Cl, and Na–HCO3–Cl water types are the dominant water types in this investigation area. R mode factor and correlation analysis was done to analyze the chemical variation. According to R-mode factor analysis, total dissolved solids, Na, Cl, HCO3, and NH3 are the most important parameters. Again, Water Quality Index (WQI) was applied to understand the suitability for drinking purpose & investigation of ground water quality. Variation between dry & wet season was examined too. (Varol and Davraz, 2014)

2.2 Different methods of evaluating WQI

In previous studies only one method of WQI is used for evaluating water quality. Most of the studies use assigned weight water quality index and Weighted Arithmetic Water Quality Index for assessing water suitability. In our studies we use three methods of water quality index like integrated water quality index, assigned weight water quality index and Weighted Arithmetic Water Quality Index methods. As a result, we compare the results of three methods and get to know their weakness and limitation of their method. The concentration of any parameter below desirable limit as well as above permissible limit will contribute to the overall increase in the index value; therefore, the index is called as Integrated Water Quality Index (IWQI) (Mukate et al., 2019). IWQI and Weighted Arithmetic method shows 49% and 31% of total samples goes under unsuitable category. But only 2% of total sample goes under in assigned weight water quality index. So, we find that assigned Weight Water Quality Index method shows different results than other methods. In this method, we assigned weight by the significant of the parameters and it creates biasness among other methods. By comparing different methods of water quality index, we find more accurate results from previous studies.

2.3 Multivariate analysis

The most common statistical analysis that are widely used to identify the dominating components and sources that explain the variations in the water quality and their impacts on water environments are hierarchical cluster analysis, principal component analysis (PCA), correlation matrix analysis (Howladar et al., 2021). In our studies we use factor analysis for knowing the pollution source of ground water which consist of effluent from textile industries, combine mill, pharmaceutical industries, nitrogenous fertilizer in agricultural area, rock and water interaction in the study area. Pearson correlation matrix shows strong positive correlation and strong negative correlation between parameters in our study. We find three cluster in our study area (18 zones) and these eighteen zones of Gazipur city are divided into three clusters as cluster I (8 zones), cluster II (2 zones), and cluster III (8 zones) by the homogeneity of samples.

CHAPTER THREE: STUDY AREA AND DATA COLLECTION

3.1 General

It is too much important to select a perfect location for analysis of the research project. It will help us to get the results & solutions in an accurate way. Otherwise, efficiency of the research will not become satisfactory.

3.2 Study Area

Gazipur is a major city which is full of industries in Bangladesh. It has an area of 1741.53 km2. Gazipur (town) has 9 Wards and 31 Mahallas. The area of the town is 49.32 km2. The town's population is 123,531; male 52.52%, female 47.48%; density is 2,505 per km2 ("Gazipur District", 2021). We have taken 18 separate locations for studying situated beside the highway. Basically, we have tried to examine the Drinking water. That's why restaurant water is taken as our data sample. The area is selected in such a way that all the territory of Gazipur city can be covered. We have tried to show all the covered & uncovered locations in a ArcMap which will give a better understanding.

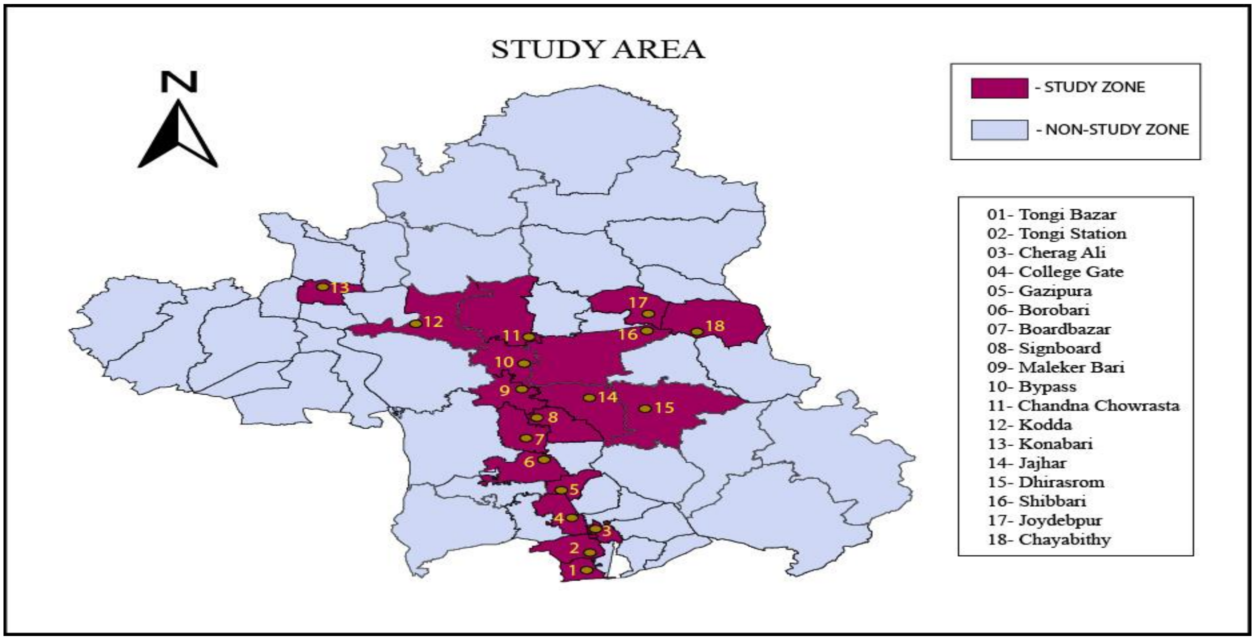

Figure 1 Study Area

3.3 Data Collection

The data has been collected from previous study titled DRINKING WATER QUALITY SERVED IN RESTAURANTS AND TEA STALLS IN GAZIPUR AREA.

CHAPTER FOUR: METHODOLOGY

4.1 General

This section of the book will discuss about detailed step by step procedure of work that has been carried out. The whole process has been divided into several phases:

- Hierarchical Cluster Analysis
- Water Quality Indices using different models
- Pearson correlation matrix
- Factor analysis

4.2 Hierarchical Cluster Analysis

Hierarchical cluster analysis combines cases one at a time into homogenous clusters in a series of sequential steps (Hand, 2010). In each step either new cluster is formed or previously grouped clusters are joined by one case (Yim & Ramdeen, 2015). Hierarchical clusters can be agglomerative and divisive. In the first step in agglomerative approach each case is separated into its own individual clusters ((Norusis, 2007)). Finally, one single cluster is formed by grouping together similar cases or clusters.

4.2.1 Distance Measure

To calculate similarities or distance between cases a statistic must be determined. Distance measure is most commonly used for cluster analysis as it will be an assessment for pattern (Yim & Ramdeen, 2015).

Squared Euclidian distance is the most commonly used distance measure for continuous variables (Yim & Ramdeen, 2015).

The Euclidean distance, $\sum_{i=1}^{k}(a_i - b_i)^2$ (Srivastava & Sahami, 2009).

Here a and b are two cases which are being compared on the variable I, whereas k being the total number of variables that are included in the analysis (Srivastava & Sahami, 2009).

4.2.2 Linkage Measure

As clusters contains more than one cases and Euclidian distance can be can be calculated between pairs, there must be a accurate way to calculate distance measure between pairs of clusters containing more than one cases for each variable. Linkage between clusters is the best way to find the clusters that are nearest to each other and can be merged together. There are several linkage measures which define distance between pars in their own way (Yim & Ramdeen, 2015).

4.2.3 Ward's method

In hierarchical cluster analysis ward's method is an applied criterion. Joe. H Ward presented ward's minimum variance method as a case of special objective function (Ward, 1963). Ward explained a general agglomerative hierarchical clustering method where cluster pairs are chosen as an optimal value of objective function (Ward, 1963). Defining this objective as the error sum of squares is known as ward's minimum variance method.

4.2.4 The minimum variance criterion

Euclidian distance between points is considered as the first cluster distance in Ward's method,

$$d_{ij} = d(\{X_i\}, \{X_j\}) = \|X_i - X_j\|^2$$

4.2.5 Lance Williams algorithms

Recursive Lance Williams algorithm can define and implement ward's minimum variance method. For updating clustering distances in each step recursive Lance William algorithm is an infinite family of agglomerative clustering algorithm (Murtagh & Legendre, 2014). Optimizing the objective function in each step is a necessary.

Let, C_i and C_j are two clusters. They need to be merged together. All current pairwise distances are known. Updated cluster distances pending the merge of clusters C_i and C_j can be given by the recursive formula.

Again, let, pairwise distance between C_i, C_j *and* C_p are d_{ij}, d_{ip} *and* d_{jp} , respectively and $d_{(ij)p}$ is the distance between the clusters $C_i \cup C_j$ and C_p.

Updated cluster distance $d_{(ij)p}$ can be calculated by recursive Lance William algorithm as,

$$d_{(ij)p} = \alpha_i d_{ip} + \alpha_j d_{jp} + \beta d_{ij} + \gamma |d_{ip} - d_{jp}|$$

Where $\alpha_i, \alpha_j, \beta, and\, \gamma$ are parameters depended on cluster size with distance function d_{ij} determines the cluster algorithm.

Now, Lance Williams formula can implement ward's minimum variance method (Murtagh & Legendre, 2014). If clusters C_i, C_j *and* C_p are disjoined with sizes n_i, n_j and n_p respectively:

$$d(C_i \cup C_j, C_p) = \frac{n_i + n_p}{n_i + n_j + n_p} d(C_i, C_p) + \frac{n_j + n_p}{n_i + n_j + n_p} d(C_j, C_p) - \frac{n_p}{n_i + n_j + n_p} d(C_i, C_j).$$

Hence Lance William algorithm can implement Ward's method with

$$\alpha_i = \frac{n_i + n_p}{n_i + n_j + n_p}, \quad \alpha_j = \frac{n_j + n_p}{n_i + n_j + n_p}, \quad \beta = -\frac{n_p}{n_i + n_j + n_p}, \quad \gamma = 0$$

Hierarchical Cluster Analysis has been done Using IBM SPSS 25.

4.3 Water Quality Index (WQI)

Water Quality Index is a technique of rating which defines overall quality of water by considering cumulative influence of individual water quality parameters (Reza & Singh, 2010). Water Quality Index (WQI) is best method to evaluate water quality. A number of water quality parameters are included in a mathematical equation to rate water quality, determining the suitability of water for drinking (Akter et al., 2016). To evaluate Water quality indices there are several methods which has their own weaknesses and limitations. There is a need to develop a universally accepted water quality index (WQI) which is flexible enough to represent drinking water suitability all over world (Mukate et al., 2019). Relying on parameters selection, common scale transformation i.e., sub-index values, weights assignment and subindices aggregation, many water quality indices were generated since 1965 (Mukate et al., 2019).

General Water quality index can be described in the following steps:

- Selection of water quality parameters which are to be used for analysis.
- Common scale transformation of the raw parameters.
- Allocation of relative weights to the index components.
- Aggregate function is specified with controlled sampling design of the water quality monitoring data.

This study has taken three methods or models into consideration. Weighted water quality index method, Universal water quality index method and integrated water quality index method are three methods that has been considered to evaluate water quality. A total of thirteen physicochemical parameters viz., pH, Color, Turbidity, DO, TDS, Cl(residual), F, Hardness as CaCO3, Fe, Mn, NO3, SO42-, NH3 are used for determining water quality indices. The analysis was based on desirable limits (DL) and permissible limit (PL) defined by Bangladesh Drinking Water Standard (BDWS 2005).

4.3.1 Weighted Arithmetic Water Quality Index Method (WAWQI)

Weighted arithmetic water quality index method is the most used water quality index method studies all around the world. Here Subindex value can be calculated using Eq. 2.1.1

Q_i = Subindex for ith parameter, then,

$Q_i = \frac{V_i}{S_i} \times 100$……… (2.1.1) where V_i is the monitored concentration of ith parameter and S_i represents the recommended standard value of the ith parameter according to Bangladesh Drinking Water Standards (BDWS 2005).

Now, unit weightage w_I can be calculated using Eq. 2.1.2

$w_i = \frac{k}{s_i}$……………… *(2.1.2)*,

Here, k =proportionality constant and $k = \frac{1}{\sum\left(\frac{1}{s_i}\right)}$

Now, Weightage W_i can be calculated using Eq. 2.1.3

$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$……………… *(2.1.3)*

Overall WQI, $WQI = \sum W_i \, Q_i$

Table 1 Determination of weightage

Parameters	**DL**	**PL**	**1/Si**	**wi**	**Wi**
pH	6.5	8.5	0.117647	0.006034	0.006034
Color	0	15	0.066667	0.003419	0.003419
Turbidity (NTU)	0	25	0.04	0.002052	0.002052
DO	0	6	0.166667	0.008549	0.008549
TDS	0	1000	0.001	5.13E-05	5.13E-05
Cl(residual)	0	0.2	5	0.256457	0.256457
Fluoride	0	1	1	0.051291	0.051291
Hardness (CaCO3)	200	500	0.002	0.000103	0.000103
Fe	0.3	1	1	0.051291	0.051291
Mn	0	0.1	10	0.512913	0.512913
Nitrate	0	10	0.1	0.005129	0.005129
Sulfate	0	400	0.0025	0.000128	0.000128
Ammonia	0	0.5	2	0.102583	0.102583
Sum			19.49648	1	
$k = \frac{1}{\sum\left(\frac{1}{S_i}\right)}$			0.051291		

All values are expressed in mg/l except Turbidity (NTU) and pH on scale

Table 2 Categorization of water quality

WQI Value	Rating of Water Quality
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
> 100	Unsuitable

4.3.2 Integrated Water Quality Index (IWQI)

Integrated water quality index is a comprehensive and unbiased water quality index for water resources based on physicochemical parameters and it associates with existing drinking water quality standards (Mukate et al., 2019).

4.3.2.1 Calculation of Integrated water quality index

Integrated water quality index can be calculated in 5 steps. These steps are described in the following:

Step 1: Selection of parameters

A total of 13 physiochemical parameters viz., pH, Color, Turbidity, DO, TDS, Cl(residual), F, Hardness as CaCO3, Fe, Mn, NO3, SO42-, NH3 were selected to evaluate drinking quality by using IWQI. The analysis was based on desirable limits and permissible limit defined by Bangladesh Drinking Water Standard (BDWS 2005).

Step 2: Range Calculation

Desirable Limit (DL) and permissible limit which was defined by Bangladesh Drinking Water Standard (BDWS 2005) according to their threat to public health was used to calculate range. Values of range was calculated by this Eq. 2.2.1

Range = Permissible Limit (PL) – Desirable Limit (DL)……. (2.2.1) (Mukate et al., 2019).

The calculated values of range of selected parameters along with DL, PL are represented in Table 3.

Table 3 Range of selected parameters along with DL, PL

Parameters	DL	PL	Range (PL-DL)
pH	6.5	8.5	2
Color	0	15	15
Turbidity (NTU)	0	25	25
DO	0	6	6
TDS	0	1000	1000
Cl (residual)	0	0.2	0.2
Fluoride	0	1	1
Hardness (CaCO3)	200	500	300
Fe	0.3	1	0.7

Mn	0	0.1	0.1
Nitrate	0	10	10
Sulfate	0	400	400
Ammonia	0	0.5	0.5

All values are expressed in mg/l except Turbidity (NTU) and pH on scale

Step 3: Modified Permissible Limit computation

Modified permissible limit was calculated in Eq. 2.2.2 as difference between permissible limit and 15% deficit of the range calculated in Table 4 (Mukate et al., 2019).

Modified Permissible Limit (MPL) = Permissible Limit (15%Range) …… (2.2.2) (Mukate et al., 2019).

Table 4 Values of MPL

Parameters	Permissible Limit	Modified PL (MPL) (15% deficit to original)
pH	8.5	8.2
Color	15	12.75
Turbidity (NTU)	25	21.25
DO	6	5.1
TDS	1000	850
Cl (residual)	0.2	0.17
Fluoride	1	0.85
Hardness (CaCO3)	500	455
Fe	1	0.895
Mn	0.1	0.085
Nitrate	10	8.5
Sulfate	400	340
Ammonia	0.5	0.425

All values are expressed in mg/l except Turbidity (NTU) and pH on scale

Step 4: Calculation of Sub-indices (SI)

Any concentration of parameters below or above DL and PL respectively, deteriorates water quality heavily. Any concentration of parameters between DL and PL are considered excellent for water quality. So, concept of integrated water quality is based on these facts shown on Figure 2.

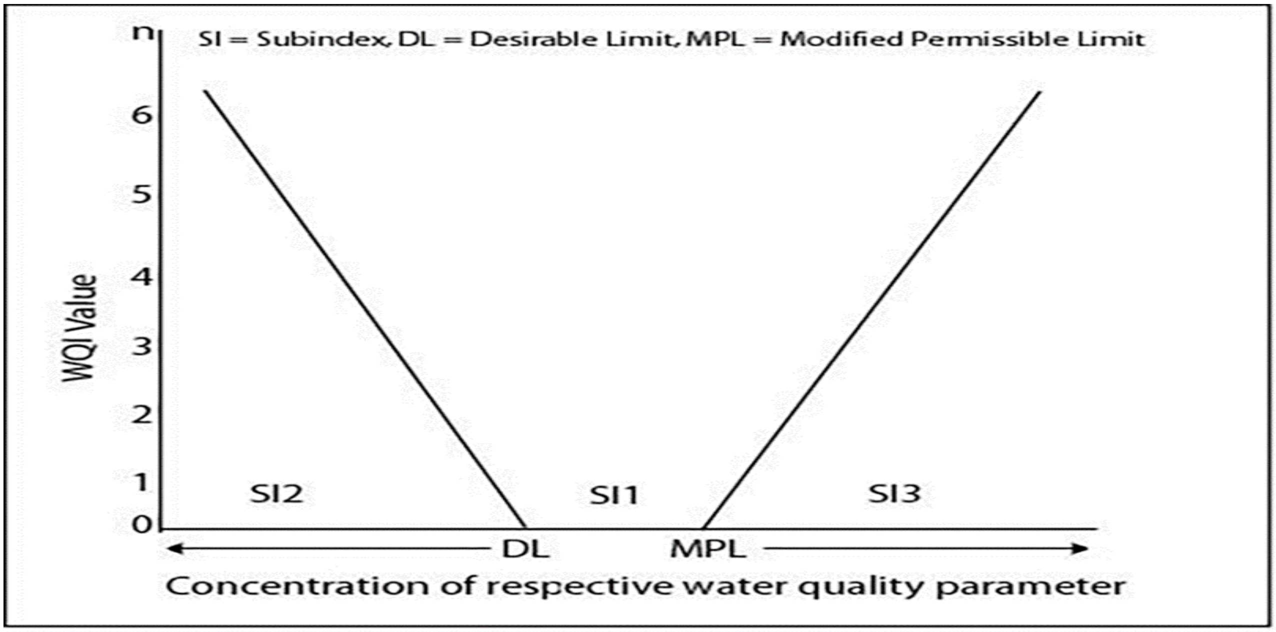

Figure 2 The conceptual Integrated Water Quality Index (IWQI) model (Mukate et al., 2019).

Now if monitored value of ith parameter, V_i is between DL and MPL i.e., DL ≤ V_i ≥ MPL then,

$SI_1 = 0$ ……… (2.2.3)

Again When $V_i \leq$ DL

$SI_2 = \frac{(DL - V_i)}{DL}$, …… (2.2.4)

Lastly When, $V_i \geq$ MPL

$SI_3 = \frac{(V_i - MPL)}{PL}$, When, $V_i \geq$ MPL …… (2.2.5)

Where, SI = Sub-Index Value, V_i = Monitored value of ith parameter

Step 5: Determination of IWQI

Final Integrated water quality index of ith sample can be calculated by summing up all sun-indices value acquired from Eq. 2.2.3 to 2.2.5. So,

$IWQI_i = \sum_{j=1}^{n} SI_{ij}$, Where SI_{ij} = Sub-index of jth parameter of ith sample

Finally, Water quality can be evaluated through IWQI values according to Table

Table 5 Categorization of water quality

WQI Value	Rating of Water Quality	Explanation
< 1	Excellent	Excellent for Drinking
1 to 2	Good	Good for Drinking
2 to 3	Marginal	Acceptable for Domestic
3 to 5	Poor	Not Suitable for Drinking
> 5	Unsuitable	Unsuitable for Drinking

4.3.3 Water Quality Index (Assigned Weight Method)

It is one of the widely used method of water quality index. Different weights are assigned to selected parameters. The WQI can be calculated in following steps:

Step 1:

The weight is assigned to the 13 parameters which were selected for WQI analysis. The weights are ranged from 1.46 to 5 according to their importance. But some of the weights are assigned from previous studies (Yadav et al., 2010) (Ramakrishnaiah et al., 2009) (Mohanty 2004). The mean values were taken as assigned weight. And rest of them were assigned according to their role in influencing quality of water. The assigned weight of 5 means most significant parameter and lowest value 1.46 means least significant parameter.

Then relative weight of selected parameters was calculated by Eq. 2.3.1

$$RW_i = \frac{AW_i}{\sum_{i=1}^{n} AW} \qquad (2.3.1)$$

Where, AW_i= Assigned of ith parameter, RW_i = Relative weight of ith parameter, n = Number of selected parameters for analysis.

The assigned weight values and relative weight values are presented in Table 6.

Table 6 Assigned weight values and relative weight values

Parameters	**Standard**	**Assigned Weightage (AWI)**	**Relative Weight**
pH	8.5	2.54	0.053575
Color	15	4	0.08437
Turbidity (NTU)	25	3	0.063278
DO	6	4.09	0.086269
TDS	1000	2.75	0.058005
Cl(residual)	0.2	4	0.08437

		4	
Fluoride	1		0.08437
Hardness (CaCO3)	500	1.46	0.030795
Fe	1	4	0.08437
Mn	0.1	5	0.105463
Nitrate	10	2.57	0.054208
Sulfate	400	5	0.105463
Ammonia	0.5	5	0.105463

Step 2:

Now Quality rating scale Q_i can be calculated using Eq. 2.3.2

$Q_i = \frac{V_i}{S_i} \times 100$……… (2.3.3) where V_i is the monitored concentration of ith parameter and S_i represents the recommended standard value of the ith parameter according to Bangladesh Drinking Water Standards (BDWS 2005).

Step 3:

Sub-indices value can be calculated using Eq. 2.3.3

$SI_i = W_r \times Q_i$……………………………… (2.3.3)

Where, SI_i = Sub-index value of ith parameter, W_r = Relative weight of ith parameter and Quality rating scale Q_i.

Finally, $WQI = \sum SI_i$

Now they are several scales available to rate or class water quality based on WQI value. These studies are presented in Table calculated value of WQI were rated according to most recent study by (Yadav et al., 2010).

Table 7 Different Scale of Water Quality Index (Assigned Weight Method)

WQI Mohanty (2004)	WQI (Yadav et al., 2010)	WQI (Ramakrishnaiah et al., 2009)	Rating of Water Quality
<50	<50	0-25	Excellent
50-100	50-100	26-50	Good
100-200	100-200	51-75	Poor
200-300	200-300	76-100	Very Poor

>300	>300	> 100	Unsuitable

Calculated value of WQI were rated according to most recent study by Yadav et al., 2010.

4.4 Pearson's Correlation Coefficient (r)

Pearson's correlation is a statistical measure of linear correlation between two variables. Karl Pearson developed this correlation technique between variables. The correlation coefficient is donated by r.

If x, y are two variables, and both variables contain n pair of values, then Pearson's correlation coefficient can be calculated by Eq 3.1

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

Where, r values are ranged from -1 to 1. Here, +1 means strong positive correlation and -1 being strong negative correlation. Whereas 0 means no correlation between x and y.

4.5 Principle Component Analysis (PCA) and Factor Analysis (FA)

Principle component analysis is a multivariate analysis which is a very power technique. It can recognize pattern and explain variance of large set of variables (intercorrelated) (Bu, Tan, Li and Zhang, 2009). Then it can transform these variables into smaller set of independent variables (Bu, Tan, Li and Zhang, 2009). Now it can be calculated as:

$$\boldsymbol{Z_{ij} = a_{1j}X_{1j} + a_{2j}X_{2j} + a_{3j}X_{3j} + \ldots\ldots\ldots + a_{mj}X_{mj}} \ldots\ldots\ldots\ldots \quad (4.1)$$

If we want to further simplify and reduce our result, we can use Factor Analysis (FA) Bu, Tan, Li and Zhang, 2009). It can be computed:

$$\boldsymbol{Z_{ij} = a_{f1}f_{1i} + a_{f2}f_{2i} + a_{f3}f_{3i} + \ldots\ldots\ldots + a_{fm}f_{mi} + e_{fi}} \ldots\ldots\ldots\ldots\ldots\ldots \quad (4.2)$$

where z, a, i, x, m, j, e and fare component score, factor loading, sample numbers, measured value of variable, total number of variables, other source of variation and the factor score, respectively (Howladar, Al Numanbakth and Faruque, 2017).

As to limit the factors which are needed to be extracted, we can consider factors with eigenvalues greater than 1 with Kaiser Normalization.

Now IBM SPSS 25 software was used to carry out R-mode factor analysis (varimax rotation with Kaiser normalization). From the software we can extract factors under consideration.

CHAPTER FIVE: RESULT AND DISCUSSION

5.1 Cluster analysis (CA)

Cluster analysis is a group of multivariate technique whose primary aim is to assemble objects based on the characteristics they possess (Shrestha and Kazama, 2007). Hierarchical clustering combines cases into homogeneous clusters by merging them together one at a time in a series of sequential steps (Yim and Ramdeen, 2015).

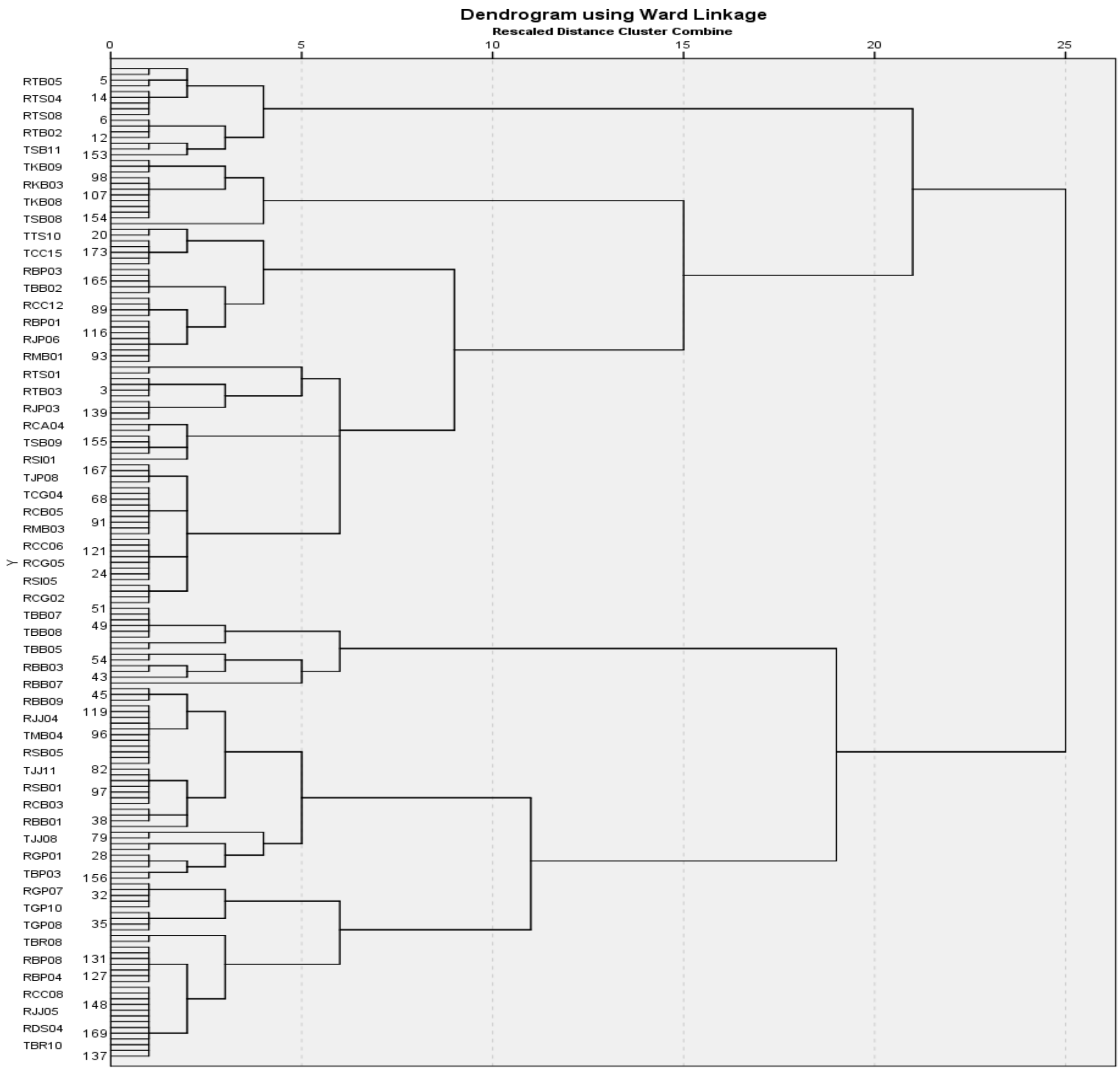

Figure 3 The dendrogram of the cluster analysis

The dendrogram of 173 samples cluster analysis are shown in *Figure 3*. The result of cluster analysis shows that eighteen zones of 173 samples are grouped into three clusters as cluster I (8 zones), cluster II (2 zones), and cluster III (8 zones). Cluster analysis shows that 45.086% of total samples are grouped in cluster I and Cluster II consisted of 5.86% and finally cluster III grouped in 45.66% of total samples. To know the homogeneity of grouped samples the analysis of the physio-chemical parameters is shown in *Tables 8, 9 & 10*. The eighteen zones of the Gazipur area are divided into three clusters are shown in *Table 11*.

Table 8 Physio-chemical parameters of cluster I

Parameters	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**
pH	78	1.16	6.62	7.78	7.1995	0.23719	0.056
Color	78	94	2	96	22.51	22.730	516.669
Turbidity	78	4.21	0.09	4.30	0.7201	0.66145	0.438
DO	78	3.58	4.11	7.69	6.8723	0.65053	0.423
TDS	78	342.0	121.0	463.0	219.563	54.0748	2924.083
EC	78	689	257	946	455.67	103.873	10789.498
Chlorine	78	0.31	0.00	0.31	0.0642	0.07219	0.005
Fluoride	78	1.08	0.00	1.08	0.3035	0.26712	0.071
Hardness	78	71	15	86	53.03	18.516	342.856
Iron	78	1.190	0.000	1.190	0.15708	0.206717	0.043
Manganese	78	0.490	0.000	0.490	0.11497	0.115715	0.013
Nitrate	78	4.50	0.00	4.50	0.5215	0.67730	0.459
Sulfate	78	1	0	1	0.09	0.288	0.083
Ammonia	78	0.29	0.00	0.29	0.1460	0.07556	0.006
Valid N (listwise)	78						

Table 9 Physio-chemical parameters of cluster II

Parameters	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
pH	16	0.54	6.86	7.40	7.2125	0.16093	0.026
Color	16	32	3	35	14.81	10.134	102.696
Turbidity	16	2.540	0.300	2.840	0.93081	0.802761	0.644
DO	16	1.05	6.02	7.07	6.6869	0.33686	0.113
TDS	16	139	150	289	197.50	44.705	1998.533
EC	16	269	313	582	407.25	86.883	7548.733
Chlorine	16	0.29	0.01	0.30	0.1269	0.09721	0.009
Fluoride	16	0.90	0.02	0.92	0.6200	0.24784	0.061
Hardness	16	75	33	108	44.94	17.968	322.863
Iron	16	0.12	0.00	0.12	0.0375	0.03550	0.001
Manganese	16	0.324	0.012	0.336	0.14500	0.133725	0.018
Nitrate	16	0.77	0.03	0.80	0.3413	0.22488	0.051
Sulfate	16	2.0	1.0	3.0	2.006	0.7215	0.521
Ammonia	16	0.17	0.00	0.17	0.0825	0.06424	0.004
Valid N (listwise)	16						

Table 10 Physio-chemical parameters of cluster III

Parameters	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
pH	79	1.24	7.03	8.27	7.4234	0.25021	0.063
Color	79	90	0	90	15.03	13.182	173.769
Turbidity	79	9.890	0.040	9.930	0.93958	1.235420	1.526
DO	79	1.84	5.98	7.82	7.0057	0.35764	0.128
TDS	79	430.0	160.0	590.0	309.591	108.1170	11689.295

EC	79	537	329	866	521.86	68.316	4667.121
Chlorine	79	0.530	0.000	0.530	0.05256	0.075104	0.006
Fluoride	79	1.39	0.00	1.39	0.3105	0.37057	0.137
Hardness	79	167	21	188	76.24	40.182	1614.595
Iron	79	1.020	0.000	1.020	0.09634	0.134573	0.018
Manganese	79	0.650	0.000	0.650	0.28349	0.164394	0.027
Nitrate	79	3.40	0.00	3.40	0.4724	0.55950	0.313
Sulfate	79	1	0	1	0.06	0.245	0.060
Ammonia	79	0.27	0.00	0.27	0.0868	0.06717	0.005
Valid N (listwise)	79						

Table 11 Zoning of three clusters

Cluster 1	**Cluster 2**	**Cluster 3**
Cherag Ali	Tongi	Gazipura
College Gate	Tongi station	Board Bazar
Maleker bari		Kodda
Kona bari		Jajhar
Chayabitty		Boro bari
Shib bari		Drirasram
Joydebpur -		Bypass
Chandra Chourasta		Signboard

In cluster III the pH (mean=7.423) is a higher value than the sample grouped in cluster I (mean=7.199) and cluster III (mean=7.2125). Similarly, pH Turbidity (mean=.93958), DO (mean=7.007), TDS (mean= 309.591), EC (mean= 521.86), Hardness (mean=76.24) and Manganese (mean=.28349) are also show higher value than Cluster I and cluster II. In cluster II Chlorine (mean=.1269), Fluoride (mean=.62) and Sulfate (mean=2.006) has higher value than cluster I Chlorine (mean=.0642), Fluoride (mean=.3035) and Sulfate (mean=.09) and cluster III Chlorine (mean=.053), Fluoride (mean=.3105) and Sulfate (mean=.06). The value of Color (mean=22.51), Iron (mean=.15708), Nitrate (mean=.5215), Ammonia (mean=.146) in cluster I is greater than cluster II Color (mean=14.81), Iron (mean=0375), Nitrate (mean=.3413), Ammonia (mean=.0825) and cluster III Color (mean=15.03), Iron (mean=.09634), Nitrate (mean=.4724), Ammonia (mean=.0868). In conclusion Cluster I is (Color-Iron-Nitrate-Ammonia) type of water, cluster II (Chlorine-Fluoride-Sulfate) type of water, and cluster III (Hardness-pH-TDS-DO-Turbidity) type of water. In the study area, these parameters are dominating in groundwater quality. The eight zones of Gazipur area (Cherag Ali, College Gate, Maleker bari, Kona bari, Chayabitty, Shib bari, Joydebpur, Chandra Chourasta) are grouped in cluster I, two zones (Tongi, Tongi station) are in cluster II and eight zones (Gazipura, Board Bazar, Kodda, Jajhar, Boro bari, Drirasram, Bypass, Signboard) are grouped in cluster III. Three major clusters are shown in *Figure 4.*

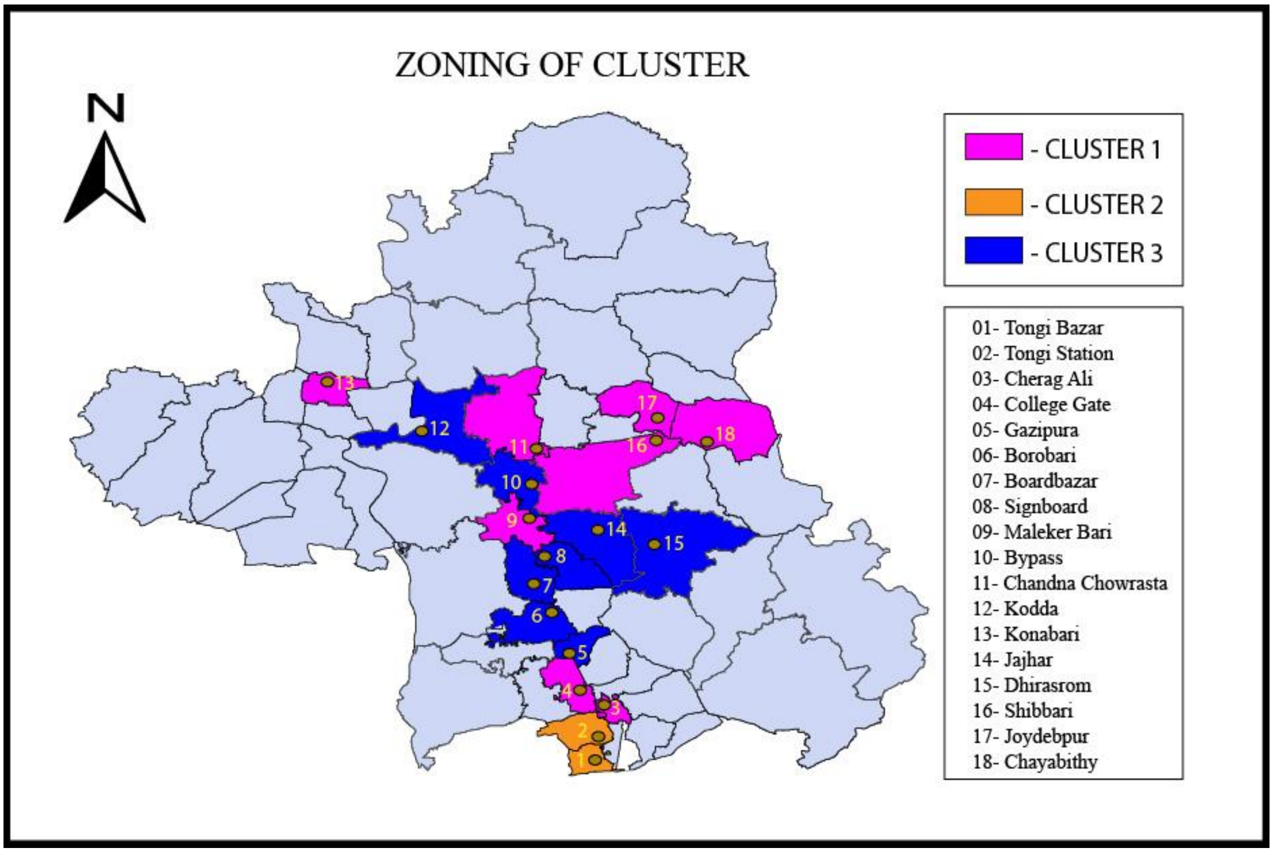

Figure 4 Zoning of Clusters

5.2 Water Quality Index

In this study, water quality indices have been measured using three methods. Different methods gave different results. In this section results produced by different methods will be discussed.

5.2.1 Weighted Arithmetic Water Quality Index Method (WAWQI)

In Cluster I, weighted arithmetic water quality index represented in *Figure 5*, shows that water quality of 41% of total samples are unsuitable, 13% of total samples are excellent and 24% of total samples are good.

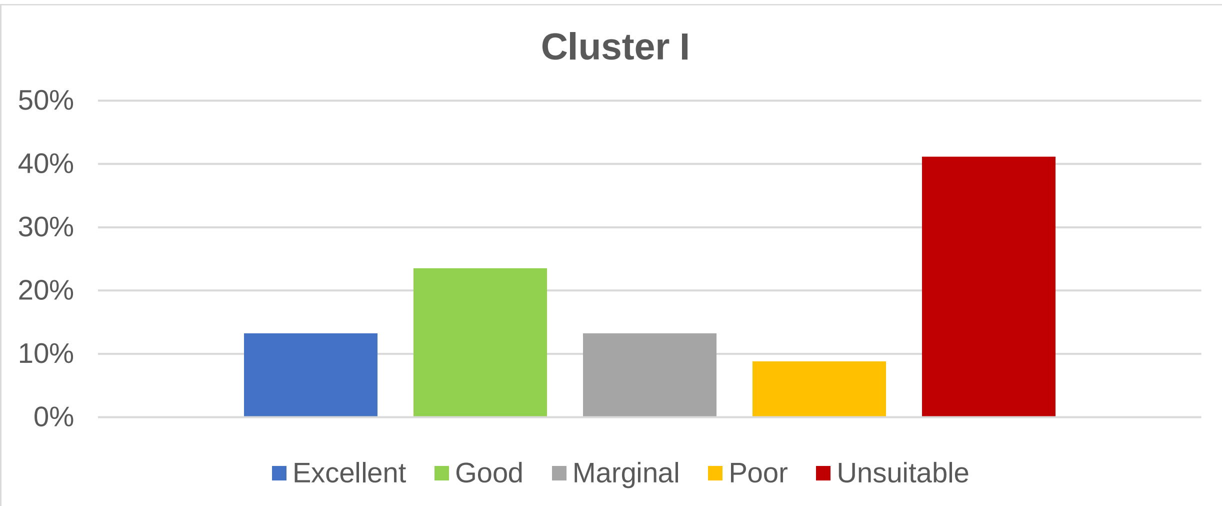

Figure 5 Weighted Arithmetic Water Quality Index Method (WAWQI) in Cluster I

Also, water quality of 9% and 13% of total sample are poor and marginal respectively. According to this method water quality of Cluster I can be considered unsuitable and can be represented using ArcMap (Figure 6).

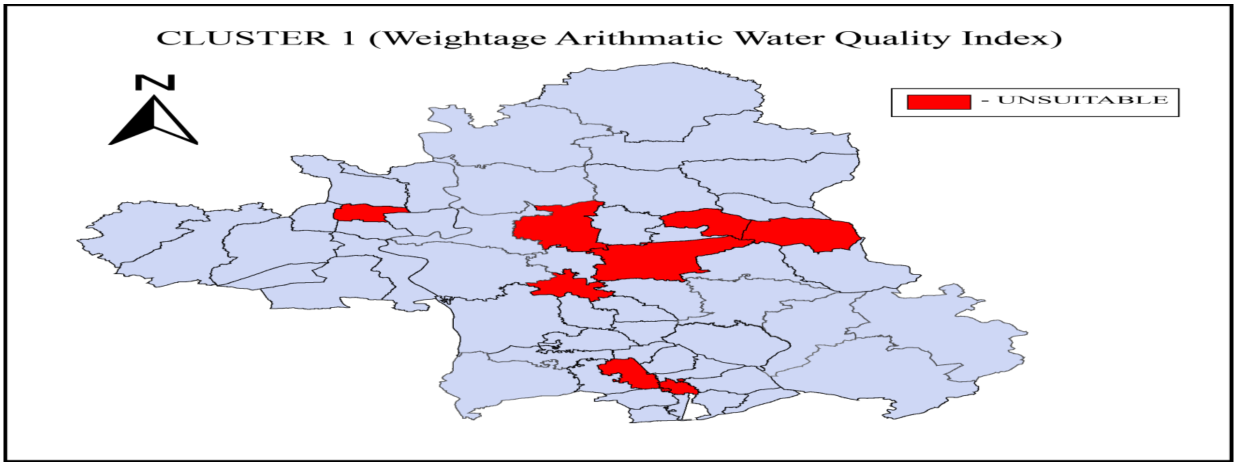

Figure 6 ArcMap of Cluster I

In Cluster II, Weighted Arithmetic Water Quality Index methods represented in *Figure 7* shows that water quality of 38% of total samples are unsuitable, whereas 29% of total samples are excellent.

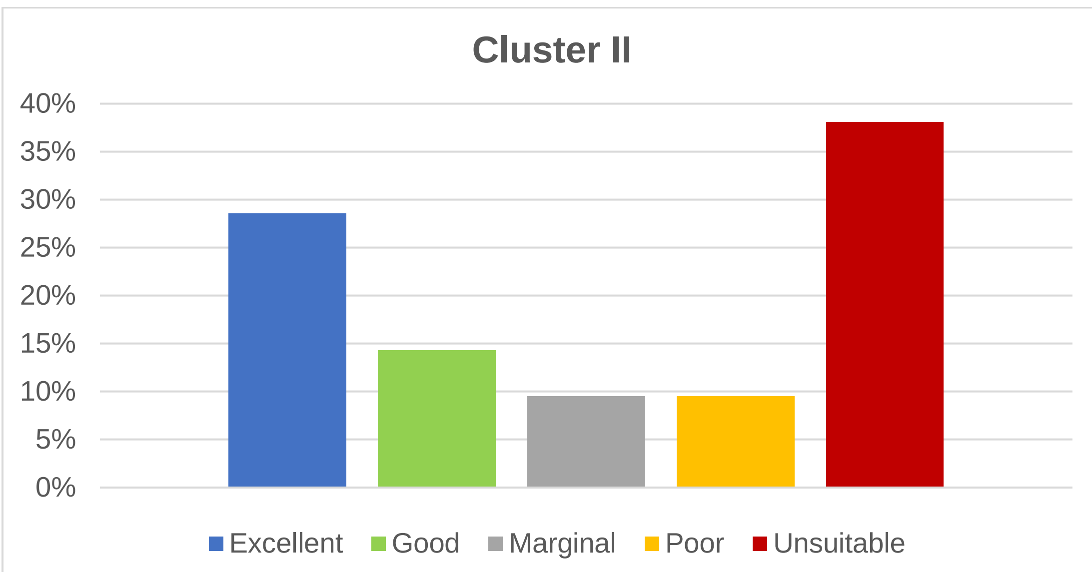

Figure 7 Weighted Arithmetic Water Quality Index Method (WAWQI) in Cluster II

Again, it also shows that water quality of 14%, 10%, 10% of total samples are good, marginal and poor respectively. Highest 38% samples are unsuitable, so we can conclude according this method that water quality of Cluster II can be considered unsuitable overall and represented using ArcMap (Figure 8).

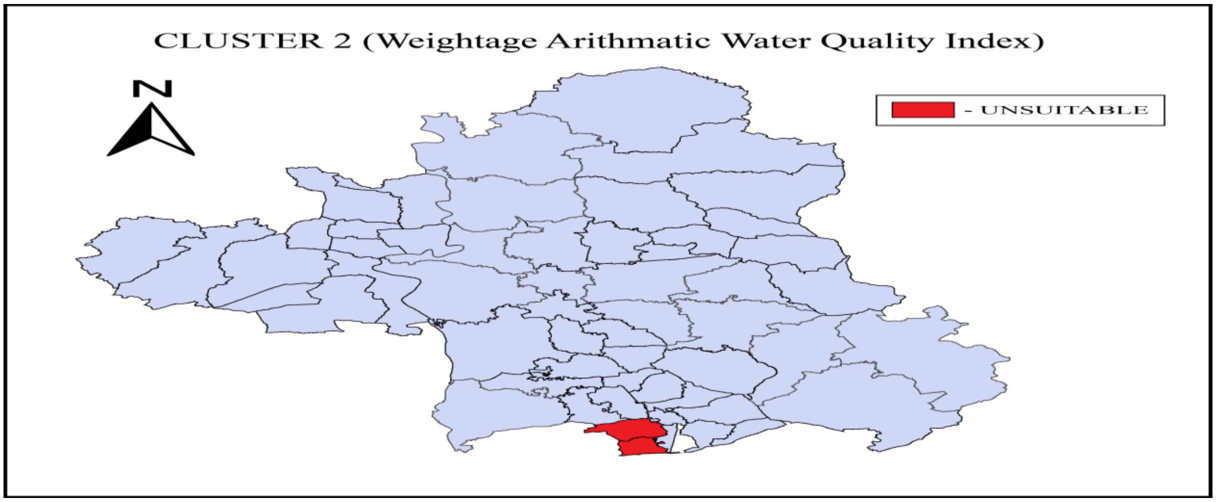

Figure 8 ArcMap of Cluster II

In Cluster III, represented in *Figure 9* this method shows that water quality of 57% of total samples are unsuitable, whereas only 10% of total samples are excellent. It also shows that only 13% of samples are of good quality, although 10% and 105 of samples are of marginal and poor quality.

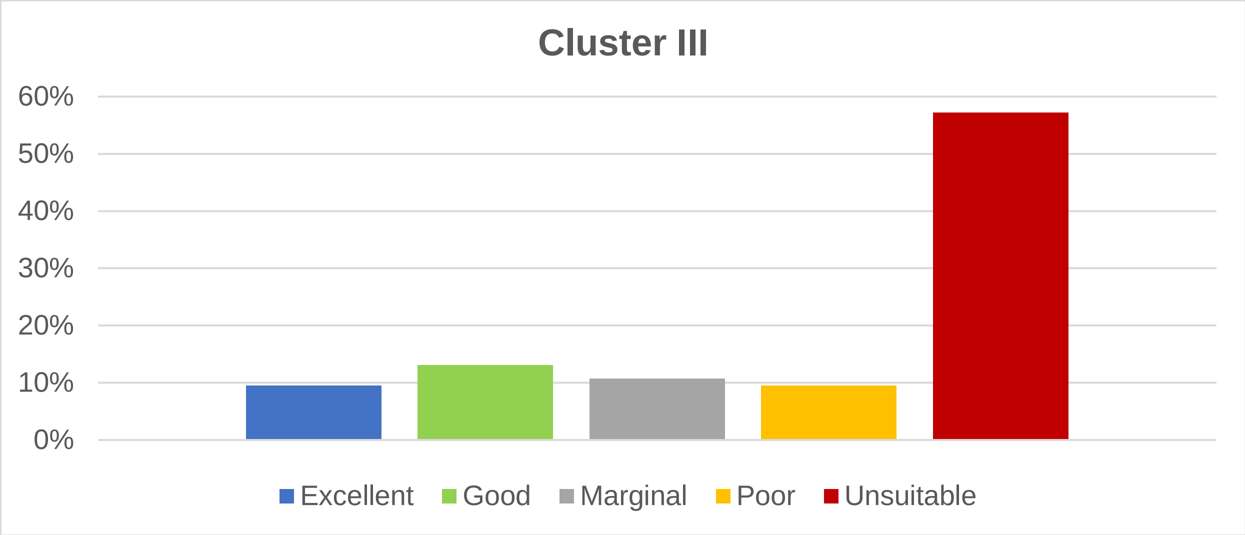

Figure 9 Weighted Arithmetic Water Quality Index Method (WAWQI) in Cluster III

So, Cluster III can be also considered unsuitable in terms of water quality according to this method and represented by ArcMap (*Figure 10*).

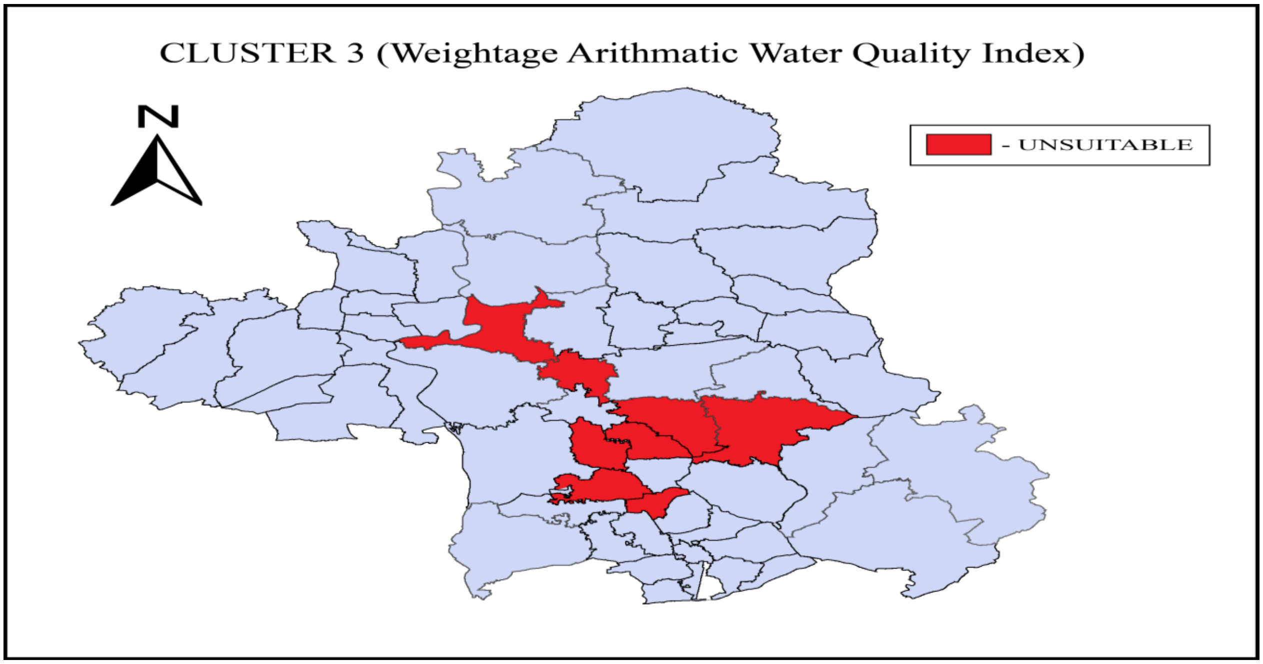

Figure 10 ArcMap of Cluster III

5.2.2 Integrated Water Quality Index

According to Integrated Water Quality Index method represented in *Figure 11* in Cluster I, water quality of 22% samples is unsuitable, but only 1% of samples are excellent. Integrated method shows a maximum of 26% samples are poor, whereas 25% and 25% samples are good and marginal respectively.

Figure 11 Integrated Water Quality Index in Cluster I

According to Integrated method Water quality of Cluster I can be considered as poor and represented in ArcMap.

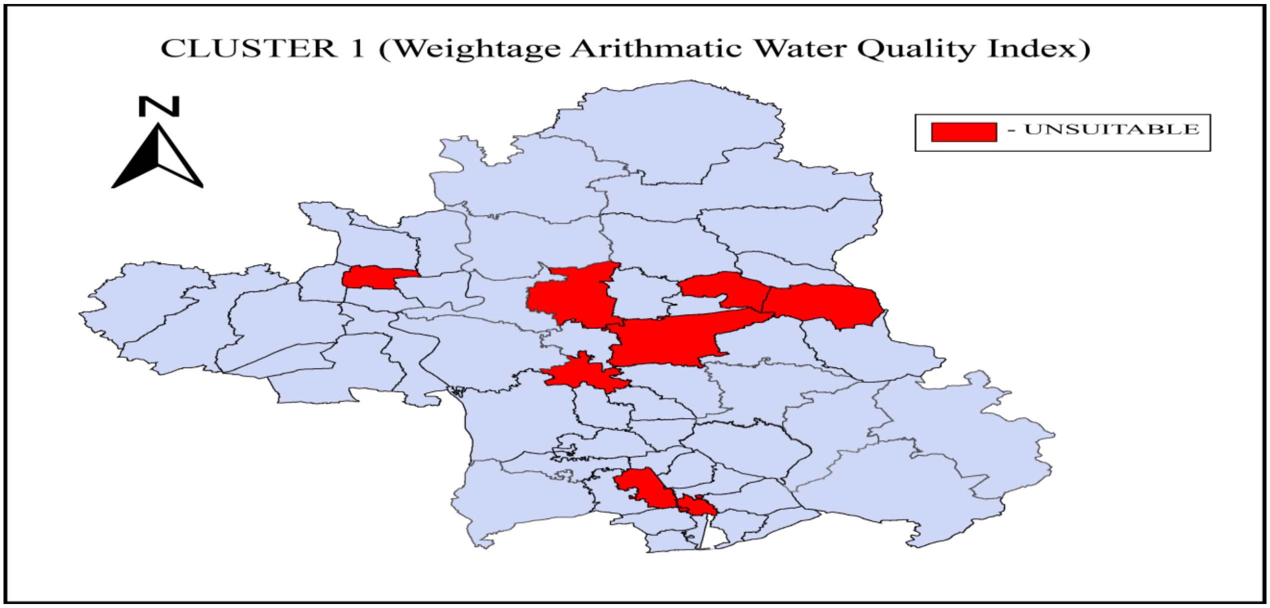

Figure 12 ArcMap of Cluster I

In Cluster II, according to Integrated Water Quality Index method represented in *Figure 13*, shows that water quality of 19% of samples arte unsuitable, but there are no excellent quality samples in Cluster II.

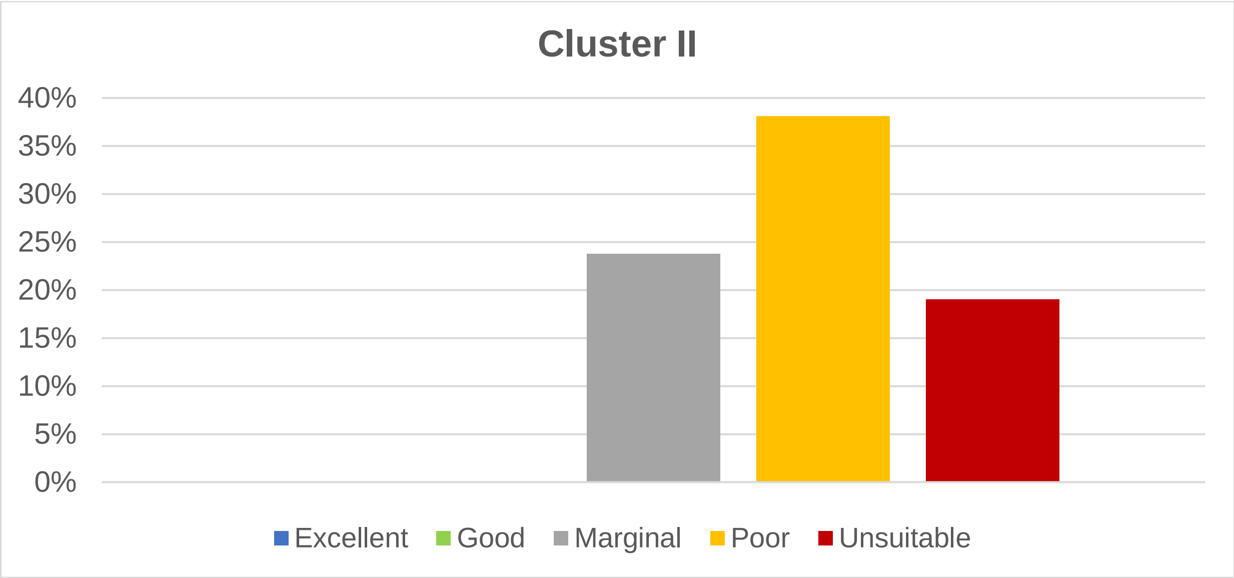

Figure 13 Integrated Water Quality Index in Cluster II

A maximum of 38% of samples are poor, whereas 24% samples are marginal. Again, there are no good quality samples in Cluster II. Cluster II can be considered as poor in terms of water quality and represented in ArcMap.

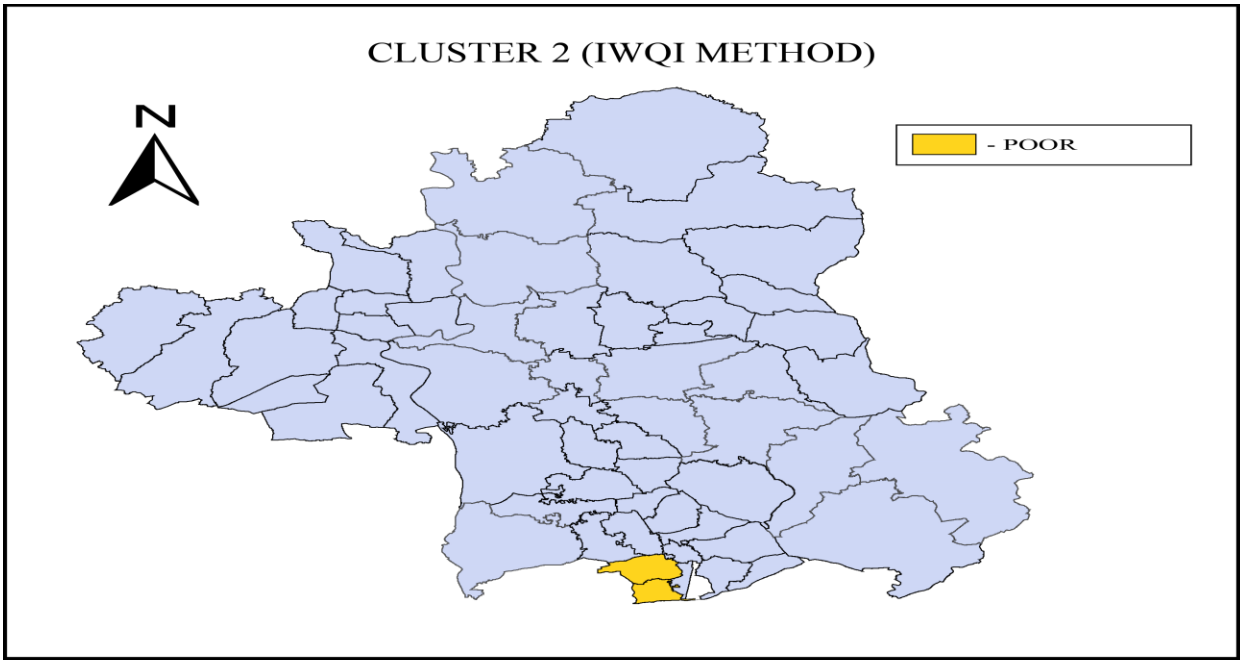

Figure 14 ArcMap of Cluster II

In Cluster III, according to Integrated Water Quality Index method represented in *Figure 14*, water quality of 42% samples is unsuitable, whereas only 2% samples are excellent.

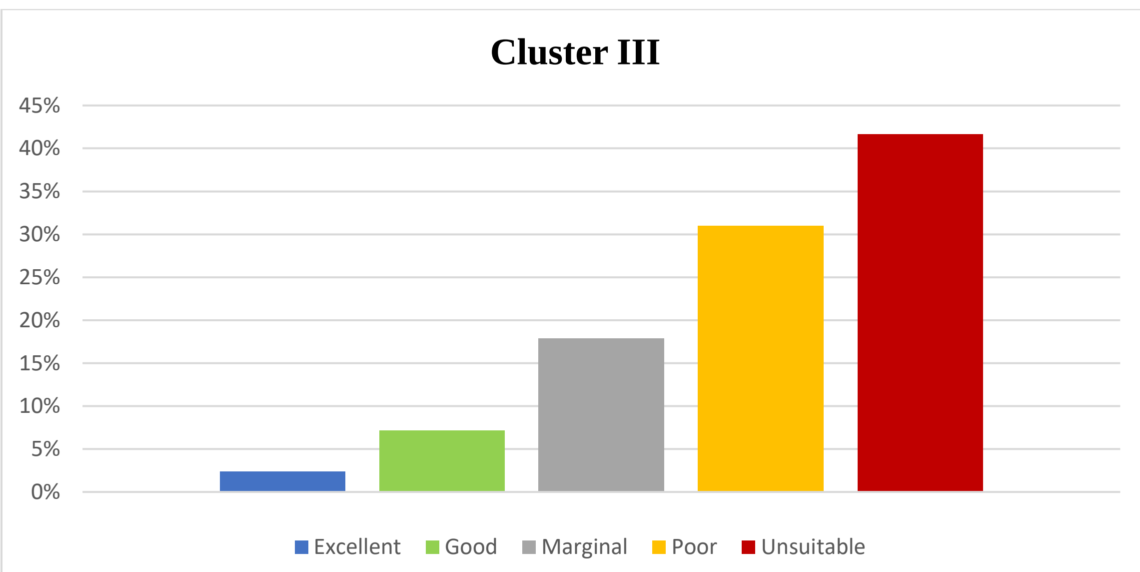

Figure 15 Integrated Water Quality Index in Cluster II

IWQI also shows that water quality of 7%, 18% and 315 are good, marginal and poor respectively. Water quality of Cluster III can be considered as unsuitable and can be represented using ArcMap.

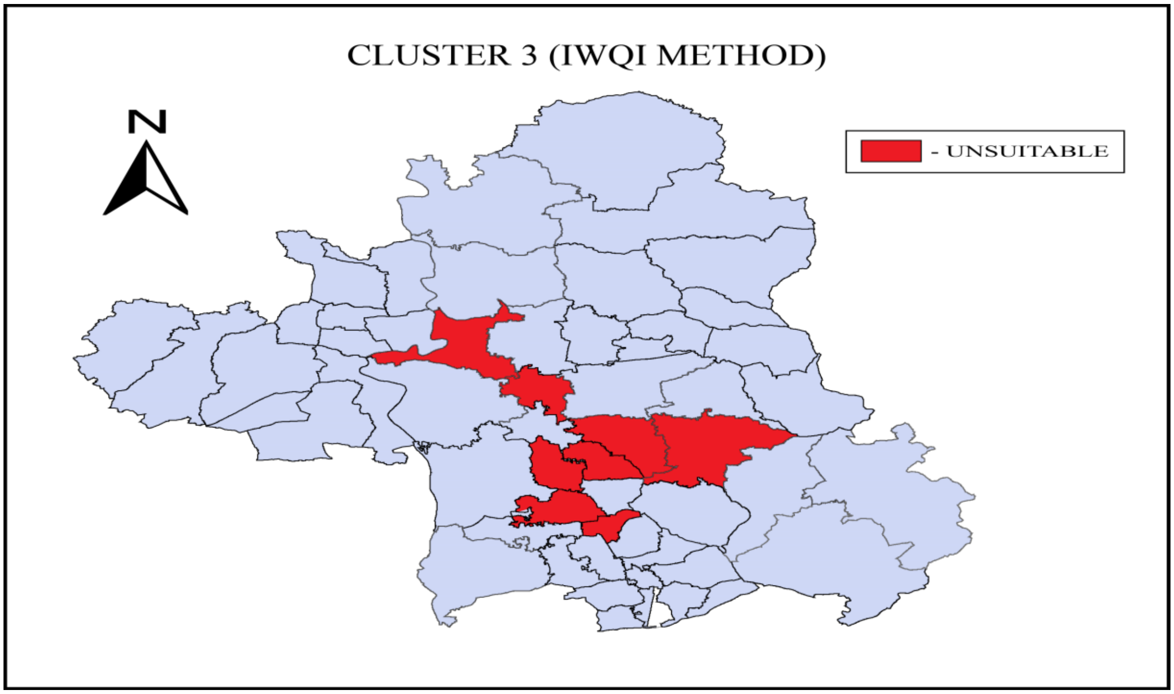

Figure 16 ArcMap of Cluster III

5.3 Water Quality Index (Assigned Weight Method)

According to this method represented in *Figure 17*, in Cluster I water quality of 3% samples are unsuitable and 1% samples are excellent. Whereas, water quality of 50% samples is good. 31% and 15% samples are marginal and poor respectively.

Figure 17 Water Quality Index (Assigned Weight Method) in Cluster I

As 50% samples were off good quality, we can be considered Cluster I to be good by this method in terms of water quality. Cluster I, in terms of water quality can be represented by ArcMap.

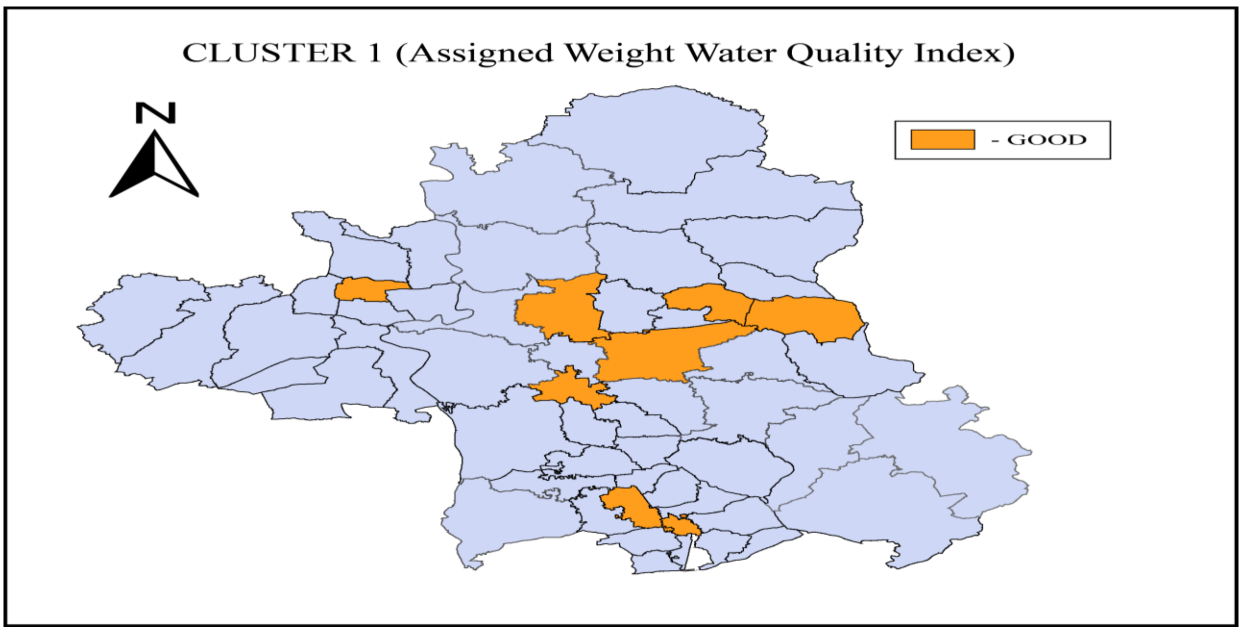

Figure 18 ArcMap of Cluster I

In Cluster II, the method shows that no samples are unsuitable, whereas 10% samples are of excellent water quality. A highest of 52% sample are of good quality, but 19% and 19% sample are of marginal and poor quality respectively.

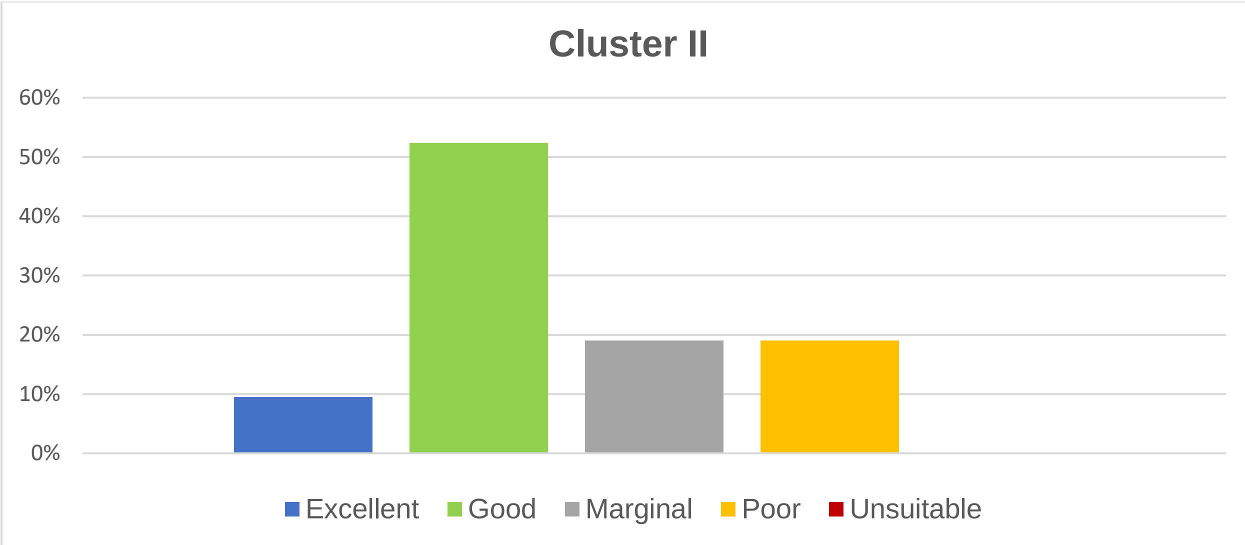

Figure 19 Water Quality Index (Assigned Weight Method) in Cluster II

Finally, we can conclude that Cluster II can be considered as of good quality and can be represented in ArcMap.

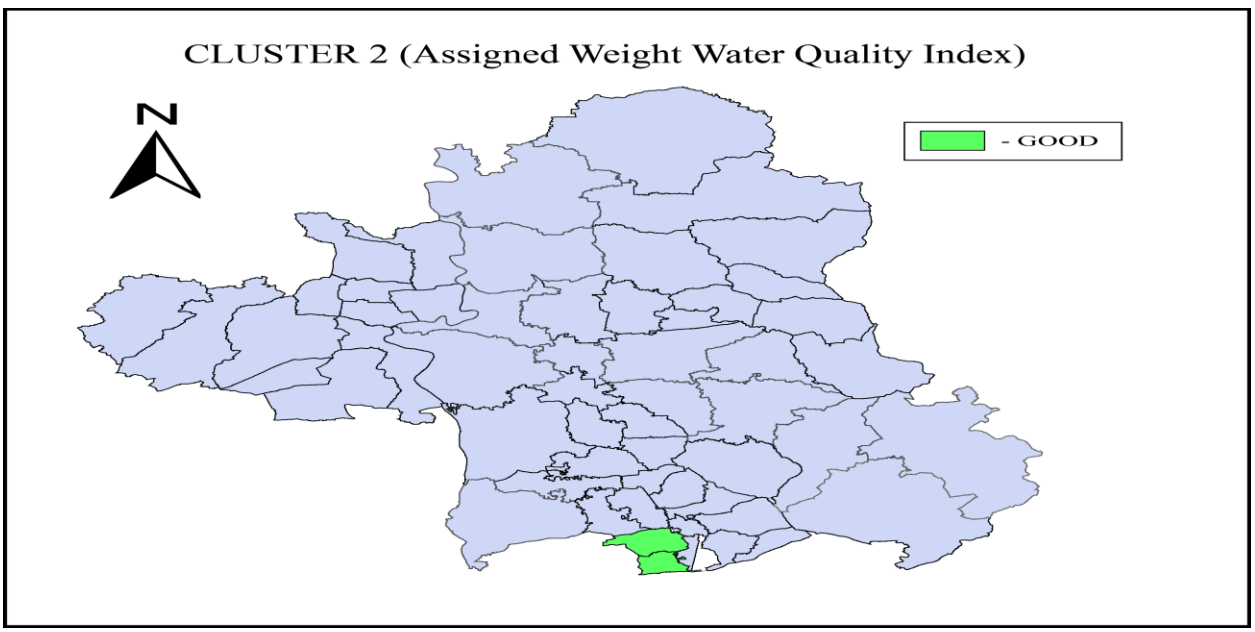

Figure 20 ArcMap of Cluster II

In Cluster III, this method of water quality shows that only 1% sample are of unsuitable quality and there are no sample of excellent quality. 29%, 46%, 24% sample are of good, marginal and poor quality respectively.

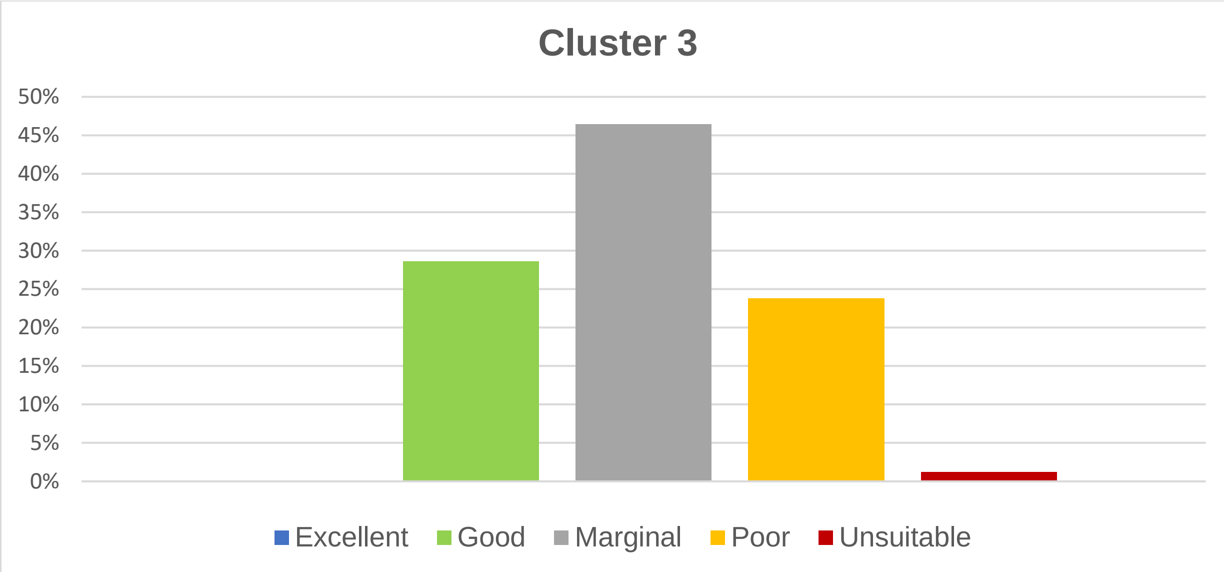

Figure 21 Water Quality Index (Assigned Weight Method) in Cluster I

So, Cluster III can be considered as of marginal in terms of water quality and can be represented in ArcMap.

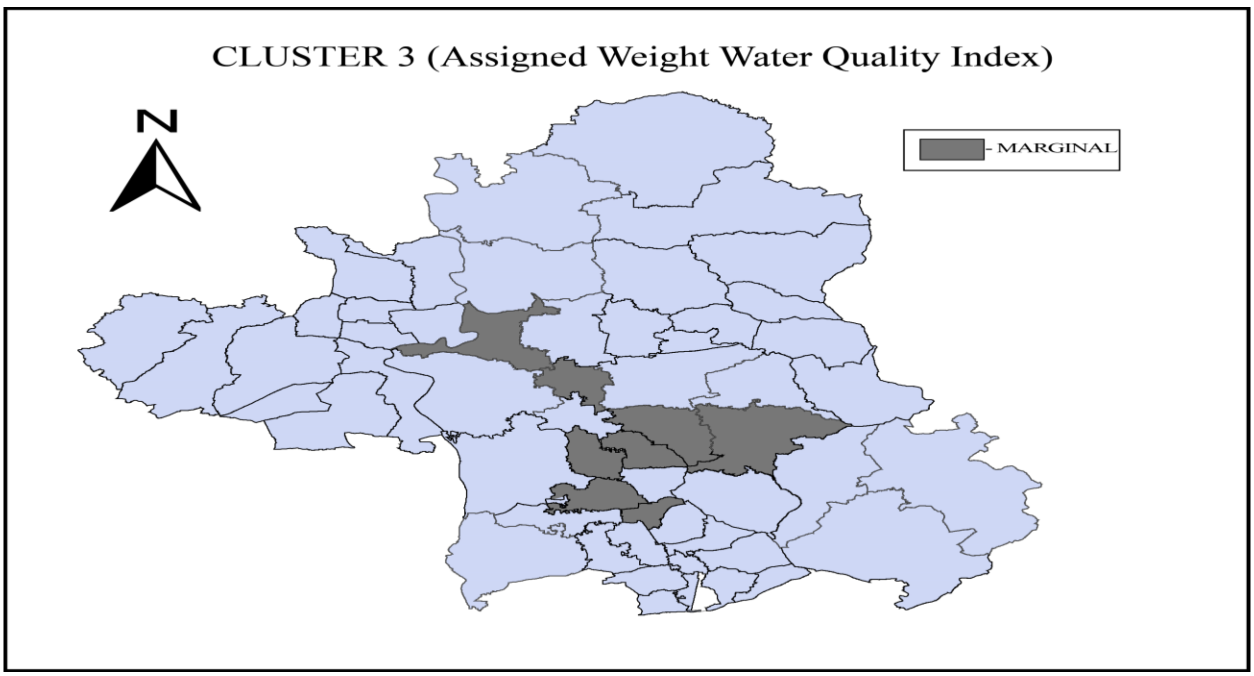

Figure 22 ArcMap of Cluster III

5.4 Comparisons of WQI methods

Different methods of water quality index show us different results in Clusters I, II and III. But when considering all the sample together, comparison of these methods is possible.

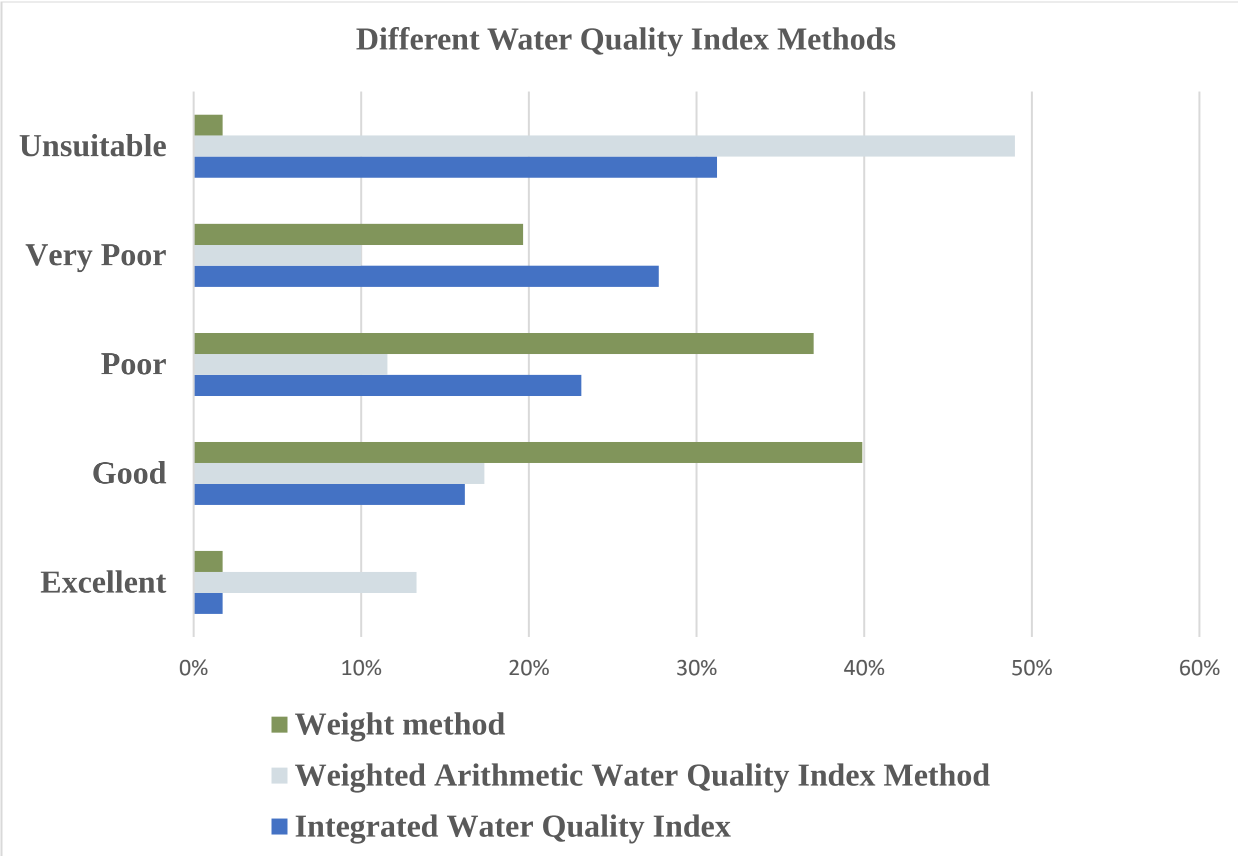

Figure 23 Comparisons of WQI methods

According to overall scenario in *Figure 23*, water quality of 2%, 49% and 31% sample overall are of unsuitable quality according to Assigned weight, WAWQI and IWQI respectively. These results reveal that WAWQI and IWQI are giving similar results, although Assigned weight method gives a different result. According to water quality of Gazipur City is Good, whereas WAWQI and IWQI show that water quality of Gazipur City is unsuitable. Also 2%, 13% and 2% are of excellent quality according to Assigned weight, WAWQI and IWQI respectively.

5.5 Pearson Correlation Matrix

The correlation analysis to establish the relationships between physicochemical characteristics of water samples, which can reveal the origin of solutes and the process that generated the observed water compositions (Hamzaoui-Azaza et al., 2010). Pearson correlation shows the negative and positive correlation between the parameters. Correlation coefficient 1 or near 1 defines good correlation and if the value is 0 then there is no correlation between parameters. It also said that parameters showing r >0.7 are considered strongly correlated whereas r between 0.5 and 0.7 shows moderate correlation (Manish et al. 2006). The significance level should less than .05 (p<.05). The positive correlation means that when one parameter is increasing then another parameter also increasing along with that parameter. Negative correlation means that when one parameter value is increasing then another parameter value is decreasing and their source, characteristics are not homogenous (Howladar et al., 2021). Three *Figures 24,25,26* have shown the positive and negative correlation between the parameters. In the Pearson correlation analysis Cluster I show strong and moderate positive correlation between parameters like TDS-EC (0.987) has strong positive correlation and Color-Manganese (0.292) has moderate positive correlation. In cluster II TDS-EC (0.994), Color-Manganese (0.704) show a strong positive correlation, and TDS-Hardness (0.690), Sulfate-Ammonia (0.676), EC-Hardness (0.619) show moderate positive correlation. Additionally, it also shows negative strong correlation between pH -color (-0.769), Fluoride-Nitrate (-0.828) and

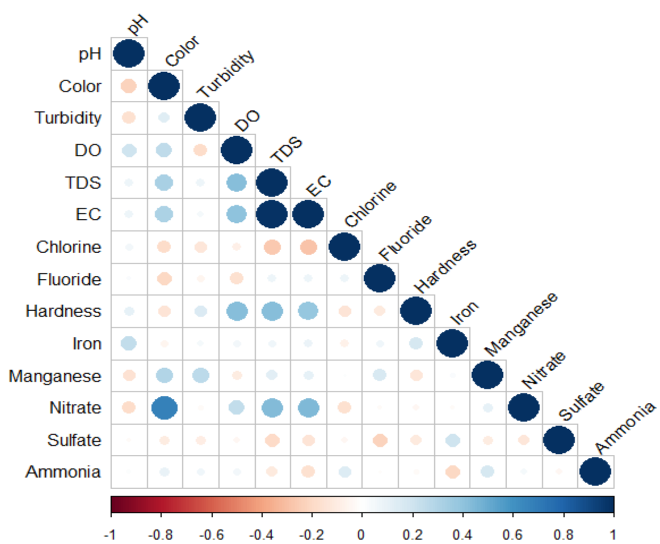

Figure 24 Pearson correlation for cluster I

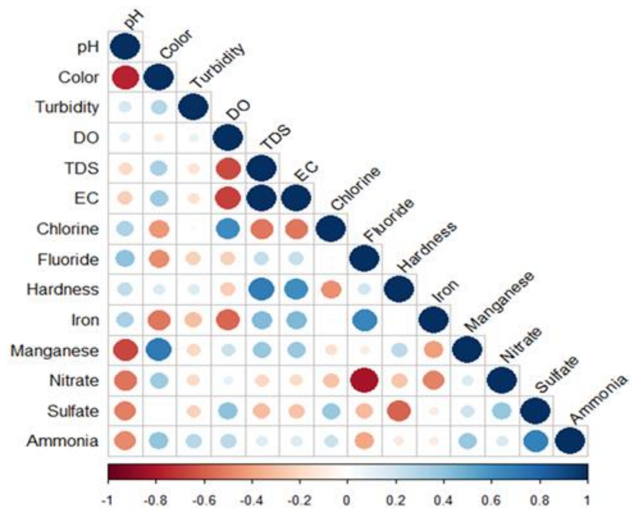

Figure 25 Pearson correlation for cluster II

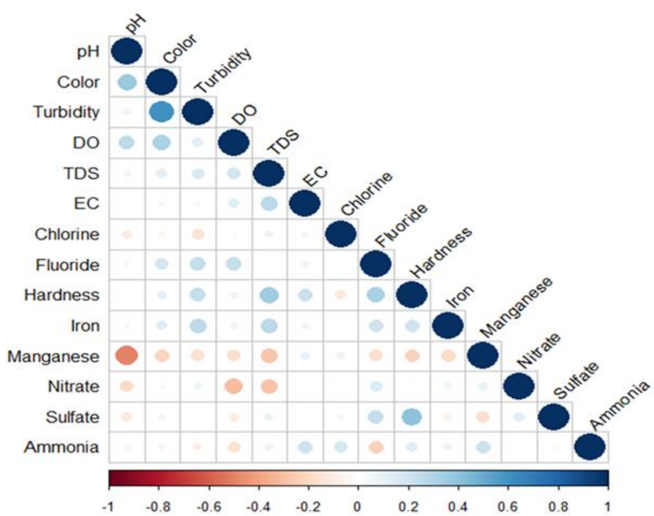

Figure 26 Pearson correlation for cluster III

negative moderate correlation between DO-TDS (-0.655), DO-EC (-0.690), pH-Manganese (-0.663). In Cluster III there is positive moderate correlation between Color-Turbidity (0.610). But there is no strong positive and negative correlation in cluster III.

5.6 Factor Analysis

Factor analysis is one of the most important statistical methods for interpretation of hydrochemistry of groundwater (Subba Rao, 2005). Factor analysis can identify several pollution factors reasonably but the interpretation of these factors in terms of actual controlling sources and processes is highly subjective (Matalas and Reiher, 1967; Bahar and Yamamuro, 2008; Sharifinia, 2016). The 173 samples of 14 variables are collected from the Gazipur area used to evaluate the most significant parameters. Factor loadings are classified by Liu et al. (2003) as ‘‘strong’’, ‘‘moderate’’, and ‘‘weak’’ corresponding to absolute loading values of 0.75, 0.75–0.50, and 0.50–0.30, respectively. In the result of factor analysis in Cluster I, Cluster II and Cluster III total cumulative variance explained respectively 73.095%,91.335% and 68.013%.

In Cluster I, six factors eigenvalue is greater than 1 that explained the total cumulative variance of 73.095%. Factor 1 has strong positive loading value of TDS (.780), EC (.746) and Hardness (.794) and moderate loading value DO (.675). TDS, EC, Hardness came from the effluent of textile, combine mill waste, and Diaries. Factor 2 has positive strong loading value of Color, Nitrate. These parameters are associated with a brown shade in water often comes from rust in the water pipes. In factor 3 has strong positive loading of Turbidity (.874) and moderate loading of Mn (.557). Turbidity. Mn associated with Diary Industry, Phosphate Fertilizer plant. Factor 4 has strong loading like Fluoride (.858) and that is come from weathered and leached out bearing rocks. Ammonia is the positive strong loading of Factor 5 and it is associated with Chemical and pharmaceutical manufacturing. Factor 6 has positive strong loading value of Iron (.847) and moderate loading value of Sulfate (.513). It represents Sulfate bearing fertilizer and Bacterial oxidation of fertilizer involve in the study area. Factor loading including eigenvalue and total cumulative variance of cluster I are shown in *Table 12,13* and Eigenvalues of Components in Cluster I is shown in *Figure 27*.

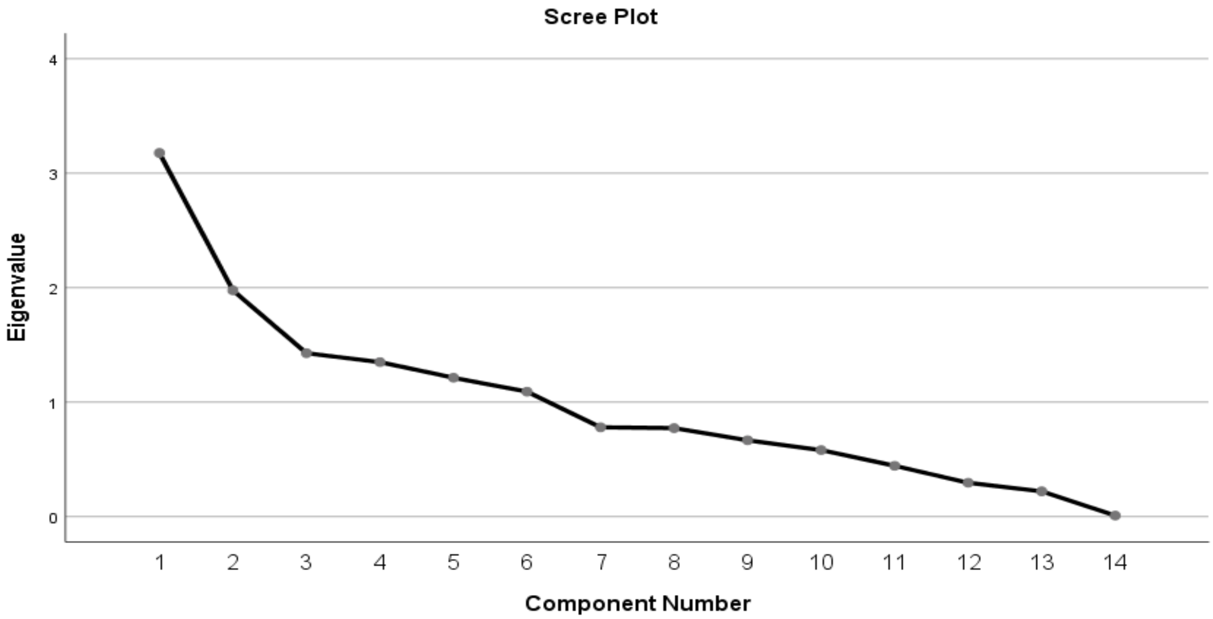

Figure 27 Eigenvalues of Components in Cluster I

Table 12 Factor loading including eigenvalue and total cumulative variance of cluster I

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.177	22.691	22.691	3.177	22.691	22.691	2.560	18.289	18.289
2	1.976	14.113	36.804	1.976	14.113	36.804	2.241	16.009	34.298
3	1.427	10.195	46.999	1.427	10.195	46.999	1.442	10.302	44.600
4	1.349	9.636	56.636	1.349	9.636	56.636	1.391	9.932	54.532
5	1.213	8.663	65.299	1.213	8.663	65.299	1.320	9.427	63.959
6	1.091	7.794	73.093	1.091	7.794	73.093	1.279	9.134	73.093
7	0.779	5.568	78.661						
8	0.773	5.519	84.180						
9	0.666	4.758	88.938						
10	0.581	4.149	93.087						

11	0.443	3.168	96.255
12	0.295	2.110	98.365
13	0.220	1.574	99.939
14	0.009	0.061	100.000

Table 13 Factor loadings of Gazipur area in cluster I

	Component					
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
pH						0.471
Color		0.877				
Turbidity			0.874			
DO	0.675					
TDS	0.780	0.415				
EC	0.746	0.425				
Chlorine					0.537	
Fluoride				0.858		
Hardness	0.794					
Iron						0.847
Manganese			0.557			
Nitrate		0.839				
Sulfate				-0.496		0.513
Ammonia					0.802	

In cluster II, five factors eigenvalue is greater than 1 that explained the total cumulative variance of 91.335%. Factor 1 has positive strong loading value of TDS (.888), EC (.909) and negative strong loading value of DO (-.894). These parameters come from the dissolution of rock and minerals in sediment. Factor 2 represents strong positive loading value of Fluoride (.816), strong negative loading value of Nitrate (-.922) and moderate positive loading value of P^H, Iron. The factor shows the pollution source of Combined wastewater from Phosphatic fertilizer plan. Factor 3 has dominated strong positive loading value of Mn (.949) and moderate loading value of Color (.633). Mn, Color come from dissolved and suspended materials, Phosphatic fertilizer plant. Factor 4 represents strong positive loading value of Sulfate (.846) and Ammonia (.869) and replicates atmospheric deposition and diammonium phosphate plant. Factor 5 has positive strong loading value of Turbidity (.973) and it comes from the movement of different particles mixed with water. Factor loading including eigenvalue and total cumulative variance of cluster II are shown in Table 14,15 and Eigenvalues of Components in Cluster II is shown in *Figure 28*.

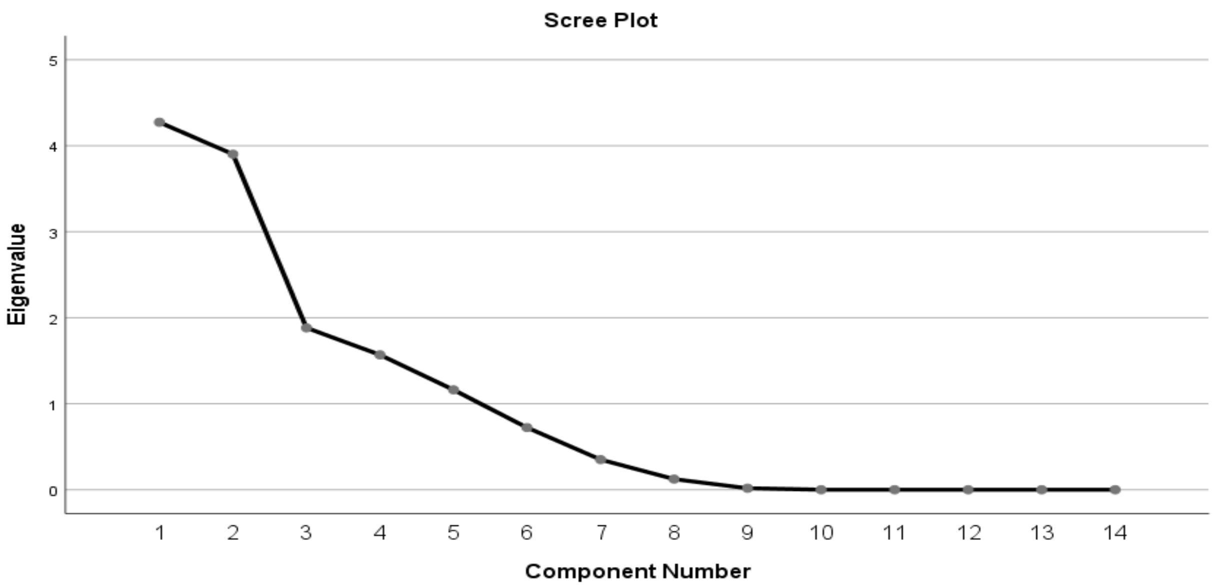

Figure 28 Eigenvalues of Components in Cluster II

Table 14 Factor loading including eigenvalue and total cumulative variance of cluster II

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.273	30.522	30.522	4.27	30.522	30.522	3.69	26.401	26.401
2	3.902	27.871	58.392	3.90	27.871	58.392	2.90	20.761	47.162
3	1.882	13.444	71.836	1.88	13.444	71.836	2.38	17.039	64.201

4	1.568	11.203	83.039	1.56	11.203	83.039	2.23	15.995	80.196
5	1.162	8.297	91.335	1.16	8.297	91.335	1.56	11.139	91.335
6	0.722	5.159	96.494						
7	0.350	2.502	98.997						
8	0.123	0.880	99.877						
9	0.017	0.123	100.000						
10	5.433E-16	3.880E-15	100.000						
11	1.764E-16	1.260E-15	100.000						
12	1.225E-16	8.747E-16	100.000						
13	-2.682E-16	-1.915E-15	100.000						
14	-4.191E-16	-2.994E-15	100.000						

Table 15 Factor loadings of Gazipur area in cluster II

	Component				
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
pH		0.597	-0.442	-0.483	
Color		-0.536	0.633		
Turbidity					0.973
DO	-0.894				
TDS	0.888				

EC	0.909			
Chlorine	-0.698	0.418		
Fluoride		0.816		
Hardness	0.453		0.459	-0.480
Iron	0.533	0.583	-0.499	
Manganese			0.949	
Nitrate		-0.922		
Sulfate				0.846
Ammonia				0.869

In cluster III, six factors eigenvalue is greater than 1 that explained the total cumulative variance of 68.013%. Factor 1 has dominated strong positive loading value of Color (.835) and Turbidity (.828). Color and Turbidity associated with the effluent of textile industry, Phosphate Fertilizer Industry. Factor 2 has strong positive loading value of Hardness (.799) and Sulfate (.799). The strong loading value of Hardness and Sulfate come from groundwater. interaction with dolomite limestone. The moderate positive loading value of DO (.732) and negative moderate loading value of Nitrate (-.716) in factor 3 come from the overfertilization of water plants. Factor 4 has strong positive loading value of Mn (.757) and moderate negative loading value of (-.728) that come from Phosphatic fertilizer plant. Factor 5 shows strong positive loading value of Ammonia (.813) and moderate negative loading value of Fluoride (-.591). The dominating loading values are associated with chemical and pharmaceutical manufacturing. Factor 6 defines strong positive loading value of Iron (.833) and it comes from Phosphoric Acid Plant. Factor loading including eigenvalue and total cumulative variance of cluster III are shown in *Table 16,17* and Eigenvalues of Components in Cluster III is shown in *Figure 29.*

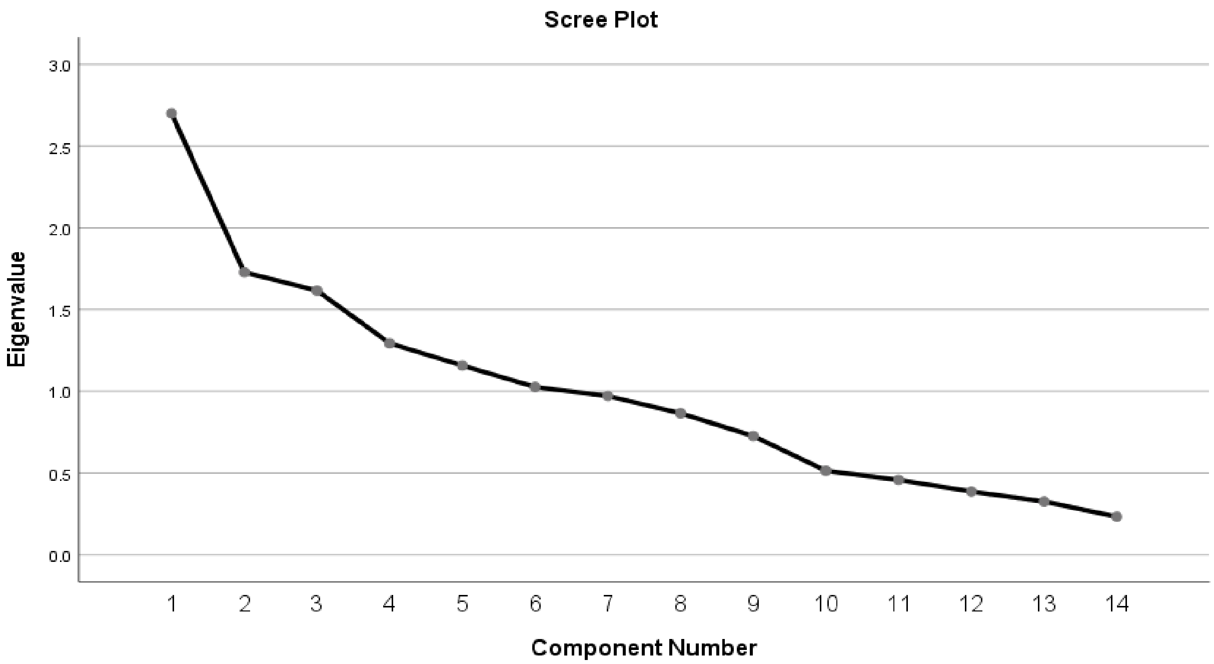

Figure 29 Eigenvalues of Components in Cluster III

Table 16 Factor loading including eigenvalue and total cumulative variance of cluster III

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.700	19.289	19.289	2.700	19.289	19.289	1.840	13.146	13.146
2	1.729	12.347	31.635	1.729	12.347	31.635	1.756	12.544	25.689
3	1.616	11.543	43.179	1.616	11.543	43.179	1.613	11.522	37.211
4	1.293	9.239	52.417	1.293	9.239	52.417	1.541	11.005	48.217
5	1.157	8.266	60.684	1.157	8.266	60.684	1.422	10.156	58.373

6	1.026	7.330	68.013	1.026	7.330	68.013	1.350	9.641	68.013
7	0.971	6.936	74.949						
8	0.865	6.178	81.127						
9	0.726	5.189	86.316						
10	0.514	3.670	89.986						
11	0.457	3.268	93.254						
12	0.386	2.758	96.012						
13	0.325	2.324	98.336						
14	0.233	1.664	100.000						

Table 17 Factor loadings of Gazipur area in cluster III

	Component					
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
pH				-0.728		
Color	0.835					
Turbidity	0.828					
DO			0.732			
TDS			0.463			0.475
EC				0.402		
Chlorine						

Fluoride				-0.591	
Hardness	0.799				
Iron					0.833
Manganese			0.757		
Nitrate		-0.716			
Sulfate	0.799				
Ammonia				0.813	

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

In this chapter the outcomes of the study have been summarized. The effectiveness of the study and how people can be benefitted from the study have also been discussed in short. Possible enhancements of this study have been discussed in short. Possible enhancement of the study and further recommendations have also been mentioned here.

6.1 Conclusion:

Gazipur city is a highly populated industrial district. It creates a huge impact in human lifestyle and environment. A high number of industries containing much population damaging surface water as well as ground water. It damages human health with the environment while drinking regularly. That’s why we have tried to analyze the present scenario of drinking water of Gazipur region. The objective of our study is to find out the water quality index using different methods and its variations, similarities in physical & chemical properties. We have analyzed in three methods (The weighted arithmetic WQI method, Integrated Water Quality Index Method, Assigned Weight Water Quality Index Method). Among them ordinary method considers either permissible limit or desirable limit. But, Integrated Water quality Index (IWQI) considers both permissible limit & desirable limit. It is more accurate in result having less limitations. Again, Assigned Weight Water Quality Index method shows different results than other methods. IWQI and Weighted Arithmetic method shows 49% and 31% of total samples goes under unsuitable category. The result shows that a much portion of Gazipur remains under unsuitable condition. Their drinking water quality is not up to the mark. It will create a great negative impact on human health in the long run.

We have classified all the regions in three different clusters on the basis of some similarities & dissimilarities. Pearson correlation analysis shows both positive and negative correlation among different parameters in clusters. This correlation also helps us to know how different parameters are impacting in a definite zone. It also helps us to know which parameters are influencing in different zones.

Gazipur district contains much number of industries. It creates huge impact on water quality. It damages both ground water & surface water. Strong loadings of components (>0.75) predict that the major portion of chemical contamination comes from Industrial effluent. That is chemical contamination are happening due to industries effluent. It is directly deteriorating the water quality.

6.2 Recommendations:

Overall study on the drinking water of Gazipur city restaurants shows the impact of industries, much population, processing & use of water precisely. This problem can be minimized taking some effective steps. Such as:

- The effluent of industries must be recycled properly. Effluent should move to the normal water body when it fulfills all the parameters of general water.
- The Industries location should be placed after completing EIA.
- The restaurants condition should be healthy. The pot used for storing, carry & serve water should be up to the mark.
- The water must be purified by filtration or by other means before supplying as drinking water.
- Further analysis can be done to solve the problem using various methods in an economical way.

REFERENCES

1. Ahmed, K., Rahman, A., Sarkar, M., Islam, J., Jahan, I., Moniruzzaman, M., Saha, B. and Bhoumik, N., 2016. Assessment on the level of contamination of Turag river at Tongi area in Dhaka. Bangladesh Journal of Scientific and Industrial Research, 51(3), pp.193-202.
2. Akter, T., Jhohura, F., Akter, F., Chowdhury, T., Mistry, S., Dey, D., Barua, M., Islam, M. and Rahman, M., 2016. Water Quality Index for measuring drinking water quality in rural Bangladesh: a cross-sectional study. *Journal of Health, Population and Nutrition*, 35(1).
3. BDWS (Bangladesh Drinking Water Standard). (2005). Bangladesh water quality standard, Dhaka, Bangladesh.
4. Bu, H., Tan, X., Li, S. and Zhang, Q., 2009. Water quality assessment of the Jinshui River (China) using multivariate statistical techniques. Environmental Earth Sciences, 60(8), pp.1631-1639.
5. Das Kangabam, R., Bhoominathan, S., Kanagaraj, S. and Govindaraju, M., 2017. Development of a water quality index (WQI) for the Loktak Lake in India. *Applied Water Science*, 7(6), pp.2907-2918.
6. Howladar, M., Chakma, E., Jahan Koley, N., Islam, S., Numanbakth, M., Ahmed, Z., Chowdhury, T. and Akter, S., 2021. The water quality and pollution sources assessment of Surma river, Bangladesh using, hydrochemical, multivariate statistical and water quality index methods. *Groundwater for Sustainable Development*, 12, p.100523.
7. Howladar, M., Chakma, E., Jahan Koley, N., Islam, S., Numanbakth, M., Ahmed, Z., Chowdhury, T. and Akter, S., 2021. The water quality and pollution sources assessment of Surma river, Bangladesh using, hydrochemical, multivariate statistical and water quality index methods. Groundwater for Sustainable Development, 12, p.100523.
8. Howladar, M., Al Numanbakth, M. and Faruque, M., 2017. An application of Water Quality Index (WQI) and multivariate statistics to evaluate the water quality around Maddhapara Granite Mining Industrial Area, Dinajpur, Bangladesh. Environmental Systems Research, 6(1).
9. Masoud, A. and Ali, M., 2020. Coupled multivariate statistical analysis and WQI approaches for groundwater quality assessment in Wadi El-Assiuty downstream area, Eastern Desert, Egypt. *Journal of African Earth Sciences*, 172, p.103982.
10. Khanoranga and Khalid, S., 2019. An assessment of groundwater quality for irrigation and drinking purposes around brick kilns in three districts of Balochistan province, Pakistan, through water quality index and multivariate statistical approaches. *Journal of Geochemical Exploration*, 197, pp.14-26.
11. Rahaman, M., Ali, M., Arefin, R., Mazumder, Q., Majumder, R. and Jahan, C., 2019. Assessment of drinking water quality characteristics and quality index of Rajshahi city, Bangladesh. *Environment, Development and Sustainability*, 22(5), pp.3957-3971.

12. Mohanty SK (2004) Water quality index of four religious ponds and its seasonal variation in the temple city Bhuvaneshwar. In: Kumar A (ed) Water pollution. APH Publishing Corporation, New Delhi, pp 211–218
13. Mukate, S., Wagh, V., Panaskar, D., Jacobs, J. and Sawant, A., 2019. Development of new integrated water quality index (IWQI) model to evaluate the drinking suitability of water. *Ecological Indicators*, 101, pp.348-354.
14. Şener, Ş., Şener, E. and Davraz, A., 2017. Evaluation of water quality using water quality index (WQI) method and GIS in Aksu River (SW-Turkey). *Science of The Total Environment*, 584-585, pp.131-144.
15. Hamzaoui-Azaza, F., Ketata, M., Bouhlila, R., Gueddari, M. and Riberio, L., 2010. Hydrogeochemical characteristics and assessment of drinking water quality in Zeuss–Koutine aquifer, southeastern Tunisia. Environmental Monitoring and Assessment, 174(1-4), pp.283-298.
16. Islam, M., Tusher, T., Mustafa, M. and Mahmud, S., 2013. Effects of Solid Waste and Industrial Effluents on Water Quality of Turag River at Konabari Industrial Area, Gazipur, Bangladesh. Journal of Environmental Science and Natural Resources, 5(2), pp.213-218.
17. Liu, C., Lin, K. and Kuo, Y., 2003. Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. Science of The Total Environment, 313(1-3), pp.77-89.
18. Matalas, N. and Reiher, B., 1967. Some comments on the use of factor analyses. Water Resources Research, 3(1), pp.213-223.
19. Şener, Ş., Şener, E. and Davraz, A., 2017. Evaluation of water quality using water quality index (WQI) method and GIS in Aksu River (SW-Turkey). Science of The Total Environment, 584-585, pp.131-144.
20. Shrestha, S. and Kazama, F., 2007. Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan. Environmental Modelling & Software, 22(4), pp.464-475.
21. Subba Rao, N., 2005. Seasonal variation of groundwater quality in a part of Guntur District, Andhra Pradesh, India. Environmental Geology, 49(3), pp.413-429.
22. Yim, O. and Ramdeen, K., 2015. Hierarchical Cluster Analysis: Comparison of Three Linkage Measures and Application to Psychological Data. The Quantitative Methods for Psychology, 11(1), pp.8-21.
23. Murtagh, F. and Legendre, P., 2014. Ward's Hierarchical Agglomerative Clustering Method: Which Algorithms Implement Ward's Criterion? *Journal of Classification*, 31(3), pp.274-295.
24. Norusis, M., 2007. *SPSS 15.0 Guide to Data Analysis*. Englewood Cliffs, N.J.: Prentice Hall.
25. Ramakrishnaiah, C., Sadashivaiah, C. and Ranganna, G., 2009. Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India. *E-Journal of Chemistry*, 6(2), pp.523-530.

26. Srivastava, A. and Sahami, M., 2009. *Text mining*. Boca Raton: CRC Press.
27. Ward, J., 1963. Hierarchical Grouping to Optimize an Objective Function. *Journal of the American Statistical Association*, 58(301), pp.236-244.
28. Yadav, A., Khan, P. and Sharma, S., 2010. Water Quality Index Assessment ofGroundwater in Todaraisingh Tehsil of Rajasthan State, India-A Greener Approach. *E-Journal of Chemistry*, 7(s1), pp. S428-S432.

APPENDIX

Appendix A Water Quality Indices value for WAWQI

	Sample No.	WQI	Comment	Excellent	Good	Poor	Very Poor	Unsuitable
Tongi Bazar	**RTB01**	253.17	Unsuitable	**30%**	**10%**	**10%**	**10%**	**40%**
	RTB02	42.086	Good					
	RTB03	21.67	Excellent					
	RTB04	140.35	Unsuitable					
	RTB05	129.153	Unsuitable					
	RTB06	13.32	Excellent					
	RTB07	13.57	Excellent					
	TTB08	55.78	Poor					
	TTB09	75.23	Very Poor					
	TTB10	189.89	Unsuitable					
2. Tongi Station	**RTS01**	253.17	Unsuitable	**27%**	**18%**	**9%**	**9%**	**36%**
	RTS02	42.04	Good					
	RTS03	21.67	Excellent					
	RTS04	140.3492	Unsuitable					
	RTS05	129.153	Unsuitable					
	RTS06	13.32	Excellent					
	RTS07	13.57	Excellent					
	RTS08	36.77	Good					
	TTS09	55.78	Poor					
	TTS10	75.23	Very Poor					

	TTS11	189.89	Unsuitable					
3. Cherag Ali	**RCA01**	193.89	Unsuitable	**17%**	**0%**	**0%**	**0%**	**83%**
	RCA02	136.084	Unsuitable					
	RCA03	10.994	Excellent					
	RCA04	112.9682	Unsuitable					
	RCA05	222.074	Unsuitable					
	TCA06	352.794	Unsuitable					
4. Gazipura	**RGP01**	235.187	Unsuitable	**0%**	**50%**	**0%**	**10%**	**40%**
	RGP02	202.315	Unsuitable					
	RGP03	29.35548	Good					
	RGP04	239.39	Unsuitable					
	RGP05	98.958	Very Poor					
	RGP06	245.918	Unsuitable					
	RGP07	46.82	Good					
	TGP08	28.19	Good					
	TGP09	55.83	Good					
	TGP10	30.37	Good					
5. Board Bazar	**RBB01**	255.91	Unsuitable	**10%**	**19%**	**10%**	**10%**	**51%**
	RBB02	261.57	Unsuitable					
	RBB03	116.37	Unsuitable					
	RBB04	32.05	Good					
	RBB05	58.41	Poor					
	RBB06	231.91	Unsuitable					
	RBB07	20.782	Excellent					

	RBB08	261.52	Unsuitable					
	RBB09	210.23	Unsuitable					
	RBB10	182.25	Unsuitable					
	RBB11	93.44	Very Poor					
	TBB01	175.937	Unsuitable					
	TBB02	168.524	Unsuitable					
	TBB03	149.9153	Unsuitable					
	TBB04	43.2647	Good					
	TBB05	46.4423	Good					
	TBB06	9.672721	Excellent					
	TBB07	152.075	Unsuitable					
	TBB08	52.53786	Poor					
	TBB09	89.87127	Very Poor					
	TBB10	26.21718	Good					
6. College Gate	**RCG01**	41.39108	Good	**10%**	**60%**	**20%**	**0%**	**10%**
	RCG02	48.94121	Good					
	RCG03	52.40894	Poor					
	TCG04	34.56511	Good					
	RCG05	10.59669	Excellent					
	RCG06	74.67655	Poor					
	TCG07	126.4308	Unsuitable					
	TCG08	39.56425	Good					
	TCG09	33.2555	Good					

	TCG10	48.08828	Good					
7. Kodda	**RKD01**	19.23951	Excellent	**33%**	**0%**	**0%**	**0%**	**67%**
	RKD02	187.0215	Unsuitable					
	TKD03	133.759	Unsuitable					
8. Jajhar	**RJJ01**	181.1165	Unsuitable	**9%**	**9%**	**9%**	**9%**	**64%**
	TJJ02	140.7731	Unsuitable					
	RJJ03	257.7558	Unsuitable					
	RJJ04	258.5551	Unsuitable					
	RJJ05	128.9539	Unsuitable					
	RJJ06	35.8544	Good					
	RJJ07	89.84405	Very Poor					
	TJJ08	296.0593	Unsuitable					
	TJJ09	16.16762	Excellent					
	TJJ10	275.7935	Unsuitable					
	TJJ11	163.1327	Unsuitable					
9.Borobari	**RBR01**	242.035	Unsuitable	**10%**	**0%**	**30**	**0%**	**60**
	RBR02	69.81158	Poor					
	RBR03	146.4352	Unsuitable					
	RBR04	53.79425	Poor					
	RBR05	128.8407	Unsuitable					
	RBR06	270.6226	Unsuitable					
	RBR07	13.54805	Excellent					

	TBR08	239.095	Unsuitable					
	TBR09	70.21412	Poor					
	TBR10	142.2065	Unsuitable					
10. Maleker Bari	**RMB01**	94.47699	Very Poor	**0%**	**0%**	**0%**	**20%**	**80%**
	RMB02	102.6074	Unsuitable					
	RMB03	117.0843	Unsuitable					
	TMB04	253.1364	Unsuitable					
	TMB05	169.6928	Unsuitable					
11. Konabari	**RKB01**	129.7573	Unsuitable	**0%**	**10%**	**30%**	**0%**	**60%**
	RKB02	50.56401	Poor					
	RKB03	92.65555	Very Poor					
	RKB04	41.856	Good					
	RKB05	89.101	Very Poor					
	RKB06	109.303	Unsuitable					
	RKB07	195.181	Unsuitable					
	TKB08	59.416	Poor					
	TKB09	138.141	Unsuitable					
	TKB10	71.129	Poor					
12. Chayabithy	**RCB01**	98.775	Very Poor	**0%**	**33%**	**17%**	**33%**	**17%**
	RCB02	35.754	Good					
	RCB03	148.902	Unsuitable					
	RCB04	94.219	Very Poor					
	RCB05	67.67	Poor					
	TCB06	29.808	Good					

13. Shibbari	**RSI01**	214.386	Unsuitable	**40%**	**20%**	**0%**	**0%**	**40%**
	RSI02	143.542	Unsuitable					
	RSI03	21.192	Excellent					
	RSI04	43.635	Good					
	RSI05	10.139	Excellent					
14. Dhirasrom	RDS01	232.593	Unsuitable	**0%**	**0%**	**20%**	**0%**	**80%**
	RDS02	172.719	Unsuitable					
	RDS03	66.757	Poor					
	RDS04	193.115	Unsuitable					
	RDS05	182.361	Unsuitable					
15. Bypass	**RBP01**	42.385	Poor	**0%**	**8%**	**17%**	**17%**	**58%**
	RBP02	210.601	Unsuitable					
	RBP03	88.265	Very Poor					
	RBP04	137.891	Unsuitable					
	RBP05	249.484	Unsuitable					
	RBP06	241.905	Unsuitable					
	RBP07	72.486	Poor					
	RBP08	109.977	Unsuitable					
	TBP01	126.396	Unsuitable					
	TBP02	40.912	Good					
	TBP03	215.524	Unsuitable					
	TBP04	76.28	Very Poor					
16. Joydebpur	**RJP01**	200.493	Unsuitable	**27%**	**18%**	**9%**	**18%**	**27%**
	RJP02	199.313	Unsuitable					

	RJP03	25.743	Good					
	RJP04	53.481	Poor					
	RJP05	40.866	Good					
	RJP06	131.596	Unsuitable					
	RJP07	99.952	Very Poor					
	TJP08	11.02	Excellent					
	RJP09	16.831	Excellent					
	TSJP10	14.295	Excellent					
	TJP11	84.366	Very Poor					
17. Signboard	**RSB01**	190.183	Unsuitable	**25%**	**0%**	**8%**	**17%**	**50%**
	RSB02	136.366	Unsuitable					
	RSB03	13.852	Excellent					
	RSB04	97.833	Very Poor					
	RSB05	222.351	Unsuitable					
	TSB06	341.084	Unsuitable					
	TSB07	21.644	Excellent					
	TSB08	52.885	poor					
	TSB09	19.245	Excellent					
	TSB10	314.162	Unsuitable					
	TSB11	178.847	Unsuitable					
	TSB12	99.402	Very Poor					
18. Chandna Chowrasta	**RCC01**	21.812	Excellent	**13%**	**27%**	**13%**	**7%**	**40%**
	RCC02	52.888	Poor					
	RCC03	51.77	Poor					

	RCC04	152.541	Unsuitable					
	RCC05	94.253	Very Poor					
	RCC06	25.049	Good					
	RCC07	24.134	Excellent					
	RCC08	127.338	Unsuitable					
	RCC09	40.495	Good					
	RCC10	123.444	Unsuitable					
	RCC11	172.739	Unsuitable					
	RCC12	30.676	Good					
	RCC13	223.894	Unsuitable					
	TCC14	170.303	Unsuitable					
	TCC15	40.295	Good					

Appendix B Water Quality Indices For IWQI

	Sample No.	**IWQI**	**Comment**	**Excellent**	**Good**	**Marginal**	**Poor**	**Unsuitable**
1. Tongi Bazar	**RTB01**	8.79	Unsuitable	**0%**	**30%**	**30%**	**20%**	**20%**
	RTB02	1.47	Good					
	RTB03	2.19	Marginal					
	RTB04	4.16	Poor					
	RTB05	3.61	Poor					
	RTB06	1.83	Good					
	RTB07	1.57	Good					
	TTB08	2.53	Marginal					
	TTB09	2.91	Marginal					
	TTB10	6.34	Unsuitable					
2. Tongi Station	**RTS01**	8.64	Unsuitable	**0%**	**18%**	**45%**	**18%**	**18%**
	RTS02	2.11	Marginal					

	RTS03	2.19	Marginal					
	RTS04	4.16	Poor					
	RTS05	3.61	Poor					
	RTS06	1.83	Good					
	RTS07	1.57	Good					
	RTS08	2.39	Marginal					
	TTS09	2.65	Marginal					
	TTS10	2.91	Marginal					
	TTS11	6.34	Unsuitable					
3. Cherag Ali	**RCA01**	4.71	Poor	**0%**	**0%**	**33%**	**33%**	**33%**
	RCA02	3.71	Poor					
	RCA03	2.32	Marginal					
	RCA04	2.84	Marginal					
	RCA05	5.86	Unsuitable					
	TCA06	8.45	Unsuitable					
4. Gazipura	**RGP01**	7.94	Unsuitable	**0%**	**0%**	**40%**	**20%**	**40%**
	RGP02	6.71	Unsuitable					
	RGP03	2.08	Marginal					
	RGP04	6.29	Unsuitable					
	RGP05	3.34	Poor					
	RGP06	6.79	Unsuitable					
	RGP07	2.2	Marginal					
	TGP08	2.84	Marginal					
	TGP09	2.4	Marginal					
	TGP10	3.23	Poor					
5. Board Bazar	**RBB01**	7.63	Unsuitable	**10%**	**14%**	**10%**	**33%**	**33%**
	RBB02	6.79	Unsuitable					
	RBB03	3.59	Poor					
	RBB04	0.85	**Excellent**					
	RBB05	2.85	Marginal					

	RBB06	5.61	Unsuitable					
	RBB07	7.33	Unsuitable					
	RBB08	6.79	Unsuitable					
	RBB09	5.47	Unsuitable					
	RBB10	5.07	Unsuitable					
	RBB11	3.31	Poor					
	TBB01	4.13	Poor					
	TBB02	3.94	Poor					
	TBB03	3.54	Poor					
	TBB04	1.42	Good					
	TBB05	0.91	**Excellent**					
	TBB06	2.72	Poor					
	TBB07	3.71	Poor					
	TBB08	1.67	Good					
	TBB09	2.65	Marginal					
	TBB10	1.68	Good					
6. College Gate	**RCG01**	0.89	**Excellent**	**10%**	**30%**	**50%**	**10%**	**0%**
	RCG02	2.08	Marginal					
	RCG03	2.58	Marginal					
	TCG04	1.46	Good					
	RCG05	1.36	Good					
	RCG06	1.16	Good					
	TCG07	2.35	Marginal					
	TCG08	3.73	Poor					
	TCG09	2.82	Marginal					
	TCG10	2.21	Marginal					
7. Kodda	**RKD01**	4.19	Poor	**0%**	**0%**	**67%**	**33%**	**0%**
	RKD02	9.21	Unsuitable					
	TKD03	4.11	Poor					
8. Jajhar	**RJJ01**	6.36	Unsuitable	**0%**	**9%**	**18%**	**9%**	**64%**
	TJJ02	7.26	Unsuitable					

	RJJ03	6.55	Unsuitable					
	RJJ04	10.79	Unsuitable					
	RJJ05	6.65	Unsuitable					
	RJJ06	1.04	Good					
	RJJ07	2.75	Marginal					
	TJJ08	7.97	Unsuitable					
	TJJ09	2.7	Marginal					
	TJJ10	7.06	Unsuitable					
	TJJ11	4.56	Poor					
9.Borobari	**RBR01**	6.71	Unsuitable	**0%**	**10%**	**30%**	**30%**	**30%**
	RBR02	2.79	Marginal					
	RBR03	3.43	Poor					
	RBR04	1.64	Good					
	RBR05	3.18	Poor					
	RBR06	6.74	Unsuitable					
	RBR07	2.04	Marginal					
	TBR08	6.15	Unsuitable					
	TBR09	2.25	Marginal					
	TBR10	3.98	Poor					
10. Maleker Bari	**RMB01**	2.46	Marginal	**0%**	**0%**	**20%**	**60%**	**20%**
	RMB02	3.03	Poor					
	RMB03	4.36	Poor					
	TMB04	6.37	Unsuitable					
	TMB05	4.64	Poor					
11. Konabari	**RKB11**	9.34	Unsuitable	**0%**	**0%**	**0%**	**0%**	**100%**
	RKB02	8.48	Unsuitable					
	RKB03	6.96	Unsuitable					
	RKB04	6.93	Unsuitable					

	RKB05	6.78	Unsuitable					
	RKB06	8.25	Unsuitable					
	RKB07	9.91	Unsuitable					
	TKB08	5.16	Unsuitable					
	TKB09	8.33	Unsuitable					
	TKB10	6.23	Unsuitable					
12. Chayabithy	**RCB01**	2.92	Marginal	**0%**	**33%**	**50%**	**17%**	**0%**
	RCB02	1.67	Good					
	RCB03	3.43	Poor					
	RCB04	2.35	Marginal					
	RCB05	2.16	Marginal					
	TCB06	1.58	Good					
13. Shibbari	**RSI01**	4.86	Poor	**0%**	**20%**	**20%**	**60%**	**0**
	RSI02	3.6	Poor					
	RSI03	3.72	Poor					
	RSI04	1.68	Good					
	RSI05	2.1	Marginal					
14. Dhirasrom	**RDS01**	6.05	Unsuitable	**0%**	**0%**	**20%**	**40%**	**40%**
	RDS02	3.93	Poor					
	RDS03	2.48	Marginal					
	RDS04	5.17	Unsuitable					
	RDS05	4.23	Poor					
15. Bypass	**RBP01**	1.64	Good	**0%**	**8.33%**	**8.33%**	**#####**	**50%**
	RBP02	6	Unsuitable					
	RBP03	3.81	Poor					
	RBP04	4.8	Poor					
	RBP05	6.53	Unsuitable					
	RBP06	6.68	Unsuitable					
	RBP07	5.48	Unsuitable					

	RBP08	3.24	Poor					
	TBP01	7.1	Unsuitable					
	TBP02	4.49	Poor					
	TBP03	7.05	Unsuitable					
	TBP04	2.59	Marginal					
16. Joydebpur	**RJP01**	4.31	Poor	**0%**	**54.54%**	**18.18%**	**#####**	**9.09%**
	RJP02	5.19	Unsuitable					
	RJP03	1.29	Good					
	RJP04	1.47	Good					
	RJP05	1.85	Good					
	RJP06	1.69	Good					
	RJP07	3.26	Poor					
	RJP08	2.17	Marginal					
	RJP09	1.83	Good					
	TSJP10	1.5	Good					
	TJP11	2.57	Marginal					
17. Signboard	**RSB01**	4.65	Poor	**0%**	**0%**	**16.66%**	**#####**	**41.66%**
	RSB02	4.24	Poor					
	RSB03	2.95	Marginal					
	RSB04	3.6	Poor					
	RSB05	6.45	Unsuitable					
	TSB06	8.25	Unsuitable					
	TSB07	8.34	Unsuitable					
	TSB08	4.56	Poor					
	TSB09	2.07	Marginal					
	TSB10	9.56	Unsuitable					
	TSB11	6.45	Unsuitable					
	TSB12	3.69	Poor					
18. Chandna Chowrasta	**RCC01**	2.28	Marginal	**0%**	**33.33%**	**20%**	**40%**	**6.66%**
	RCC02	1.78	Good					
	RCC03	1.74	Good					
	RCC04	3.94	Poor					
	RCC05	3.05	Poor					

	RCC06	1.73	Good					
	RCC07	2.15	Marginal					
	RCC08	3.67	Poor					
	RCC09	1.79	Good					
	RCC10	3.56	Poor					
	RCC11	4.78	Poor					
	RCC12	1.63	Good					
	RCC13	5.71	Unsuitable					
	TCC14	4.41	Poor					
	TCC15	2.12	Marginal					

Appendix C Water Quality Indices Assigned Weight Method

	Sample No.	**IWQI**	**Comment**	**Excellent**	**Good**	**Marginal**	**Poor**	**Unsuitable**
Tongi Bazar	**RTB01**	98.192	Marginal	**10.0%**	**50.0%**	**20.0%**	**20.0%**	**0.0%**
	RTB02	37.837	Good					
	RTB03	33.606	Good					
	RTB04	61.193	Marginal					
	RTB05	57.893	Marginal					
	RTB06	27.501	Good					
	RTB07	21.611	Excellent					
	TTB08	46.096	Good					
	TTB09	47.153	Good					
	TTB10	78.676	Marginal					
2. Tongi Station	**RTS01**	98.192	Marginal	**9.1%**	**54.5%**	**18.2%**	**18.0%**	**0.0%**
	RTS02	37.837	Good					
	RTS03	33.606	Good					
	RTS04	61.193	Marginal					
	RTS05	57.893	Marginal					
	RTS06	27.501	Good					
	RTS07	21.611	Excellent					
	RTS08	32.567	Good					
	TTS09	46.096	Good					
	TTS10	47.153	Good					
	TTS11	78.676	Marginal					
	RCA01	65.248	Marginal	**0.0%**	**16.7%**	**66.7%**	**0.0%**	**16.7%**

3. Cherag Ali	**RCA02**	57.433	Marginal					
	RCA03	32.212	Good					
	RCA04	64.046	Marginal					
	RCA05	70.075	Marginal					
	TCA06	102.771	Unsuitable					
4. Gazipura	**RGP01**	87.386	Marginal	**0.0%**	**50.0%**	**20.0%**	**30.0 %**	**0.0%**
	RGP02	76.337	Marginal					
	RGP03	29.921	Good					
	RGP04	69.827	Marginal					
	RGP05	52.171	Marginal					
	RGP06	84.782	Marginal					
	RGP07	31.236	Good					
	TGP08	38.998	Good					
	TGP09	39.834	Good					
	TGP10	40.276	Good					
5. Board Bazar	**RBB01**	86.400	Marginal	**0.0%**	**28.6%**	**57.1%**	**14.3 %**	**0.0%**
	RBB02	73.071	Marginal					
	RBB03	64.086	Marginal					
	RBB04	42.290	Good					
	RBB05	53.055	Marginal					
	RBB06	82.671	Marginal					
	RBB07	91.697	Marginal					
	RBB08	72.948	Marginal					
	RBB09	64.406	Marginal					
	RBB10	71.317	Marginal					
	RBB11	55.454	Marginal					
	TBB01	67.052	Marginal					
	TBB02	69.672	Marginal					
	TBB03	55.660	Marginal					
	TBB04	42.130	Good					
	TBB05	39.290	Good					
	TBB06	43.770	Good					
	TBB07	62.890	Marginal					
	TBB08	42.844	Good					
	TBB09	53.899	Marginal					
	TBB10	31.090	Good					
6. College Gate	**RCG01**	36.980	Good	**0.0%**	**90.0%**	**0.0%**	**10.0 %**	**0.0%**
	RCG02	47.233	Good					

	RCG03	43.690	Good					
	TCG04	35.167	Good					
	RCG05	27.330	Good					
	RCG06	44.828	Good					
	TCG07	58.099	Marginal					
	TCG08	47.104	Good					
	TCG09	32.640	Good					
	TCG10	38.710	Good					
7. Kodda	**RKD01**	36.570	Good	**0.0%**	**33.3%**	**66.7%**	**0.0%**	**0.0%**
	RKD02	70.560	Marginal					
	TKD03	56.159	Marginal					
8. Jajhar	**RJJ01**	60.728	Marginal	**0.0%**	**27.3%**	**36.4%**	**36.4 %**	**0.0%**
	TJJ02	52.629	Marginal					
	RJJ03	81.090	Marginal					
	RJJ04	77.564	Marginal					
	RJJ05	48.840	Good					
	RJJ06	38.623	Good					
	RJJ07	53.980	Marginal					
	TJJ08	99.080	Marginal					
	TJJ09	37.530	Good					
	TJJ10	91.020	Marginal					
	TJJ11	58.050	Marginal					
9.Borobari	**RBR01**	88.400	Marginal	**0.0%**	**30.0%**	**40.0%**	**40.0 %**	**0.0%**
	RBR02	47.101	Good					
	RBR03	54.080	Marginal					
	RBR04	51.533	Marginal					
	RBR05	58.414	Marginal					
	RBR06	81.590	Marginal					
	RBR07	33.711	Good					
	TBR08	84.069	Marginal					
	TBR09	36.240	Good					
	TBR10	54.756	Marginal					
10. Maleker Bari	**RMB01**	50.000	Good	**0.0%**	**20.0%**	**60.0%**	**20.0 %**	**0.0%**
	RMB02	58.155	Marginal					
	RMB03	63.480	Marginal					
	TMB04	82.260	Marginal					
	TMB05	59.820	Marginal					
11. Konabari	**RKB01**	96.690	Marginal	**0.0%**	**0.0%**	**20.0%**	**70.0 %**	**10.0%**
	RKB02	88.390	Marginal					

	RKB03	76.000	Marginal					
	RKB04	75.926	Marginal					
	RKB05	84.142	Marginal					
	RKB06	89.259	Marginal					
	RKB07	102.912	Unsuitable					
	TKB08	65.900	Marginal					
	TKB09	94.312	Marginal					
	TKB10	69.208	Marginal					
12. Chayabithy	**RCB01**	52.065	Marginal	**0.0%**	**33.3%**	**66.7%**	**0.0%**	**0.0%**
	RCB02	32.800	Good					
	RCB03	56.649	Marginal					
	RCB04	47.333	Good					
	RCB05	37.590	Good					
	TCB06	33.930	Good					
13. Shibbari	**RSI01**	81.258	Marginal	**0.0%**	**60.0%**	**20.0%**	**20.0 %**	**0.0%**
	RSI02	58.745	Marginal					
	RSI03	31.399	Good					
	RSI04	34.719	Good					
	RSI05	28.064	Good					
14. Dhirasrom	RDS01	71.818	Marginal	**0.0%**	**20.0%**	**80.0%**	**0.0%**	**0.0%**
	RDS02	62.243	Marginal					
	RDS03	45.664	Good					
	RDS04	61.154	Marginal					
	RDS05	65.334	Marginal					
15. Bypass	**RBP01**	37.280	Good	**0.0%**	**16.7%**	**41.7%**	**41.7 %**	**0.0%**
	RBP02	77.282	Marginal					
	RBP03	64.646	Marginal					
	RBP04	65.117	Marginal					
	RBP05	85.874	Marginal					
	RBP06	79.965	Marginal					
	RBP07	65.020	Marginal					
	RBP08	51.512	Marginal					
	TBP01	78.232	Marginal					
	TBP02	53.511	Marginal					
	TBP03	86.313	Marginal					
	TBP04	47.846	Good					
16. Joydebpur	**RJP01**	64.996	Marginal	**9.1%**	**63.6%**	**27.3%**	**0.0%**	**0.0%**
	RJP02	69.768	Marginal					

	RJP03	26.993	Good					
	RJP04	37.419	Good					
	RJP05	40.785	Good					
	RJP06	59.831	Marginal					
	RJP07	47.945	Good					
	TJP08	26.830	Good					
	RJP09	27.868	Good					
	TSJP10	23.022	Excellent					
	TJP11	44.078	Good					
17. Signboard	**RSB01**	67.861	Marginal	**0.0%**	**25.0%**	**50.0%**	**16.7 %**	**8.3%**
	RSB02	61.583	Marginal					
	RSB03	38.517	Good					
	RSB04	65.195	Marginal					
	RSB05	58.653	Marginal					
	TSB06	97.723	Marginal					
	TSB07	36.607	Good					
	TSB08	59.613	Marginal					
	TSB09	42.022	Good					
	TSB10	104.162	Unsuitable					
	TSB11	78.232	Marginal					
	TSB12	52.251	Marginal					
18. Chandna Chowrasta	**RCC01**	39.870	Good	**0.0%**	**60.0%**	**40.0%**	**0.0%**	**0.0%**
	RCC02	38.592	Good					
	RCC03	41.956	Good					
	RCC04	55.567	Marginal					
	RCC05	42.834	Good					
	RCC06	30.743	Good					
	RCC07	37.501	Good					
	RCC08	52.436	Marginal					
	RCC09	34.887	Good					
	RCC10	56.996	Marginal					
	RCC11	55.503	Marginal					
	RCC12	37.218	Good					
	RCC13	71.673	Marginal					
	TCC14	61.048	Marginal					
	TCC15	33.120	Good					