A STUDY ON THE RISK OF CONTAMINATION OF DRINKING WATER IN INTERMITTENT PUBLIC WATER SUPPLY SYSTEM AND PACKAGED DRINKING WATER.

A thesis submitted toward partial fulfillment of the requirements for the degree of

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

submitted by

MONALISA GUHA BISWAS

Exam Roll No: M6WRP19004

Under the guidance of

PROF. (Dr.) ARUNABHA MAJUMDER
Emeritus Professor
And
PROF. (Dr.) PANKAJ KUMAR ROY
Professor

School of Water Resources Engineering, Jadavpur University

School of Water Resources Engineering
M.E. (Water Resources & Hydraulic Engineering) course affiliated to Faculty of Engineering & Technology
Jadavpur University
Kolkata 700032, India
2019

M.E. (Water Resources & Hydraulic Engineering) course affiliated to
Faculty of Engineering & Technology
Jadavpur University
Kolkata, India

Certificate of Recommendation

This is to certify that the thesis entitled "**A Study on the risk of contamination of drinking water in intermittent public water supply system and packaged drinking water.**" is a bonafide work carried out by **Ms. Monalisa Guha Biswas** under our supervision and guidance for partial fulfillment of the requirement for the Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academic session 2017-2018

THESIS ADVISOR
Prof. (Dr.) Arunabha Majumder
Emeritus Professor
School of Water Resources Engineering
Jadavpur University
Kolkata-700032

THESIS ADVISOR
Prof. (Dr.) Pankaj Kumar Roy
Professor
School of Water Resources Engineering
Jadavpur University
Kolkata-700032

DIRECTOR
Prof. (Dr.) Asis Mazumdar
School of Water Resources Engineering
Jadavpur University
Kolkata-700032

DEAN
Prof. (Dr.) Pankaj Kumar Roy
Faculty of Interdisciplinary Studies, Law & Management
Jadavpur University

M.E. (Water Resources & Hydraulic Engineering) course
affiliated to
Faculty of Engineering & Technology
Jadavpur University
Kolkata, India

CERTIFICATE OF APPROVAL **

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

Committee

_____

Final Examination
for the evaluation
of the thesis

_____

_____

** Only in case the thesis is approved.

Declaration of Originality and Compliance of Academic Ethics

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of my **Master of Engineering** in **Water Resources & Hydraulic Engineering** in the Faculty of Interdisciplinary Studies, Jadavpur University during academic session 2018-19

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

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

Name : **Monalisa Guha Biswas**

Exam Roll Number : **M6WRP19004**

Thesis Title : **A Study on the risk of contamination of drinking water in intermittent public water supply system and packaged drinking water.**

Signature with Date :

ACKNOWLEDGEMENT

I express my sincere gratitude and thanks to my supervisor ***Prof. (Dr.) Arunabha Majumder,*** *Emeritus Professor of School of Water Resources Engineering, Jadavpur University and* ***Prof. (Dr.) Pankaj Kumar Roy,*** *Professor of School of Water Resources Engineering, Jadavpur University. Without their support and guidance, it was impossible for me to carry out this project*

I would also like to express my sincere gratitude to ***Prof. (Dr.) Asis Mazumdar****, Director;* ***Dr. Subhasish Das,*** *Assistant Professor of School of Water Resources Engineering, Jadavpur University for their valuable suggestions.*

Moreover, I would like to express my sincere thanks to ***Dr. Gourab Banerjee****, Assistant Professor of School of Water Resources Engineering, Jadavpur University for his support and hard work during my thesis work.*

Thanks are also due to all staff of School of Water Resources Engineering of Jadavpur University and the Regional centre for their help and support.

In addition, I also express my special thanks and gratitude to my husband Mr. Aritra Dasgupta for his constant support and help throughout the whole work. I would also like to express a thanks to one of my senior Somnath Pal and my friend Chaiti Ray for encouraging me from the very beginning of this course.

Most significantly I would like to express my gratitude, thanks and gratefulness to my parents without whom I would not be able to do anything in my life.

Date : 31 May, 2019

MONALISA GUHA BISWAS
Examination Roll No- M6WRP19004

ABSTRACT

This study was done to compute the physicochemical and bacteriological quality of water supplied by Kolkata Municipal Corporation (KMC) (initial 15 minutes) and packaged drinking water (PDW) purchased from various brands in the city and its effects on human health. Here the two types of water quality has been compared with respect to Indian and others standards. The samples were collected from different key locations of the Kolkata city. These samples include 17 types of bottled packaged drinking water and 17 types of KMC tap water. The physical, chemical and bacteriological parameters of these samples were tested in the laboratory of School of Water Resources and Hydraulic Engineering, Jadavpur University, as per the guidelines of APHA and some test were conducted with some kit. No bacteria were found in the samples of PKD but in the samples of KMC supply water (initial 15 minutes) there are some bacteria in most of the cases. In this study PKD water had pH value less than 6.5 at least 20% and which was acidic but the KMC water had the pH within the range 6.5-8.5. In case of PKD water the value of TDS was low. The PKD had low concentration of other minerals also. So long term consumption of PKD drinking water had adverse effect on human health. On the other side KMC water had higher values of all minerals and only exception was found in case of bacteria when the water was collected early in the morning.

CONTENT

CHAPTER 1

INTRODUCTION

1.1 AN OVERVIEW

Water is one of the most valued, indispensible resources available in planet for all living organisms. Internal consumption of water (direct drinking, cooking) by human beings through any means should always be hygienic enough as per IS 10500:2012 (Indian standard Drinking water specification). It is very much important to analyze the water to assess its potability as per BIS Standard (10500:2012). In public water supply system, the water supplied to the consumers must be safe and accordingly, water must be free from bacteriological and chemical contamination. Water and health are interlinked. Drinking of contaminated water may cause water-borne diseases. Hence, adequate as well as safe water supply will safeguard public health.

Main sources of drinking water typically in Indian cities can be broadly classified into two categories i.e.

1. **Surface water (River, Lake, Pond, Canals etc.)**
2. **Ground water (Bore-well, Tube-well, Dug well etc)**

In India, Surface water after conventional treatment is supplied in mega / metro cities. In small towns ground water drawn through bore-wells is supplied to the consumers. However, surface water after conventional treatment is also supplied in small towns subject to the availability of the surface sources. In cities and towns, water is mostly supplied through piped network system. Around 85 % of rural populations in the country are dependent on groundwater for public water supply.

In India, as per Constitution, Water is a State subject. Therefore, in urban areas water is supplied by Municipal Corporations or Municipalities. In rural areas responsibility of water supply lies with Public Health Engineering Department and Panchayats.

Increasing growth of population, climate change, and rapid urbanization and land conversion resulted in increasing demand of water consumption. It is observed that nationwide scarcity of drinking water almost each and every year, especially during summer, creates a serious problem among the people and livestock in rural areas as well as in the outskirts of the cities/towns. In such a situation it is a challenge for the concerned agencies to maintain water supply as per required quantity and desired quality. However sometimes due to sudden damage in the pipe lines, valves etc. in the water supply system may cause risk of contamination.

In piped water supply system, water is supplied intermittently. The supply time varies between 3 and 7 hours normally. During non-supply time, water in the pipelines remains under non-pressure condition and as a result water in the pipe line may get contaminated due to entry of pollutants through cracks / leakages. Thus, there may be risk in drinking water from the taps during initial supply time (may be for 10 / 15 min) as the water may be bacteriologically contaminated.

Packaged drinking water are getting manufactured in the country due to increasing demand from the consumers. People are becoming conscious about the quality of drinking water. Manufacturers of packaged drinking water have to maintain quality of water as per Specification / Standard laid down by BIS. The packaged drinking water manufactures normally adopt micro-filtration, ultrafiltration, activated carbon filtration, nano-filtration, membrane filtration (reverse osmosis), ozonization and U-V disinfection etc. Several entrepreneurs and renowned manufacturing agencies have set-up their respective production plants/units nationwide for carrying out business of **packaged drinking water**. Nowadays, it is been seen that in cities and towns, people consume

packaged drinking water for fulfilling their drinking and cooking needs instead of drinking water from public supply taps.

Packaged Drinking Water

Fig1: Packaged drinking water bottles.

1.2 STUDY AREA

The study area was carried out in the Kolkata Municipal area. The latitude of Kolkata is 22.5726°N and longitude 88° 3639' E. The total city area is 205 km^2 and it is located on the bank of Hooghly river. Kolkata is the 7^{th} populated city in India and its population is about 45 lakhs. (As per the provisional reports released on 31 March 2011.The use of packaged drinking water is getting latger in our daily life in this city. At the same time people also use the street tap water which is supplied by the Kolkata Municipal Corporation. All the samples were collected from Gariahat, Sealdah, Howrah station, Esplanade, Jadavpur area, Charu market, Budge Budge. Some samples were also collected from KMC tap water (collected first water early in the morning). These samples were collected from different ward under KMC mainly in south Kolkata.The details of the ward are as follows:

Table:1 List of Ward name and location:

Sl.No	Ward No.	Covered Area /Location
1.	81	New Alipore
2.	89	Charu Market
3.	91	Kasba
4.	93	Lake Gardens
5.	94	Naveena Cinema Hall
6.	95	Azadgargh
7.	96	Bijoygargh
8.	97	Ashok Nagar
9.	98	Gandhi Colony
10.	99	Jadavpur
11.	100	Naktala
12.	101	Baghajatin
13.	102	KPC Medical College
14.	103	New Santoshpur
15.	110	Township Garia
16.	112	Bansdroni
17.	113	Kalitala

1.3 OBJECTIVE:

1. Toassess the quality of water in public water supply system for the city of Kolkata during initial period of intermittent supply.
2. To study health risk associated with drinking of water during initial period of intermittent supply for city of Kolkata.
3. To study the quality of **packaged drinking water** consumed by the citizens in Kolkata. (registered)

1.4 SCOPE OF WORK:

i. Collection and analysis of supply water from city taps during initial time of intermittent supply (Initial 15 minutes)

ii. Analysis of water for chemical and bacteriological parameter as per SOP (standard operational procedure) (APHA) in the laboratory.

iii. Collection of **packaged drinking water**bottle from different location of the city for qualitative analysis of water.

iv. Qualitative analysis of **packaged drinking water**as per SOP (APHA) in the laboratory.

v. Review the results of the water quality analysis and assess the risk of drinking if any.

vi. To suggest control measure to minimize hazards and risk of water contamination.

.

1.5 METHODOLOGY:

(a) Collection of sample

(I) **KMC Tap Water:** The samples were collected in sterilized bottle from different wards under KMC and following informations were noted:

1. Sample identification mark
2. Date of Collection
3. Covered area / Location
4. Quantity of sample
5. Ward number.

(II) **Packaged Drinking Water-:** The samples were collected from (various brands) different parts of the Kolkata city and the following informations were noted:

1. Sample identification mark.
2. Date of Collection.
3. Location.
4. Brand name.
5. Manufacturer name
6. Date of manufacture.

(b) Testing of sample

The presence of coliform bacteria was detected by H2S strip (Field Kit)

Simultaneously the samples were analysed in the laboratory for different parameters, such as; pH, **turbidity**, **total dissolved solid** (TDS), **total hardness** (TH), **chloride, total coliform and faecal coliform as per APHA guideline.**

CHAPTER 2

LITERATURE REVIEW

2.0 Literature review

Majumder. A, Roy.P.K. et.al (2016) managed to conduct the physical, chemical and bacteriological qualiy of PKD which was sold in Kolkata city and its side effect on human health. They compared the quality of packaged drinking water and the water supplied by Kolkata Municipal Corporation (KMC). They compared with bottled water of several brands of different countries w.r.t WHO, and other international standards. They collected 27 bottled PKD water samples, 10 bubble top(PKD) can samples and 18 samples of water which was collected from KMC. As per APHA guidelines they tested the physical, chemical and bacteriological parameterof those samples at SWRE, Jadavpur University and the sample were also tested with some Kit. Bacteria was not found in the above mentioned samples. The results showed that the pH values of PKD was below 6.5 which was acidic, rather than the water supplied by KMC had pH value within (6.6-8.5) which is in acceptable range. All the PKD had low concentration of Ca, Mg, TDS, TH whereas the water supplied by KMC had the concentration of those parameters. So it is not good for human healthto consume of low concentration of mineral.

Sudarsan et.al managed to conduct an exercise methodically in Chennai (previously known as Madras) city to determine the physical, chemical and bacteria related quality standard of sold across various blocks of the respecrive study area. Sufficient & adequate supply of safeguarded water areas is a real issue which is increasing day by day. However now a days to cater and address this problem packaged drinking water is being rapidly used in households as well as different type of working places. During this exercise they opted for 40 major blocks/locations of the Chennai city for subsequent study & analysis. All the samples were collected from the respective providers which were to be analyzed based on the above mentioned three parameters (physical, chemical and bacteriological) The whole analysis was based on WHO defined standard known as WQI, provides simple method for water quality monitoring. As per the WQI results obtained it was evident that bubble top cans & sachet were found to be polluted with respect to packaged bottle drinking water.

MihayoI.Z.et.al (2012) executed a series of experiments in MWANZA city (Tanzania) which involved study & analysis of the physical, chemical parameters in comparison with drinking water standards for different types of bottled waters available in the retail shops across the same city. The result obtained post analysis/study show that the ranged varied from very low concentration (brands A and B) to low concentrations for TDS standard. As per the classification criteria of total hardness, most of the brands were having soft water; however, the only exception was brand E which was of moderately hard in nature. In the label of bottles, the number and different parameters mentioned showed inconsistency w.r.t homogeneity. Most of the brands highlighted basic parameters like ions, though for few of the brands generic parameters were noticed. When compared with Tanzania Bureau parameters & World Health Organization defined protocols for drinking water, approximately all branded sample of bottled drinking water lied within the threshold limit defined by WHO & TBS for drinking water. As a conclusion of the whole study and analytical experiments conducted it was considered that the bottled water manufactured by those brands were safe for human consumption (drinking purposes).

Brindha et.al.(2017) collected the preliminary data regarding the behaviour of consumers against bottled drinking water. The water which is derived from portable water after passing through some treatments mainly different type of filtration (membrane filter, accretions, activated carbon filter

etc) known as packaged drinking water. In this study the consumers mainly focused in the quality of packaged drinking water of particular brand. As per consumer's viewpoint packaged drinking water was more hygienic than tap water. Manufacturers were advised to do the necessary action for hygienic point during the making of bottled drinking water. The use of bottled drinking water by people was one of the reason for pollution problems.

Patil V. T.et. al (2013) carried out the study by collecting groundwater from the month of November 2009 to February 2010 from various points in Amalner town and tested the physical, chemical parameter. For drinking purpose, the groundwater quality was assessed by Water quality index(WQI). The study showed that the samples from some areas like Shivaji Nagar, Dheku road, weekly market were good for drinking and some samples were not found good. The higher values of TDS, TH, EC, TA affected the quality of ground water.

Mufid al-hadithi (2012) evaluated the availability of groundwater for drinking purpose in Ratmao –PathriRaoWatershed, Haridwar District. WQI was used to calculate the same. In this study 21 samples were collected from 11 locations. Toexamine the physicochemical test the following parameter were used to determine WQI (pH, TH, Ca, Mg, biocarbonate, nitate, chloride, sulphate&TDS.) As a result of WQI it was categorized that 48% was good and 48% was excellent. At Teliwala village 4% which was categorized in very poor and it was not suitable for drinking. The higher value of water quality index was caused by TDS, Ca, bicarbonate and potassium.

Choudhary Ranjeeta et. al (2012) managed to conduct the physicochemical analysis of the Kerwa dam, Kolar dam and Kaliasote dam of Bhopal to execute the acceptance of surface water for the purpose of drinking.They considered two key locations of each Dam for collecting the samples and the physicochemical analysis were done to see the condition of the water of that period of time.As per WHO guidelines most of the parameters were in permissible limits only exception for COD and total hardness.The value of COD & total hardness had higher values than the values given in the WHO guidelines(1993) (18mg/l to 30mg/l and 118mg/l to 170mg/l respectively).

Edema MO et. Al (2011) conducted a study with respect to the bacteriological quality of packaged drinking water manufactured by private companies who were hardly aware about the manufacturing best practices. Also these packaged drinking water supply was increasing at an exponential growth as because the govt. of Nigeria was not able to provide the pollution free, safe water to the whole population. This test was carried out in south-western Nigeria and mainly focused on pathogenic bacteria (108 water samples), to assess the Whether this product was contributing to diseases like typhoid fever and other illness. The main investigation technique used were Ten-fold serial dilution of the samples of water and the pour plate technique to determine the presence of *Salmonella and the indicator E- coli* in sachet drinking water samples. Isolate Characterization was there by in-vitro cultural, morphological and biochemical characteristics. The results revealed the fact that 87% sachet-**packaged** drinking water samples had Salmonella / *Escherichia coli* which indicated the fecal contamination and improper treatment of water. The packaging was not upto the mark for more than 65% of the samples. More than 90% of water samples had high aerobic counts that are 6logs CFU/ml. The value of E. coli count and Salmonella counts were found to be 98 & 106

Cfu/100ml and $2.12x10^{1}$ and $2.20x10^{1}$respectively. The results of this study were that sachet-packeddrinking water samples did not fit for microbiological standards.

Ramakrishnaiah C.Ret. al (2009) did an assessment of water quality index(WQI) of groundwater in Tumkurtaluk. The WQI determination process involved collection of groundwater samples and a detail physicochemical analysis of those. WQI calculation was based on 12 parameters i.e. pH, Total Hardness, bicarbonate, nitrate, total dissolved solids, iron, fluorides, magnesium, sulphate, chloride, calcium and manganese. The range of WQI varied from 89.21 to 660.56. Mainly higher values of total dissolved solids,
Bicarbonate, iron, nitrate, manganese and fluorides resulted in higher value of WQI in the groundwater. They did an analysis with the results data to come up with a model which will help to predict the water quality. These whole analysis and study indicated that some degree of treatment were needed for groundwater of these areas before consumption and should have been safeguarded from getting contaminated.
.

Rebecca L et. al analysed the study which was published in the year of 1957- 1979 and reported about reverse connection between the hardness of water and cardiovascular destruction. In water supply system where the hardness of water level or Ca and Mg were found high, the rate of cardiovascular death were reduced. whereasthe investication reports stated that the risk of cardiovascular death was found at least 25% excess in soft water areas.

CHAPTER 3

REVIEW OF DRINKING WATER QUALITY PARAMETERS

3.1 Water Quality Parameters:

The physicochemical and bacteriological parameters are described below:

3.1.1 Physical Water Quality:

The physical quality of water includes Turbidity, suspended solids, and colour, Taste and Odour, Temperature.

Turbidity:

The quality of drinking water is significantly governed by the turbidity of the water. It indicates the degree to which the water loses its clarity and transparency because of the presence of different solids in water. Turbidity of water increases with the increased amount of total suspended solids in water. These solids may include sediments of erosion, waste discharges, algae growth, phytoplankton, runoff from urban areas etc. This parameter is measured by the amount of light scattered by the solids present in water. Higher Intensity of scattering of light indicates higher turbidity in water.

Absorption of heat by the solids results in increase of temperature of water that causes decrease in concentration of oxygen in water. As a result, aquatic life may get hampered effectively. Moreover, the ambience of water in higher temperature becomes much more suffocating than normal condition that causes growth of pathogens which in turn leads to different water borne diseases. The particles causing turbidity provides shelter to the protozoa and microbes that causes reduction functional effectiveness of disinfectants. In municipal water treatment plants, turbidity removal is a significant part that is to be monitored with higher precision. Turbid water is highly undesirable from aesthetic point of view. Disinfection is also very much important for removal of turbidity of water to be used for drinking purpose.

Suspended Solids:

Solids may present in water both in suspended as well as in dissolved form. Usually, the presence of this parameter can be observed by physical perception, but the presence of dissolved solids can be appropriately monitored in tests falling under chemical parameters.

Suspended solids may present in water in both inorganic and organic form. Organic constituents may include silt, clay and other soil particles whereas organic solids may include different biological solids like algae cells, bacteria etc. and plant fibres. Another significant source of suspended solid is waste water generated from human use that is mostly organic in nature. Surface water usually contains higher magnitude of suspended solids as compared to ground water.

Presence of suspended solids in water is not desirable at all for as far as the drinking quality of water is considered. Aesthetically, water containing suspended solid is also objectionable. Solid particles also provide sites for adsorption of biological and chemical agents. By products generated from degradation of suspended solids are also not desirable at all.

Colour:

No noticeable colour is observed in pure water. Coloured water is caused mainly because of the presence of foreign material in it. Suspended as well as dissolved both types of solids contribute to the change in colour of water. Colour caused due to the presence of suspended solids are usually known as apparent colour as this kind of colour can be removed by removing the suspended solids from water. But the colour that exists even after removal of suspended solids is called true colour as this kind of colour is a result of presence of dissolved solids in water.

A bit coloured water is not harmful always as it may be caused due to the presence of some dissolved mineral those are essential for human health. Contaminants are usually removed from water in treatment plant. But at user point, coloured water may be obtained which is a result of contamination of different elements like manganese, copper, iron etc. from the conveyance system i.e. from the pipe network. De ionized and de mineralized water tastes flat. Though a bit coloured water containing beneficial minerals are highly recommended for drinking, but people usually prefer clear water even if it is of poorer quality than the coloured water. Hence, from aesthetic point of view, coloured water is unappealing. So, the colour of water matters as far as the drinking purpose of water is considered. Even for some other domestic uses and a few industrial uses also, the colour of water affects the use. Highly coloured water is also not acceptable in laundry, paper making beverage manufacturing works. So the marketability is also affected by the colour of water.

Taste and odour:

Taste and odour are very much co related to each other and even often confused with each other as the physical perception for both of them are quiet similar. A wide range of odour and taste may be imparted in water by consumers. Elements that develops odour will invariably develop taste, whereas the reverse is not always obvious as certain minerals may present in water those imparts taste in water but not odour.

Different substances with which water comes in contact during their flow in nature or at the time of use by human imparts colour and odour in water. These includes end products from biological reactions, waste water products, mineral, metals present in soil etc. Inorganic substances has a tendency to produce taste only but not odour. A bitter taste may be caused due to the presence of alkaline material in water whereas metallic salt imparts a salty test. On the other hand, taste and odour both may result from the presence of organic matter. Decomposition of those matter may even lead to the generation of odour producing liquid and gases like rotten egg smell of H_2S gas in water.

Acceptability of water having taste and odour in society is still not that much observed as people are having a concept that tasteless and odourless water is pure and safe for drinking purpose as they associate contamination of undesirable substances with the presence of taste and odour in water. Hence, even being inferior in nature, people sometimes prefer tasteless and odourless water.

Temperature:

Though temperature is not such a parameter to judge the quality of drinking water, but indirectly it governs different activities associated with water. In surface water system, the sustainability of aquatic life is effectively controlled by the temperature of prevailing water. A specified range of

temperature is one of the controlling factor for survival of any kind of zooplankton, phytoplankton and other aquatic species present in water. An extreme temperature may cause extinction of some species.

Temperature also governs the chemical reactions in water. Solubility of minerals from the surrounding rock in higher temperature is obvious in groundwater and thus possess higher electrical conductivity. But in case of gas, it requires reverse condition. In case of oxygen, the solubility is lower in case of higher temperature. So, at higher temperature, due to the lesser amount of dissolved oxygen, existence of some aquatic species may hamper.

Physical properties of water are also affected by the prevailing temperature. Viscosity of water decreases with increase in temperature which in turn increase the permeability of ground water through the interconnected pore spaces in soil.

3.1.2 Chemical Water-Quality:

Water is widely accepted as universal solvent. Chemical parameters are associated with the degree to which different minerals are able to get dissolved in water. pH, total dissolved solids, total hardness, alkalinity, chloride, fluoride etc. are some of the significant parameters that controls the chemical quality of water. Some of the chemical parameters are briefly discussed below.

pH:

pH is one of the most significant parameter controlling the quality of water as it not only affects the survival of different organisms present in water, but it is one of the indicator of pollution level in water also.

From chemical point of view, pH indicates the relative presence of hydrogen and hydroxyl ion in water. Based on their presence, the water is termed as acidic or basic. Acidic water contains more free hydrogen ions while basic water contains more hydroxyl ions. pH is represented in logarithmic scale. The general range of pH of water is 0 to 14. pH value less than 7 indicates acidic water and above 7 indicates basic water. pH value 7 is considered as neutral. As it is represented in logarithmic scale, hence water having pH value 4 is ten times acidic than water having pH value 5. pH value is highly affected by the presence of different chemical in water and hence a significant indicative of chemical changes in water. Solubility of different minerals, biological availabilities of nutrients like ammonia, phosphorous etc. and presences of heavy metals are governed by the pH of the water sample. For example, at lower pH heavy metals are more soluble in water that may leads to increase the toxicity of the water.

Extreme values of pH are detrimental for both consumers and the supply system as well. Higher pH imparts bitter taste in water. Encrustation in pipe may happen at higher pH that may lead to the reduction in effectiveness of the applied disinfectant. On the other hand, lower pH may corrode the pipe network, dissolve other metals and substances leading to a contaminated supply at the user point.

Total dissolved solids:

As water is a very good solvent in nature, it may dissolve any kind of metal, mineral, salt, cation, anion in it those are collectively known as total dissolve solid. Inorganic salts mainly potassium,

sodium, magnesium, calcium, carbonates, bicarbonates may present as dissolve solids. Some organic matter may also get dissolved in water.

Urban runoff, waste water contribution, natural dissolution of rock minerals, industrial wastes, chemicals used in water treatment plants, nature of conveyance or the materials used for conveyance are considered as the source of dissolved solids in water. It mainly represents the sum of the amount of cations and anions present in water. The test result indicates a collective value of the ions; hence total dissolve solid test represents a general quality of water.

Presence of dissolved solids in water is considered as undesirable in most of the cases. Most of the dissolved minerals, organic matters impart unpleasant colour, taste and odour in water. Some of the chemical dissolved solids are carcinogenic in nature. Products generated after combining two or more dissolved solids may be more harmful than the original ones. But on the other hand, there are some dissolved mineral those actually enhance the quality of water and are essentially required for drinking water as far as the health issues are concerned.

Total Hardness:

Hardness is an indicative of the presence of dissolved calcium and magnesium ion in water. Water containing higher amount of both calcium and magnesium is generally known as hard water. Hardness is classified as carbonate hardness and non-carbonate hardness based on the anion with which calcium and/ or is associated. Hardness equivalent to the alkalinity of water is called carbonate hardness whereas the remaining amount is termed as non-carbonate hardness. The effect of hard water can be observed by using soap to wash hand or washing clothes and utensils. Hard water causes formation of foam and it feels like some portion of soap is left over. This is because of the reaction between calcium (present in higher amount in hard water) and soap that produces soap scum.

Hence washing with hard water requires more amount of soap. Until and unless all the hardness are precipitated and water is softened by the soap, lathering does not occur. Hard water is a point of concern for both domestic and industrial uses. Hard water when heated in a heater forms precipitation of calcium carbonate at the bottom of the heater that in turn affects the life of the utensils, cost of heating, efficiency of heating etc. However, hard water is beneficial for human health in other way. It is apparently advantageous for cardio vascular system. But magnesium hardness when associated with sulphate may lead to laxative effect on human that may cause uneasiness those who are unaccustomed with it.

Chloride:

Chlorides are salts that form due to the combination of chlorine gas with metals. It is very common and naturally found in water as a combination of salt of sodium in most of the cases, and sometimes as a combination with calcium and potassium. Weathering of soil, salt bearing stratum of soil, contribution of waste water, intrusion of ocean water in ground water etc. are some of the sources of chloride in water.

Chloride is one of the essential nutrients for human healths that human can intake mainly from foods and a very small amount from drinking water also. Though chloride is beneficial for human

health, but excessive intake of sodium chloride may lead to cause hypertension though sometimes it is reported as an effect of excess sodium also. On the other hand chloride is found to be toxic for aquatic life and imparts adverse effect on vegetation. Chlorides cannot be removed by any chemical process. Dilution is the only method for reduction of chloride from water. Hence, the harmful effects on vegetation and aquatic life cannot be reduced until and unless the dilution of chloride is occurred.

3.1.3 Microbiological Water Quality Parameter

Animals, plants&protists are the major group of microorganisms. Many of the organisms like Bcteria, Protozoa and Virus spread diseases which are transmitted to humans through contaminated food and water.

To determine the biological characteristics of natural waters mostly coliform organisms are used. There are various groups of coliform organisms like aerobic, gram-negative etc. Which are responsible for fermentation of lactose to gas. As an indicator organism *Escherichia coli* is used and if the same is present in water samples that means pathogenic organism are present in human origin. It is measured in NPN/100 ml.

.

3.2 Water Quality Standards:

Safe drinking-water is a basic need for human beings and ideally it is used for domestic purpose, consumption and personal hygine. However, even if safe drinking water does not create any risk for health during its consumption, there are cases where different age groups mainly infants, children or people who live in unhygienic environment get affected from waterborne disease.

The standard of drinking water as per current environmental situation has evolved a lot considering different sources of contamination like suspended solids, turbidity, organic toxic substances, and pathogen etc. In present days it is considered that safe drinking water should not contain the earlier mentioned parameters/factors, may it be taste and odourless, that dissolved inorganic solids be in moderate quantities. The World Health Organizationhas established minimum criteria for safe drinking water that all nations are subject to follow. In line with WHO criteria, India has also created standardized code known as: IS 10500 -2012, “Drinking Water - Specification”.

I) As per IS 10500 -2012 (drinking water – specification) ‘Drinking water’ is defined as the water which is supposed to be consumed by human beings for utilities like drinking and cooking from different sources including water (treated or untreated) supplied by any means for human consumption.

As per the code, drinking water should be compliant with the specificpre-requisitesof Physico-chemical, bacteriological factors or parameters. Also there are substances undesirable in excessive amounts, Toxic Substance and Radioactive substance parameters. Some of the key parameters along with their requirement are stated in the following table in nutshell.

Table: - Water quality parameters and BIS standards for various Physical constituents [ref: IS10500:2012]

Sl. No.	Parameters	Unit	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Remarks
1	Colour	Hazen units, *Max*	5	15	Extended to 15 only, if toxic substances are not suspected
2	Odour		Agreeable	Agreeable	
3	***p*H**		6.5 – 8.5	No relaxation	
4	Taste		Agreeable	Agreeable	
5	**Turbidity**	NTU, *Max*	1	5	Test to be conducted only after safety has been established
6	**Total Dissolved Solids (TDS),**	mg/l, *Max*	500	2000	

Only three characterstics were used to conduct the test i.e. pH, turbidity, TDS.

Table: - Water quality parameters and BIS standards for various Chemical constituents [ref: IS 10500:2012]

Sl.No.	Parameters	Unit	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Remarks
1	**Chloride** (as Cl)	mg/l, *Max*	250	1000	
2	**Total Arsenic** (as As)	mg/l, *Max*	0.01	No relaxation	
3	**Total hardness** (as CaCO3),	mg/l, *Max*	200	600	
4	Aluminium (as Al)	mg/l, *Max*	0.03	0.2	

5	Ammonia (as total ammonia-N)	mg/l, *Max*	0.5	No relaxation	
6	Calcium (as Ca)	mg/l, *Max*	75	200	
7	Copper (as Cu)	mg/l, *Max*	0.05	1.5	
8	Free residual chlorine	mg/l, *Min*	0.2	1	
9	Iron (as Fe)	mg/l, *Max*	1.0	No relaxation	
10	Magnesium (as Mg)	mg/l, *Max*	30	100	
11	Manganese (as Mn)	mg/l, *Max*	0.1	0.3	
12	Nitrate (as NO_3)	mg/l, *Max*	45	No relaxation	
13	Sulphate (as SO_4)	mg/l, *Max*	200	400	
14	Total alkalinity as calcium carbonate	mg/l, *Max*	200	600	
15	Zinc (as Zn)	mg/l, *Max*	5	15	

Chloride and total hardness were used to perform the total test procedure.

Bacteriological Requirements:

Table: Water quality parameters for various bacteriological constituents [ref: IS 10500:2012]

Sl. No.	**Organisms**	**Requirements**
(i)	All water intended for drinking: a) E. Coli or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml sample
(ii)	Treated water entering the distribution system: a) E. Coli or thermotolerant coliform bacteria b) Total coliform bacteria	(a) Shall not be detectable in any 100 ml sample (b) Shall not be detectable in any 100 ml sample
(iii)	Treated water in the distribution system: a) E. Coli or thermotolerant coliform bacteria b) Total coliform bacteria	(a) Shall not be detectable in any 100 ml sample (b) Shall not be detectable in any 100 ml sample

In this study bacteriological test was done by H_2S strip to know the coliform bacteria, Total Coliform, Fecal Coliform present or not. As per IS 10500:2012 Coliform bacteria shall not be detactable in any 100 ml of sample.

II) **Packaged Drinking-Water**: In the form of bottled or pet jars is available widely in most of the countries including developing, industrialized. The consumers use this for different types of purpose and reasons including easy and convenient availability. However, the main reasons are safety and potential benefit to health.

Standards for bottled packaged drinking-water

To make sure that the packaged drinking water quality follows the minimum standard criteria with compared to the WHO the Indian Government also introduced **IS 14543:2004 (Packaged Drinking Water (Other than Packaged Natural Mineral Water)** code in the country. In the mean time IS 10500 was last revised during 2012 and in that context the earlier mentioned code for Packaged drinking water also needs a revision. As per **IS 14543:2004** "Packaged Drinking Water" definition says water obtained from sources like sea, underground and surface are treated using processes like decantation, filtration, combination of filtration, aerations, filtration with membrane filter depth filter, cartridge filter, activated carbon filtration, demineralization, re-mineralization, reverse osmosis and packed after disinfection process of the water to ensure that it shall not result in any kind of contamination in the drinking water by use of chemical agents or physical process to decrease the amount of microorganisms to a level such that the same can be scientifically accepted for food safety or its suitability. It should be filled in containers of different forms, capacities and locked/sealed such that it is ready for direct consumption by human beings without any further treatment. However, in case remineralization is done during treatment process the content/ingredients used should be of food-grade quality and comply by the rules stated under *Prevention of Food Adulteration Act*, 1954.

Requirements:

Microbiological Requirements:

Table: Water quality parameters for various bacteriological constituents [ref: IS 14543:2004]

Sl. No.	Organisms	Requirements
(i)	E. Coli or thermotolerant coliform bacteria	Shall be absent in any 250 ml sample
(ii)	Coliform bacteria	Shall be absent in any 250 ml sample
(iii)	Faecal streptococci and Staphylococcus aureus,	Shall be absent in any 250 ml sample
(iv)	Sulphite reducing anaerobes	Shall be absent in any 50 ml sample

As per IS 14543:2004 E. Coli and Coliform bacteria shall be absent in any 205 ml sample.

In this study bacteriological test was done by H_2S strip and laboratory test to know the coliform bacteria, Total Coliform, Fecal Coliform present or not.

Table: - Physical Parameters [ref: IS 14543:2004]

Sl. No.	**Characteristic**	**Unit**	**Requirement (Acceptable Limit)**	**Remarks**
1	Colour	Hazen units, *Max*	2	Requirement -**5**, as per IS 10500-2012
2	Odour		Agreeable	Same values as of IS 10500-2012
3	***p*H**		6.5 – 8.5	
4	Taste		Agreeable	
5	**Turbidity**	NTU, *Max*	2	Requirement -**1**, as per IS 10500-2012
6	**Total Dissolved Solids (TDS),**	mg/l, *Max*	500	Same value as of IS 10500-2012

.

pH, Turbidity and TDS were tested to conduct the test.

Table: -Water quality parameters and standards for various Chemical constituents [ref: IS 14543:2004]

Sl. No.	**Characteristic**	**Unit**	**Requirement (Acceptable Limit)**	**Remarks**
1	**Chloride** (as Cl)	mg/l, *Max*	200	Requirement -**250** as per IS 10500-2012
2	**Total Arsenic (as As)**	mg/l, *Max*	0.05	Same value as of IS 10500-2012
3	**Total hardness** (as CaCO3),	mg/l, *Max*	-	Not specified in IS 14543:2004
4	Aluminium (as Al)	mg/l, *Max*	0.03	Same values as of IS 10500-2012
5	Calcium (as Ca)	mg/l, *Max*	75	
6	Copper (as Cu)	mg/l, *Max*	0.05	
7	Free residual chlorine	mg/l, *Min*	0.2	
8	Iron (as Fe)	mg/l, *Max*	0.1	Requirement -**0.3** as per IS 10500-2012

9	Magnesium (as Mg)	mg/l, *Max*	30	Same values as of IS 10500-2012
10	Manganese (as Mn)	mg/l, *Max*	0.1	
11	Nitrate (as NO_3)	mg/l, *Max*	45	
12	Sulphate (as SO_4)	mg/l, *Max*	200	
13	Total alkalinity as calcium carbonate	mg/l, *Max*	200	
14	Zinc (as Zn)	mg/l, *Max*	5	

Chloride and total hardness were used to perform the total test procedure.

CHAPTER 4

MATERIALS AND METHODS

4.0 MATERIALS AND METHODS

To conduct this study first of all the presence of total coliform were tested in bacteria detection kit/H_2S strips. After that it was important to analyze the physical, chemical parameter as per SOP (APHA) in the laboratory. The parameters were pH, turbidity, total dissolved solid, total hardness, chloride. pH meter was used to measure pH value of water and digital turbidity meter was used to measure turbidity of the sample. Whereas TDS meter was used to determine the TDS value of the sample. Total hardness and chloride was measured by titration process.

4.1 METHOD:

4.1.1 H_2S Paper Strip Method:

Presence of bacteria which produces hydrogen sulphide is detected using Hydrogen Sulphide Paper strip method which is an onsite method for analyzing the microbial quality of drinking water rather than detecting Coliform bacteria presence. This was built by Manjaetal during the year 1982. Sulphate reducing Bacteria is also present in human faces in high concentration. Also few of the bacteria like Proteous, some strains of lebsiella, Salmonella, Citrobacter are capable of producing H2S.

Sterilized paper strip is placed in glass bottle which is also sterilized and treated with media. This sample is then poured in the bottle and then kept for 24 to 48 hrs at normal room temperature (25-37 C). This water turns into black if bacteria present in the sample as and when it produces H2S.

4.1.2 Procedure Followed:

A water sample was filled in the H2S strip bottle upto the mark as per the specification recommended by the manufacturer. The sample tube at a temperature of 37 degrees Celsius was kept in an incubator for twenty-four hours. The sample containing bacteria turns into black while those don't have bacteria remains as it is with no change in color.

4.2 METHOD OF TOTAL DISSOLVED SOLID (TDS) TEST IN LABORATORY (BY DIGITAL TDS METER):

Glass Apparatus: (i) Beaker

TDS Meter: To determine the accurate value of Total Dissolved Solids in Warer digital TDS meter gives an excellent result.

***Technical Specification*:**

Range **:** 5 Ranges

0-200 ppm

		0-2000 ppm
		0-20.00 ppt (20000 ppm)
		0-2000.00 ppt (2 million ppm)
Resolution	**:**	0.1 ppm
Accuracy		1 % FS + 1 digit
Cell Constant	**:**	Adjustable with indication on display
Temperature Compensation	**:**	0-50^{o} C
TDS Cell	**:**	Platinum Dip Type.
Display	**:**	3 $^{1}/_{2}$ digital LED display
Power	**:**	230 ± 10% AC, 50 Hz
Dimensions	**:**	275 x 175 x 75 mm
Weight	**:**	2 Kg.

Photo of TDS Meter:

Fig2: Digital *TDS meter*

Function Switch : There are three poitionswitch:

i. To display 1000 in the meter ignoring the decimal point the check position is used.
ii. To measure total dissolved solids in solution The TDS position is used.
iii. To display the cell constant att he instruments CELL CONSTANT position is used.

Range Switch : To select 1 of the 5 ranges of total dissolved solid the range switch is used.

Cell Constant **:** This is used to set the actual cell constant of TDS.

Temperature : To set the temperature between 0-50^{o}C this control is used.

Back Panel Controls:

ON/OFF : This is used to start or close the instrument.

CAL Control : This is used to set 1000 in the display.

Input Connection : To fit with two banana sockets this is used to connect the TDS cell.

Fuse : It is used to control the current which is supplied from power to the machine..

Connection of the TDS Cell:

a. The TDS cell was washed with distilled.

Procedure:

The following steps are followed:

i. To determine the TDS value, the cell is immersed in the solution.
ii. Next the function switch was set tobe in 'CHECK' position.
iii. In display 1.0 must be showed if not then it was adjusted to 1.00 by using the CAL control.
iv. Cell Constant control set the cell constant value of TDS.
v. The temperature controlset the temperature of the solution.
vi. To obtain maximum resolution range switch was set.
vii. Now the display was ready to show the actual value of TDS.

4.3 METHOD OF DETERMINE pH IN THE LABORATORY (BY usingDigital pH Meter):

Reference: Standard Methods 4500_H^{+}B

Aim: To study the pH value of a given sample of water.

pH: Hydrogen ion concentration in water represents the pH value of water. It is expressed as logarithmic reciprocation of the concentration of Hydrogen ion in moles/litre. The pH scale varies from 0 to 14. When the value is acidic it shows 0, when it is alkaline then it shows 14 and when it is neutral it gives 7 value at standard temperature 25°C.To calculate the carbonate, bicarbonate and CO_2 pH is normally used. There are two methods to measure pH value of water one is Calorimetric method and another one is Electromeric method. Here Electrometric methods are used. In this method hydrogen electrode is used to measure the pH value.

Principle: Two liquids are used one is known which is placed inside the glass electrode and the another one (unknown) is plecedoutside. pH means the potentiality of hydrogen.

Apparatus used:

1. Digital pH meter with hydrogen electrode.
2. Glass beaker.

Reagents: Sollution of buffer like pH 4, 7 & 9 and distilled water.

Process: At first wash the hydrogen electrode probe with distilled water. Now the pH meter is calibrated with the buffer solution. Then the electrode is wahed with the sample and immersed the electrode in the sample to get the value of pH. After that the pH value is showed in the display of pH meter. After taking the reading the electrode is washed with distilled water. When the electrode is not used it should be kept in distilled water.

Fig3: Digital *pH meter*

4.4 METHOD TO DETERMINE THE TURBIDITY IN LAB:

Reference: Standard Methods 2130B

Aim: To study the turbidity of given sample of water by using Nephelometer.

Principle:

In this method it is compared with the amount of light intensity which is scattered by the sample and the amount of light intensity which is scattered by reference suspension. The turbidity value increases with the amount of light intensity scattered. As a turbidity standard reference suspension Formazine Polymer is used. The turbidity value of Formazine is 100 NTU.

Aparatus used: Nephelometer with its equipments.

Reagents:

1. For setting the value zero distilled water is used which is turbidity free.
2. Formazine turbidity concentrate.
3. Again for setting 100Formazine standard is used.

Process:

1. At first switch on the machine.
2. Open the top section of the chamber where the sample is to be placed.
3. A glass tube is inserted in the chambers which fills with distilled water and close the top.
4. Then distilled water is removed and glass tube is filled with Formazine standard.
5. Adjust 100 control to see 100 in the display.
6. To get the value within 0 to 100 the test procedure is repeated.
7. Now the machine is ready to give the result of the sample. Glass tube which fills with sample is now inerted and its gives the result in the display

Fig4: Digital *Nephelo turbidity meter*

Range	**Standard Solution**	**Display**
0-1 NTU	1 NTU	1.00
0-10 NTU	10 NTU	10.00
0-100 NTU	100 NTU	100.00
0-1000 NTU	500 NTU	500.00

4.5 METHOD TO DETERMINE THE TOTAL HARDNESS OF WATER AT LAB:

Reference: Standard Method 2340C

Aim: To study the total hardness of given sample of water.

Description: Hard water refers to that water which has large amount of soap. Lather is produced from this soap and also the water temperature is increased due to the production of hot water pipes, boilers etc. The actual reason of hardness is the multivalent metallic cations. Hardness of water is classified as follows:

SOFT	0-60 MG/L
MEDIUM	60-120 MG/L
HARD	120-180 MG/L
VERY HARD	>180 MG/L

Apparatus used:

1. Glass burette.
2. Conical flask.
3. Pipette.
4. Beakers.

Reagents:

1. Standard EDTA (Ethylene di-amine tetra acitic acid) used as a titrant.
2. Buffer solution of NH_4Cl and of NH_4OH.
3. As an indicator Eriochrome Black T is used.

Process:

1. At first 25ml sample is taken in a conical flask to perform this test.
2. After that 2ml buffer solution is added and indicator Eriochrome Black T is also added two drops.
3. Then the titration is started with EDTA and the colour changes from wine red to blue which is the end point. Volume of titrant used is noted.

4.6 METHOD OF CHLORIDE TEST IN WATER:

Reference: Standard Methods 500_Cl^-B

Aim: To study the amount of chloride of a sample of water.

Chloride: In water and wastewater, the important inorganic anaions are chloride which is in chloride ions form. Chloride concentration is responsible for the salty taste of potable water. When the mineral content of water is increased as well as the concentration of chloride also increases. Amount of chloride varies from mountain to river. The amount of chloride is low in mountain whereas the amount is considered normal in case of river. High intake of chloride may affect the growing plants as well as structures.

Principle: This determination can be done by titration method with the help of silver nitrate solution. In this process when the precipitation of chloride ions occurit indicates the end point of this test. Then potassium chromate which acts as an indicator react with the excess silver and the precipitation of silver chromate of red-brown colour is formed. This process should be done with the pH of 6.5-9. Low pH value affects the accuracy of end point.

Apparatus used:

1. Glass Burutte.
2. Flask (conical in shape).
3. Measuring cylinder.
4. Pipettes

Reagents: Potassium Chromate solution is used as an indicator. As a titrant silver nitrate,0.0141N is used.

Process:

1. 25ml sample are used to perform this test. pH should be maintained in between 7 to 8 for this test.
2. Then indicator Potassium Chromate is added 1ml to the sample to bring the light yellow colour.
3. After that titration is done. Ssilver nitrate ($AgNO_3$) is added to get the colour brick red. The volume of $AgNO_3$ is noted. (V1).
4. Next the same is repeated for the blank sample (distilled water) and the volume of $AgNO_3$ is noted (V2).

Calculation:

Chloride in mg/l as Cl^-= [(A – B) x N x 35450] / ml of sample.

Nomenclature:

A= titrant for samle.

B= titrant for distilled water.

N= normality.

4.7 DETAILS OF SAMPLES

4.7.1 (a). BOTTLED PACKAGED DRINKING WATER

Laboratory: School of Water Resources Engineering, Jadavpur University

Sl. No.	Sample No.	Name of Sample	Marketed by	Manufactured by	Manufactured date	Date of sample collection	Collection location	Period of test
1	BP-1	Bisleri	Orient Beverage Ltd.	Orient Beverage Ltd., Howrah	23.02.2019	15.04.2019	Jadavpur	17-19 April, 2019
2	BP-2	Kinley	Coca Cola Company	Diamond Beverage Pvt. Ltd., Taratola Road, Kolkata-88	30.01.2019	15.04.2019	Rabindrasarobar	17-19 April, 2019
3	BP-3	Aqua Sure	Eureka Forbes, Mumbai	Swachha Beverages Pvt. Ltd. Howrah	16.02.2019	15.04.2019	Tollygaung Railway Station.	17-19 April, 2019
4	BP-4	Aqua Fina	PEPSICO	Varun Beverages Ltd., 24 PGS (S), Kolkata-700084	02.12.2018	18.04.2019	Jadavpur Station	22-23 April,2019

5	BP-5	Rail Neer	IRCTC	Indian Railway Catering and Tourism Corporation Ltd., Patna	30.03.2019	18.04.2019	Sealdah Station	22-23April, 2019
6	BP-6	Amust	Amust Water Products (P) Ltd.,	Amust Water Products (P) Ltd.,	22.02.2019	18.04.2019	Sealdah	22-23April, 2019
7	BP-7	Bailley	Parle Agro Pvt. Ltd.	Keventer Agro Ltd., Barasat, 24 PGS(N)	02.02.2019	20.04.2019	Gariahat	24-25 April, 2019
8	BP-8	PRAYAG	PrayagInfotech Hi-Rise Ltd., Devoke, Mamudpur, Naihati, 24 Pgs (N)-743166	PrayagInfotech Hi-Rise Ltd., Devoke, Mamudpur, Naihati, 24 Pgs (N)-743166	21.03.2019	20.04.2019	Gariahat	24-25 April, 2019
9	BP-9	Deesani		Deesani Aqua (p) Ltd. Banagram, Rasapunja. Kol – 700104	11.11.2018	19.04.2019	Budge Budge	24-25 April, 2019
10	BP-10	Aqua Diamond	M/s Pal & Co., South Station Road, Agarpara, Kol-109	M/s Pal & Co., South Station Road, Agarpara, Kol-109	03.01.2019	21.04.2019	Tollygaung Railway Station	26-27 April, 2019
11	BP-11	Aqua Dollar	Oceania Beverages, Bonhooghly, sonarpur,24 PGS		30.11.2018	21.04.2019	Jadavpur Station	26-27 April, 2019
12	BP-12	Raindrops	Prince Food & Beverage, Kishan market,	DFB Agro, Kalyani Expressway, Shyam Nagar	26.12.2018	21.04.2019	Jadavpur Station	---do---

			Jagadhipota, Sonarpur,					
13	BP-13	Safe N Sure	Anwesa Enterprises, 16, India Exchange Place, Kolkata-700001	Rupasi Industries, 31, A. K. Mukherjee Road, Kolkata-700090.	06.03.2019	23.04.2019	Esplanade	02-03 May, 2019
14	BP-14	Mother Dairy	Loknath Aqua Industries, Narendrapur, Kolkata-700103	Loknath Aqua Industries, Narendrapur, Kolkata-700103	04.11.18	23.04.2019	Jadavpur	---do---
15	BP-15	Brahmsutra	Brahmputra Mineral Water (P) Ltd.	Brahmputra Mineral Water (P) Ltd., Cossipore Road, Kolkata-700002	25.01.2019	25.04.2019	Sealdah	---do---
16	BP-16	Amar Aqua	Amar beverage pvt. Ltd.	Amar beverage pvt. Ltd., ishlampur, howrah	03.11.2018	25.04.2019	Sealdah Station	06-08 May, 2019
17	BP-17	Kings Aquam	Kings Aqua Enterprise, Langal Beria, Gobindapur, PS-Sonarpur, 24 Pgs (S).		05.12.2018	27.04.2019	Esplanade	10-11 May,2019

4.7.1 (b). KMC SUPPLY TAP WATER

Laboratory: School of Water Resources Engineering, Jadavpur University

Sl.No.	Sample No.	Source of used water	Date of sample collection	Collection location	Period of test
1.	KM-1	KMC Supply Tap water	19.01.2019	Ward no 98, Gandhi Coloni, Kolkata- 700040	19-23 Jan,2019
2.	KM-2	KMC Supply Tap water	30.01.2019	Ward no 97, Ashok Nagar,Tollygaung	30-31jan,2019
3.	KM-3	KMC Supply Tap water	02.02.2019	Ward no 96,Bijoygargh, Kolkata	02-05feb,2019
4.	KM-4	KMC Supply Tap water	09.02.2019	Ward no 100, GangulyBagan, Kolkata-700047	09-12feb,2019
5.	KM-5	KMC Supply Tap water	14.02.2019	Ward no 110, Township Garia	14-17feb,2019
6.	KM-6	KMC Supply Tap water	22.02.2019	Ward no 99,Jadavpur	22-25feb,2019
7.	KM-7	KMC Supply Tap water	23.02.2019	Ward no 95, Azadgargh,Kolkata	23-26feb,2019
8.	KM-8	KMC Supply Tap water	01.03.2019	Ward no 93, Lake Gardens	01-0Mar,2019
9	KM-9	KMC Supply Tap water	02.03.2019	Ward no 101, Baghajatin, Kolkata-700086	02-05Mar,2019
10.	KM-10	KMC Supply Tap water	09.03.2019	Ward no 102, KPC Medical College	09-12Mar,2019
11.	KM-11	KMC Supply Tap water	13.03.2019	Ward no 103, New Santoshpur	13-15Mar,2019
12.	KM-12	KMC Supply Tap water	16.03.2019	Ward no 112, Bansdroni	16-20Mar,2019
13.	KM-13	KMC Supply Tap water	23.03.2019	Ward no 113, Kalitala,Kolkata- 700070	23-26Mar,2019
14.	KM-14	KMC Supply Tap water	27.03.2019	Ward no 89, Charu Market, Tollygaung	27-29Mar,2019
15.	KM-15	KMC	29.03.2019	Ward no 94, Naveena	29-

		Supply Tap water		Cinema Hall	31Mar,2019
16.	KM-16	KMC Supply Tap water	30.03.2019	Ward no 81, New Alipur	30March-02April,2019
17.	KM-17	KMC Supply Tap water	04.04.2019	Ward no 91, Kasba	04-08April,2019

CHAPTER 5

ANALYSIS OF RESULTS

5.1 ANLYSIS OF RESULTS

To analysis the results of the parameters like physicochemical, bacteriological the test is conducted in the laboratory. To perform this test sample collection is very important part. After getting the results of that physical, chemical and bacteriological test of water, it should be compared with the acceptable and permissible limit which is specified in different IS code. These IS codes are IS 10500:2012 for Drinking Water Specifications and IS 14543:2004 for Package Drinking Water Specifications (other than packaged natural mineral water). By calculating Water Quality Index, the quality of water is obtained.

5.2 Water Quality Index (WQI): WQI is one of the most important measurement techniquetoanalyse water quality. Usually quality analysis of drinking water (including packaged ones) can be done using the same. **Water Quality Index** (WQI) is a rating by which water quality data is summarized based on various quality parameters, mainly aimed to determine whether the water sample is safe for human consumption or not. The result data derived based on quantitative analysis and IS codes for water quality standards are the key factors which was used for calculating the WQI for each of the samples.

To identify the contaminants in drinking water and different variation in packaged drinking water quality, the WQI is used.

1. According to each parameter of water quality the weight (wi) is assigned for each parameters. Due to the relative importance of coliform in water quality the maximum weight 5 is assigned. The major risk to human is from fecal contamination. As Hardness is not so harmful the minimum weight is given to this parameter
2. In the next step, the relative weight (Wi) is calculated by:

$$Wi = wi / \sum_{i=1}^{i=n} wi$$

Where, Wi = relative weight, wi = weight of each parameter and ‘n’ = number ofparameters.

3. In the last step, a quality rating scale (qi**)** for each parameter is computed as follows:

$$qi= (Ci / Si) x 100$$

where ‘qi’ = quality rating scale, ‘Ci’ = concentration of each chemical parameter and Si = Indian drinking water standard for each parameter as described in BIS 10500, 2012 / BIS 14543 : 2004.

To compute WQI the Sub Index (SI) is to be determined first then the WQI is calculated from the following equation:

$$SIi= Wi .qiWQI = \Sigma SIi$$

Table : Relative weightage of physiochemical and biological parameters.

Sample No.	Parameter	Requirement as per Indian Standard (Si)	Weight (wi)	Relative weightage (Wi)	Observed Results (Ci)	Quality Rating Scale qi=(Ci/Si)x100	Sub-Index SIi=(Wi.qi)
1	Coliform (MPN/250 ml)	Nil	5	0.500			
	pH	6.5-8.5	4	0.300			
	Turbidity (NTU)	1	3	0.04			
	Total Dissolved Solids (TDS) (mg/l)	500	4	0.09			
	Total Hardness (TH) (as $CaCO_3$) (mg/l)	200	2	0.04			
	Chloride (as Cl^-) (mg/l)	200	3	0.03			
	Total		**25**	**1.00**	**Water Quality Index (WQI)**		**Σ**

Table : Water quality classification based on WQI value

Range of WQI Values	Type of water for drinking purpose
< 50	Excellent
50 – 75	Good
75 – 100	Fair
100 – 200	Poor
200 – 300	Very poor
> 300	Unsuitable for drinking

5.3 OBSERVED RESULTS:

5.3.1 (a): BOTTLED PACKAGED DRINKING WATER

Parameter Tested		1		2	3	4	5	6
		Coliform Bacteria (MPN)		pH	Turbidity (NTU)	TDS (mg/l)	Total Hardness as $CaCO_3$ (mg/l)	Chloride (mg/l)
Accepted Limit as per IS : 10500 : 2012 *		**Shall not be detectable in any 100 ml sample**		**6.5 – 8.5**	**1**	**500**	**200**	**250**
Accepted Limit as per IS : 14543 : 2004 #		**Shall be absent in any 250 ml sample**		**6.5 – 8.5**	**2**	**500**	**-**	**200**
Sample No.	**Name**							
BP-1	Bisleri	Ab	<2	6.65	0.15	68.5	28	36
BP-2	Kinley	Ab	<2	6.79	0.10	20.7	15	10
BP-3	Aqua Sure	Ab	<2	6.51	0.08	78.5	12	20
BP-4	Aqua Fina	Ab	<2	6.12	0.09	5.0	4	4
BP-5	Rail Neer	Ab	<2	6.77	0.08	51.2	6	9
BP-6	Amust	Ab	<2	7.32	0.12	95	78	12
BP-7	Bailley	Ab	<2	6.7	0.16	43	32	10
BP-8	Prayag	Ab	<2	7.23	0.10	20	15	7
BP-9	Deesani	Ab	<2	6.85	0.08	27.1	32	5
BP-10	Aqua Diamond	Ab	<2	7.36	0.18	69	9	10
BP-11	Aqua Dollar	Ab	<2	6.45	0.19	55	12	20
BP-12	Raindrops	Ab	<2	6.20	0.09	35	23	13
BP-13	Safe N Sure	Ab	<2	6.30	0.14	40.6	9	18
BP-14	Mother Dairy	Ab	<2	6.67	0.07	22.8	8	8
BP-15	Brahmsutra	Ab	<2	7.12	0.13	43.1	39	4
BP-16	Amar Aqua	Ab	<2	7.43	0.15	63.0	BDL	19
BP-17	Kings Aquam	Ab	<2	6.52	0.08	45	55	9
AverageAb		**<26.76**		**0.12**	**46.3**	**23.56**	**12.5**	

Note: BDL = Below detection limit; Ab = Absent; * Drinking Water Specifications; # Package Drinking Water Specifications (other than packaged natural mineral water)

TYPICAL CALCULATION OF WATER QUALITY INDEX (WQI) OF BOTTLED PKG DRINKING WATER

Table : Relative weightage of physiochemical and biological parameters and Water Quality Index (WQI).

Sample No.	Parameter	Requirement as per Indian Standard (S_i)	Weight (w_i)	Relative weightage (W_i)	Observed Results (C_i)	Quality Rating Scale $q_i=(Ci/Si)x100$	Sub-Index $SI_i=(W_i . q_i)$
Bottled Package Drinking Water							
BP-1	Coliform (MPN/250 ml)	Nil	5	0.500	Nil	0.00	0.00
	pH	6.5-8.5	4	0.300	6.65	102.31	30.69
	Turbidity (NTU)	1	3	0.04	0.15	15.00	0.6
	Total Dissolved Solids (TDS) (mg/l)	500	4	0.09	68.5	13.7	1.233
	Total Hardness (TH) (as $CaCO_3$) (mg/l)	200	2	0.04	28	14	0.56
	Chloride (as Cl^-) (mg/l)	200	3	0.03	36	18	0.54
	Total		**21**	**0.84**	**Water Quality Index (WQI)**		**33**
BP-2	Coliform (MPN/250 ml)	Nil	5	0.500	Nil	0.00	0.00
	pH	6.5-8.5	4	0.300	6.79	104.46	31.33
	Turbidity (NTU)	1	3	0.04	0.10	10	0.4
	Total DissolvedSolids (TDS) (mg/l)	500	4	0.09	20.70	4.14	0.37
	Total Hardness (TH) (as $CaCO_3$) (mg/l)	200	2	0.04	15	7.5	0.3
	Chloride (as Cl^-) (mg/l)	200	3	0.03	10	5.00	0.15

	Total	**21**	**0.84**	**Water Quality Index (WQI)**	**33**

TABLE- : WATER QUALITY INDEX OF PACKAGE DRINKING WATER

Sample No.	**Water Quality Index (WQI)**
Bottled Packaged Drinking Water	
BP-1	33
BP-2	33
BP-3	30
BP-4	32
BP-5	31
BP-6	38
BP-7	33
BP-8	35
BP-9	33
BP-10	36
BP-11	32
BP-12	30
BP-13	31
BP-14	32
BP-15	35
BP-16	36
BP-17	33

Range of WQI Values	Type of water for drinking purpose	Percentage of studied water samples (Bottled PKD Water)	
< 50	Excellent	100%	
50 – 75	Good		
75 – 100	Fair		
100 – 200	Poor		
200 – 300	Very poor		
> 300	Unsuitable for drinking		

5.3.1 (b) WATER QUALITY PARAMETERS OF DIRECT TAP COLLECT WATER OF KMC SUPPLY IN THE MORNING

KMC Direct Supply Water quality parameter								
			1	2	3	4	5	6
Parameter Tested			**Coli-form bacteria**	**pH**	**Turbidity (NTU)**	**TDS (mg/l)**	**Total Hardness as $CaCO_3$ (mg/l)**	**Chloride (mg/l)**
Accepted Limit as per IS : 10500 : 2012 *			**Shall not be detectable in any 100 ml sample**	**6.5 – 8.5**	**1**	**500**	**200**	**250**
Sample No.	**Collection Time**	**Name**						
KM-1	7.05 A.M.	Ward no 98, Gandhi Coloni, Kolkata- 700040	**Present 2**	7.68	0.72	173	164	265
KM-2	7:05 A.M.	Ward no 97, Ashok Nagar,Tollygaung	**Present 4**	7.56	4.12	216	220	270
KM-3	7:05 A.M.	Ward no 96,Bijoygargh, Kolkata	**Present 5**	7.54	5.05	203	212	275

KM-4	7:05 A.M.	Ward no 100, GangulyBagan, Kolkata- 700047	**Absent**	7.48	0.55	225	180	144
KM-5	7:05 A.M.	Ward no 110, Township Garia	**Present 4**	7.77	0.98	178.1	172	280
KM-6	7:05 A.M.	Ward no 99, Jadavpur	**Present 4**	7.8	1.69	236	312	270
KM-7	7:05 A.M.	Ward no 95, Azadgargh,Kolkata	**Present 4**	7.69	0.51	279	210	285
KM-8	7:05 A.M.	Ward no 93, Lake Gardens	**Absent**	7.45	0.64	234	180	75
KM-9	7:05 A.M.	Ward no 101, Baghajatin, Kolkata- 700086	**Absent**	7.61	0.62	181.7	196	72
KM-10	7:05 A.M.	Ward no 102, KPC Medical College	**Absent**	7.66	1.5	258.7	202	65
KM-11	7:05 A.M.	Ward no 103, New Santoshpur	**Present 2**	7.45	1.2	205	182	280
KM-12	7:05 A.M.	Ward no 112, Bansdroni	**Present 1**	7.83	1.54	256	174	260
KM-13	7:05 A.M.	Ward no 113, Kalitala,Kolkata-700070	**Absent**	7.70	0.89	232	186	130
KM-14	4:30A.M.	Ward no 89, Charu Market, Tollygaung	**Present 4**	7.73	1.62	280	320	282
KM-15	4:30A.M.	Ward no 94, Naveena Cinema Hall	**Present 2**	7.67	0.91	240	177	270
KM-16	7:05 A.M.	Ward no 81, New Alipur	**Absent**	7.63	0.77	232	188	130

KM-17	7:05 A.M.	Ward no 91, Kasba	**Absent**	7.54	0.81	203	190	95

* Drinking Water Specifications

TABLE- : WATER QUALITY INDEX OF KMC SUPPLY TAP WATER

Sample No.	**Water Quality Index (WQI)**
KM-1	55
KM-2	98
KM-3	92
KM-4	48
KM-5	60
KM-6	58
KM-7	51
KM-8	46
KM-9	46
KM-10	51
KM-11	51
KM-12	54
KM-13	49
KM-14	58
KM-15	51
KM-16	48
KM-17	47

As per the above results it is observed that the value of water quality index of KMC supply tap water (initial 15 minutes) is more than 50 that means the quality of this water is not in excellent category.

5.4. A). PLOTTING OF DIFFERENT PARAMETERS FOR PACKAGE DRINKING WATER (BOTTLED)

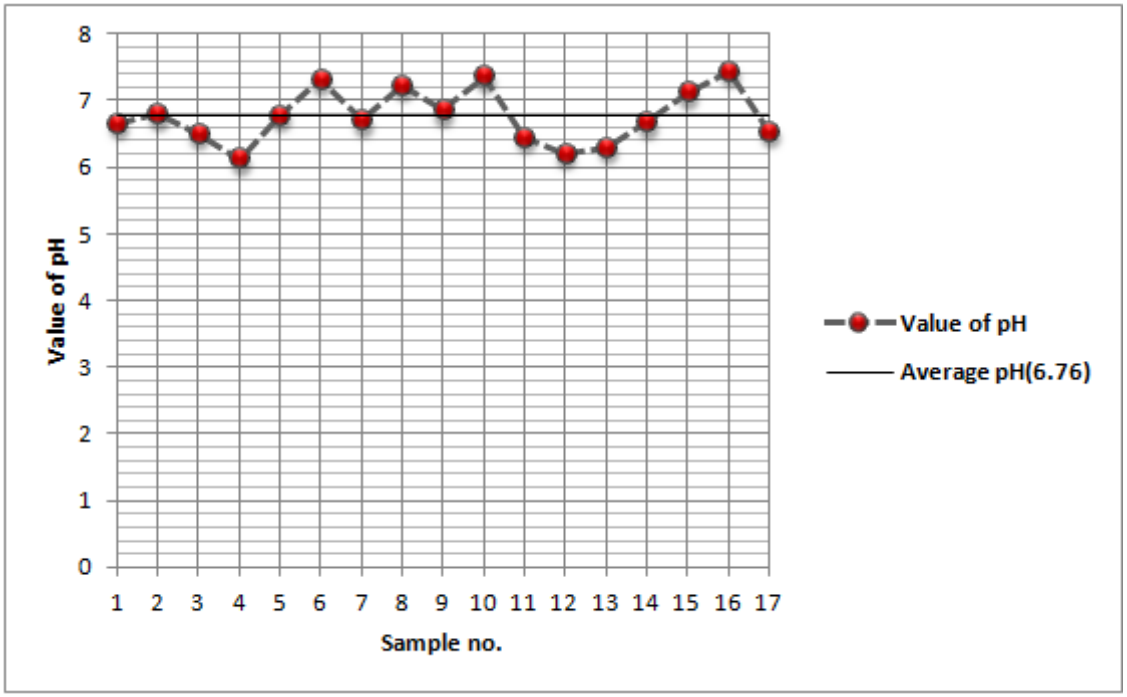
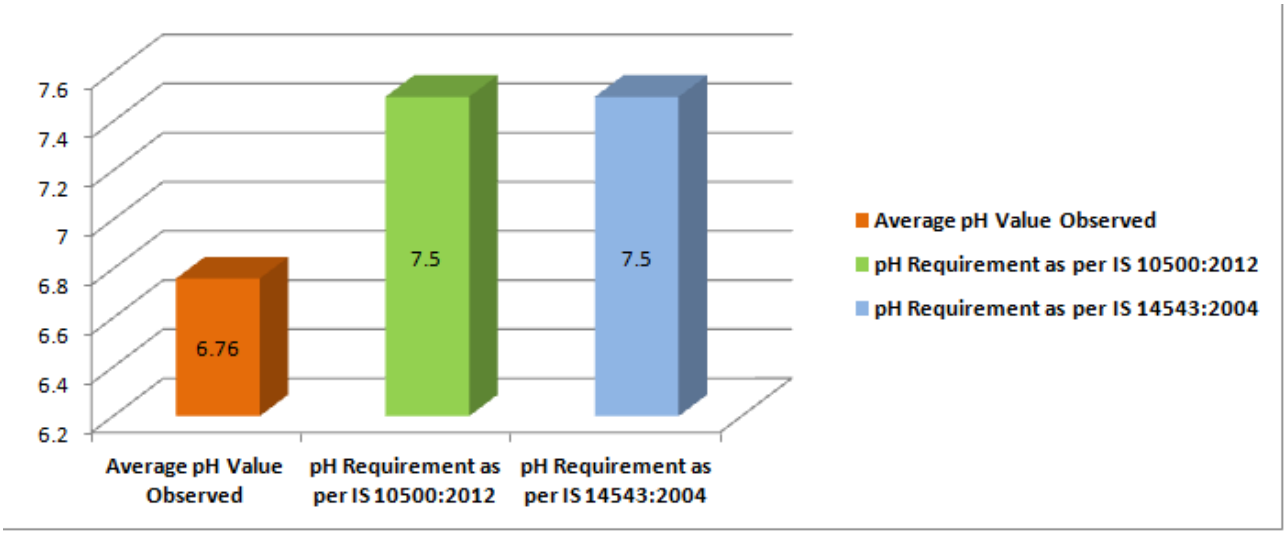


Fig5: Plot of pH Vs Samples of package drinking water (bottled)



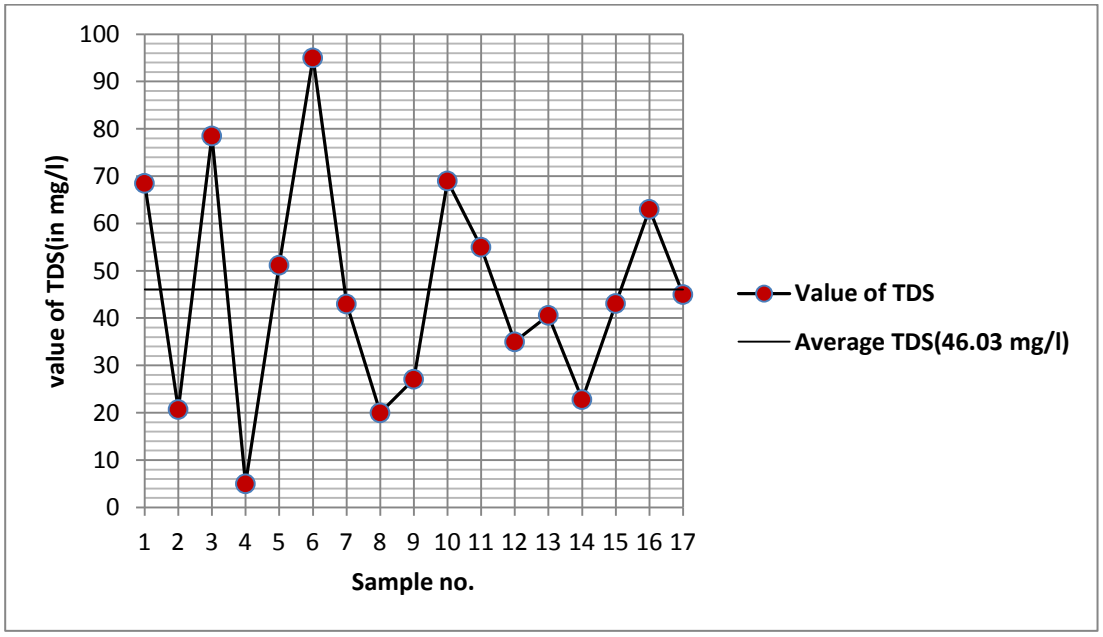
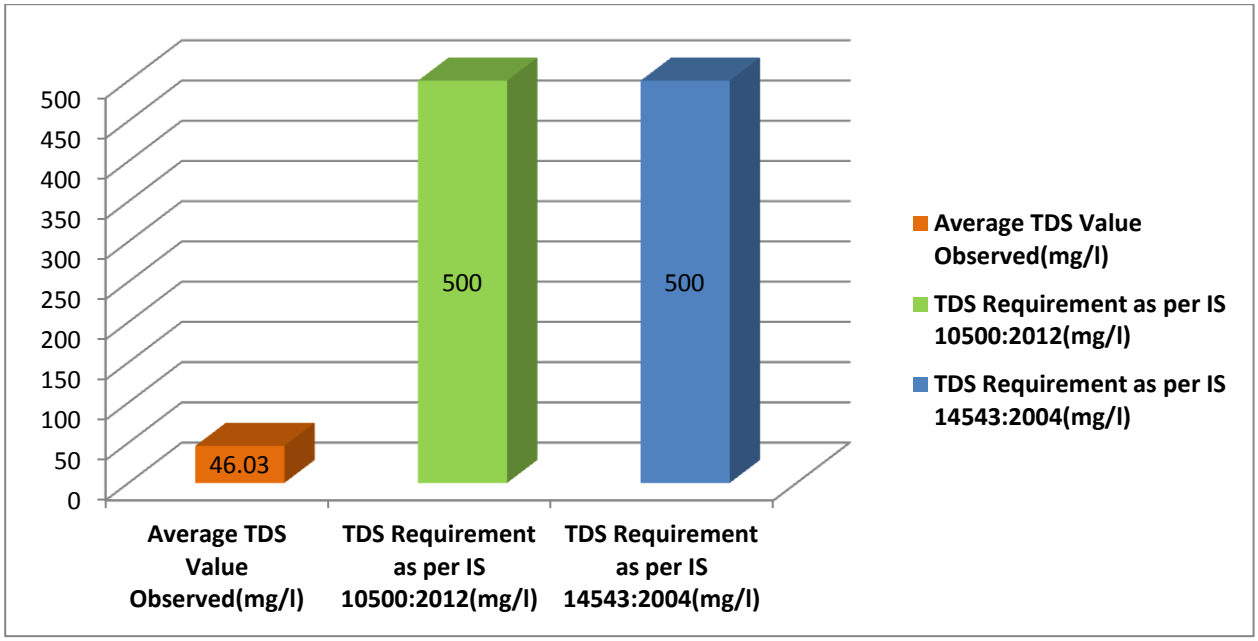


Fig6: Plot of TDS (mg/l) Vs Samples of package drinking water (bottled)



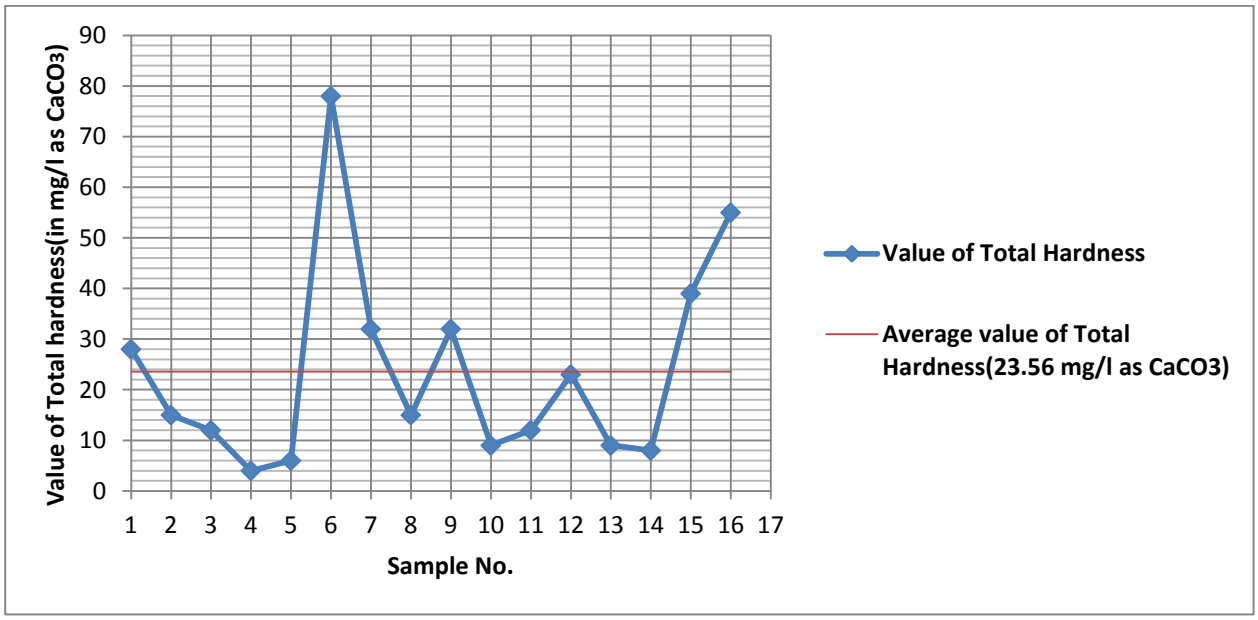
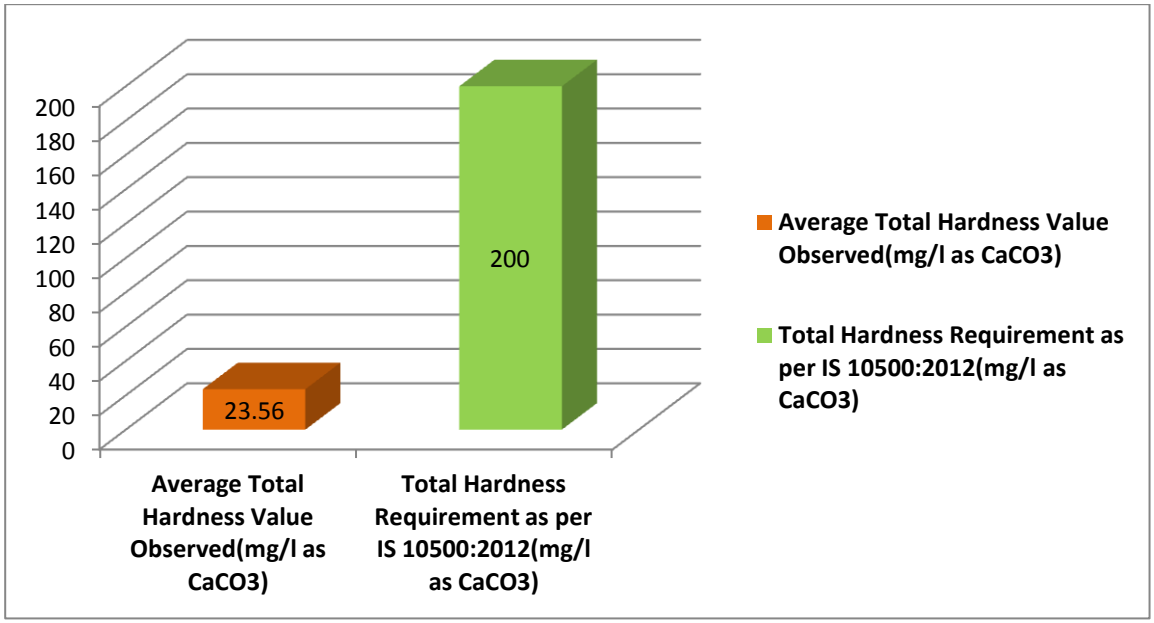


Fig7: Plot of Total Hardness (mg/l as CaCO3) Vs Samples of package drinking water (bottled)



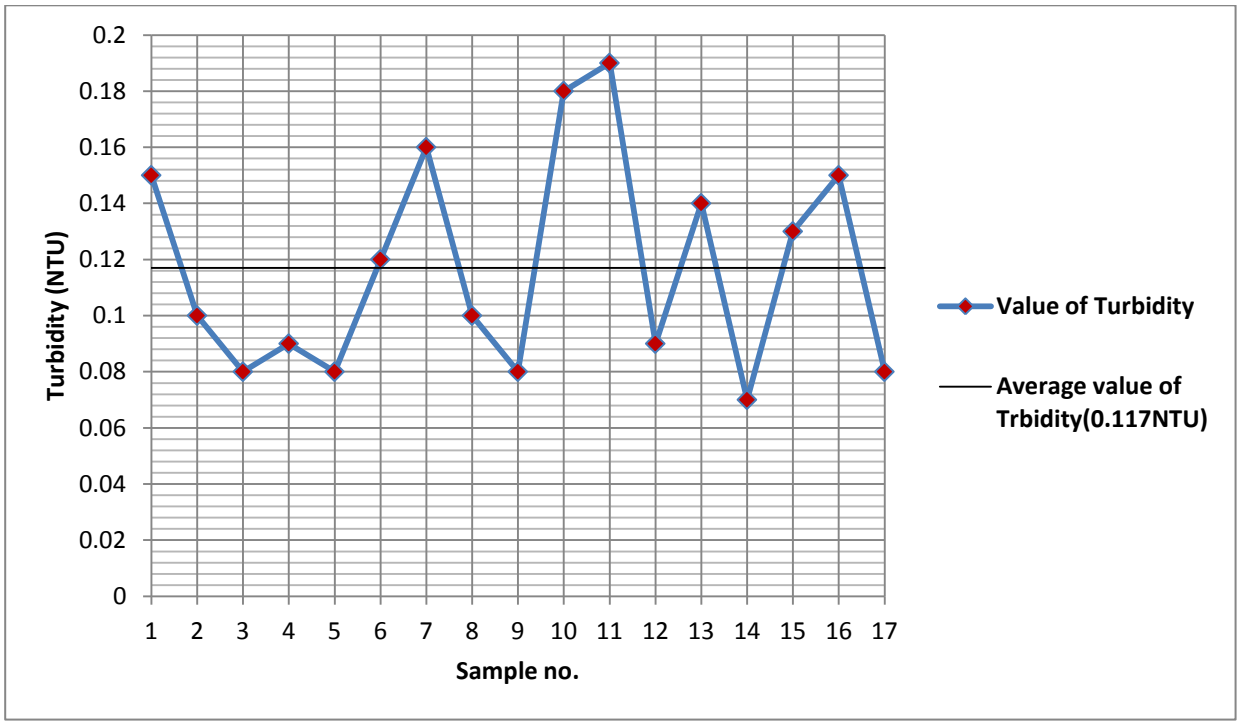
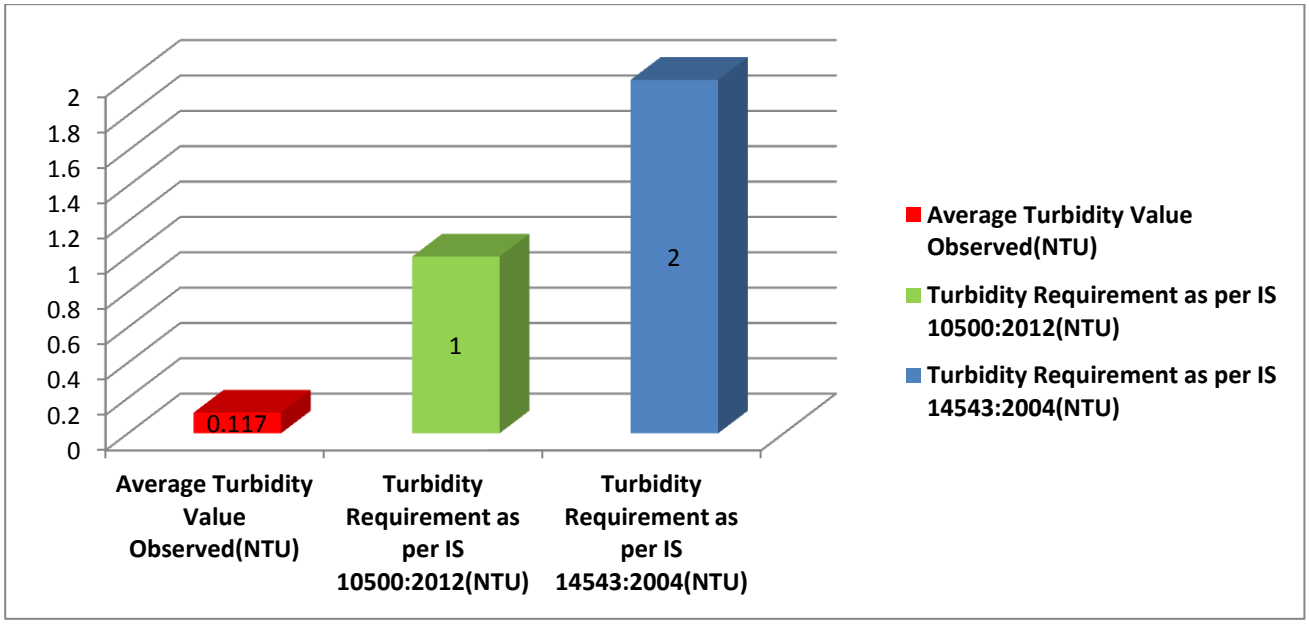


Fig8: Plot of Turbidity (NTU) Vs Samples of package drinking water (bottled)



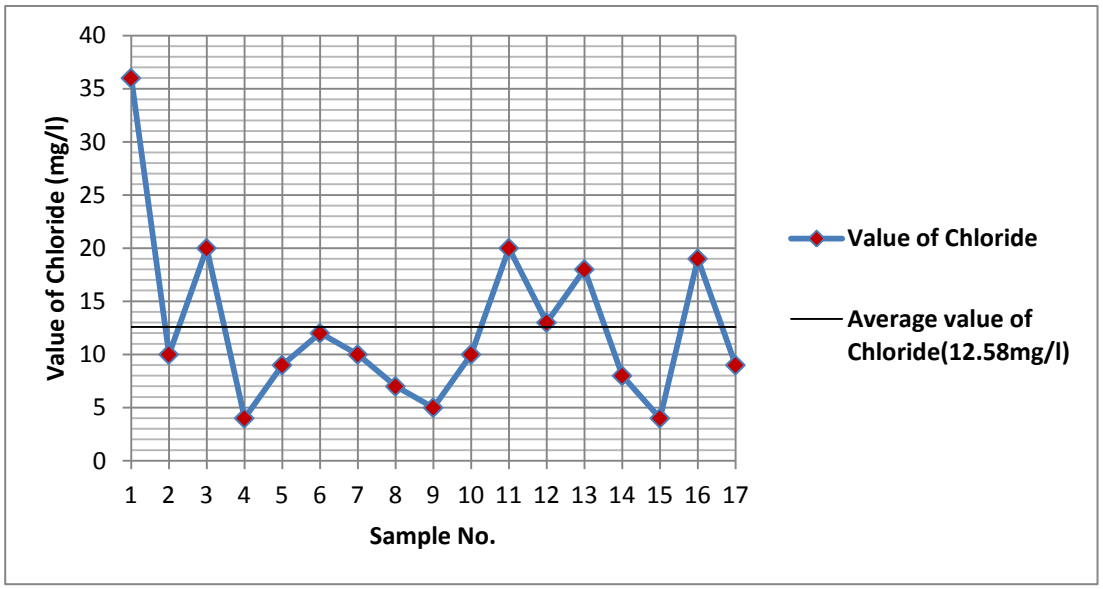
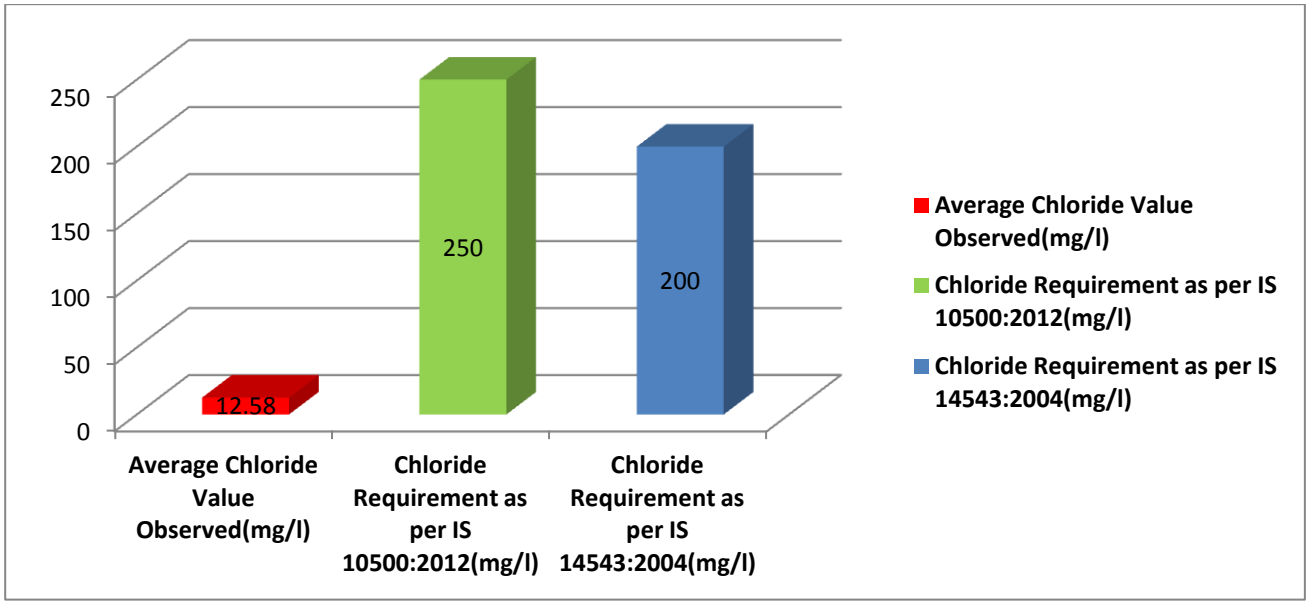


Fig9: Plot of Chloride (mg/l) Vs Samples of package drinking water (bottled)



5.4. B). PLOTTING OF DIFFERENT PARAMETERS FOR DIRECT TAP WATER OF KMC SUPPLY

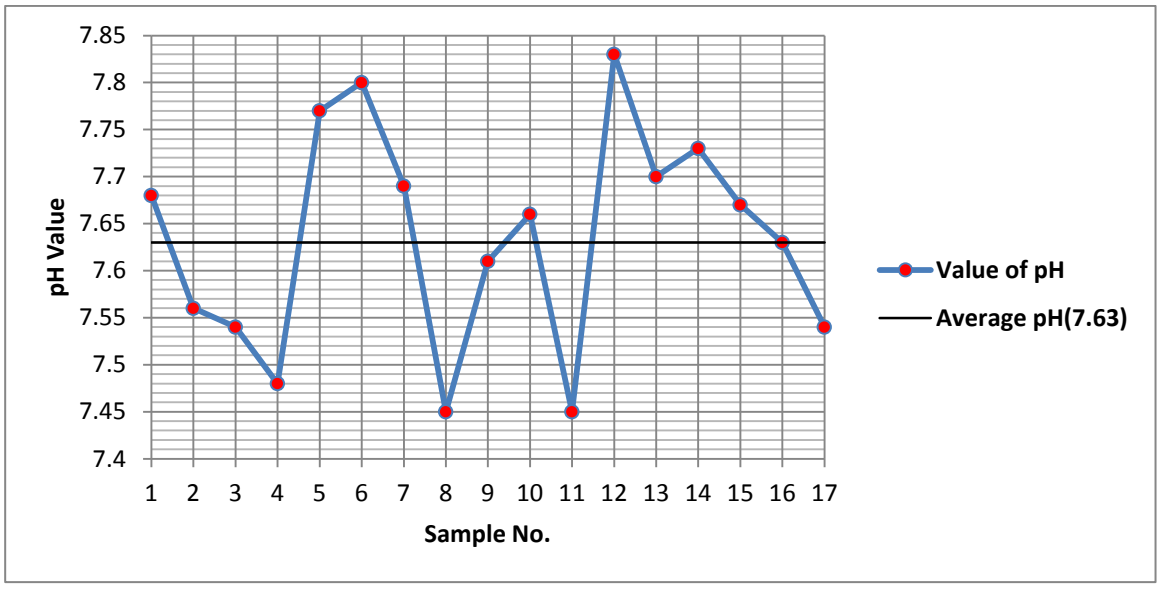
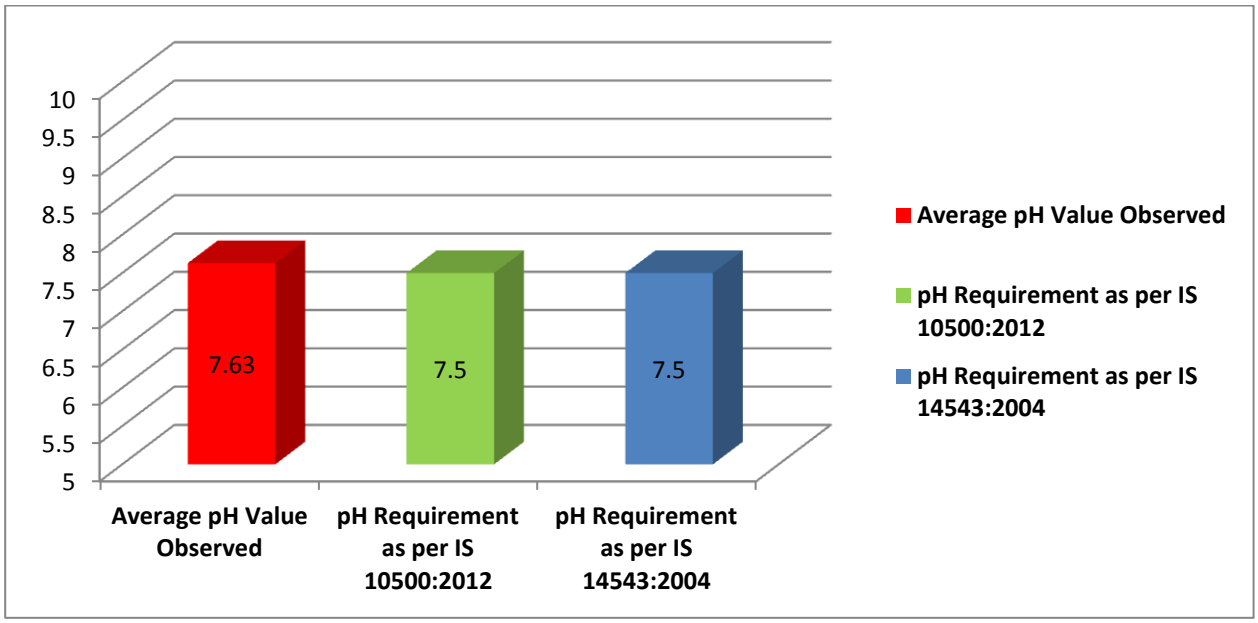


Fig10: Plot of pH Vs Samples of direct tap water of KMC



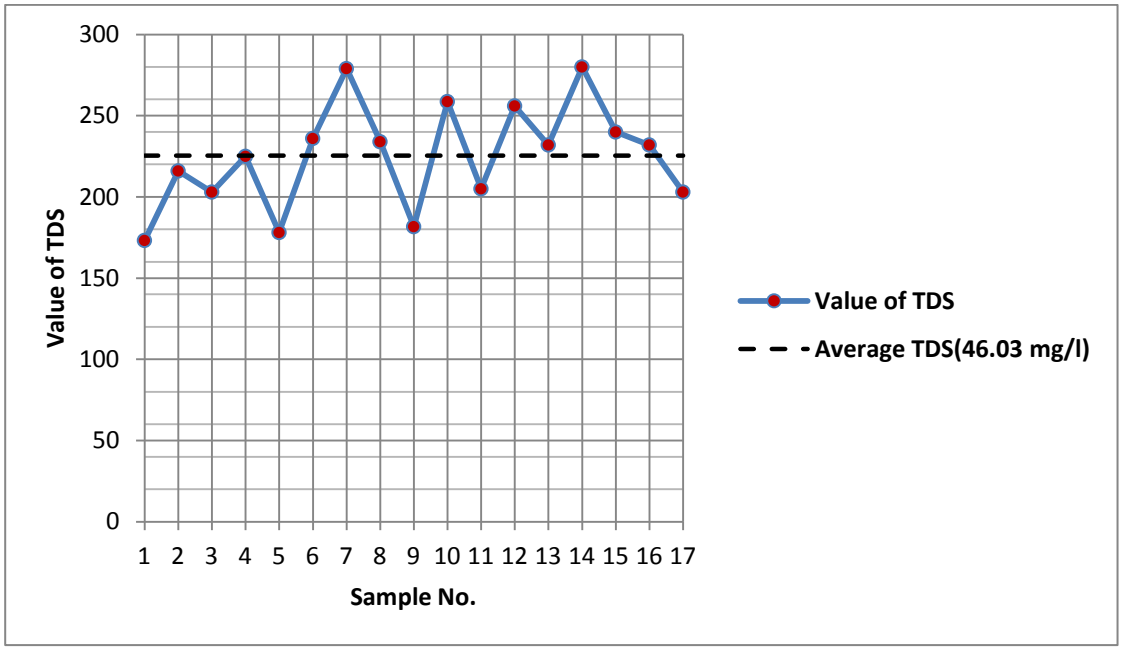
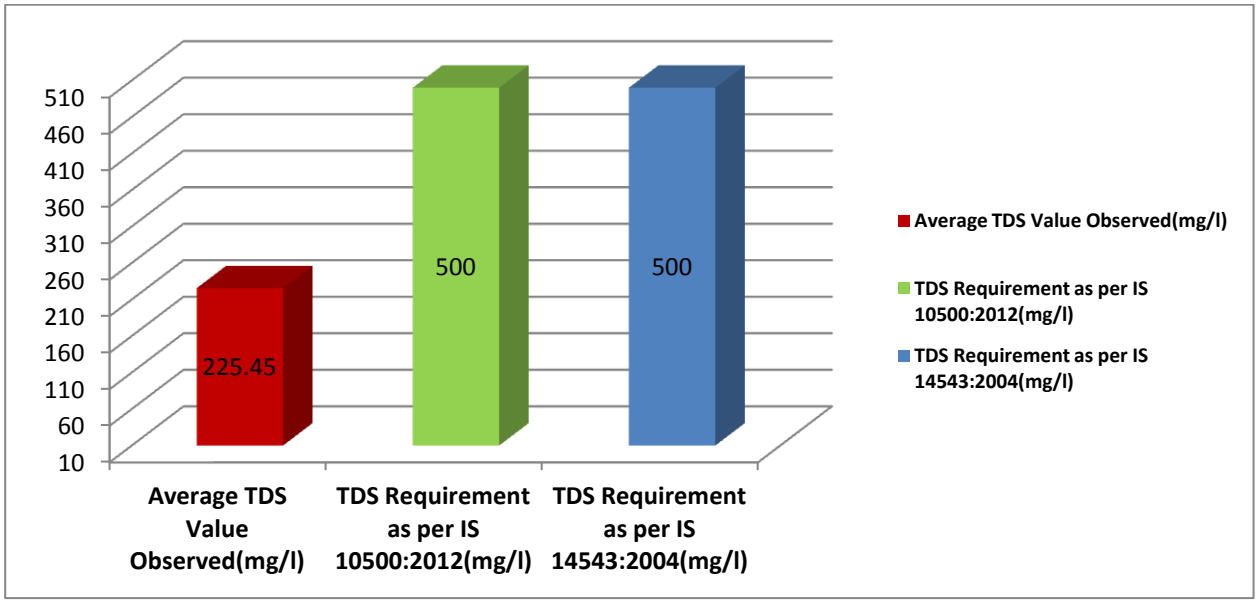


Fig11: Plot of TDS (mg/l) Vs Samples of direct tap water of KMC



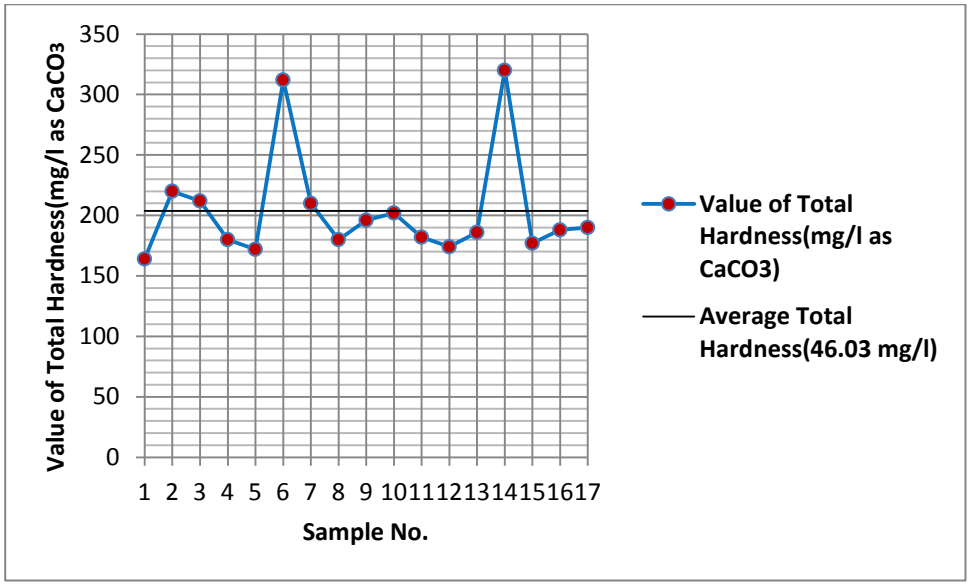
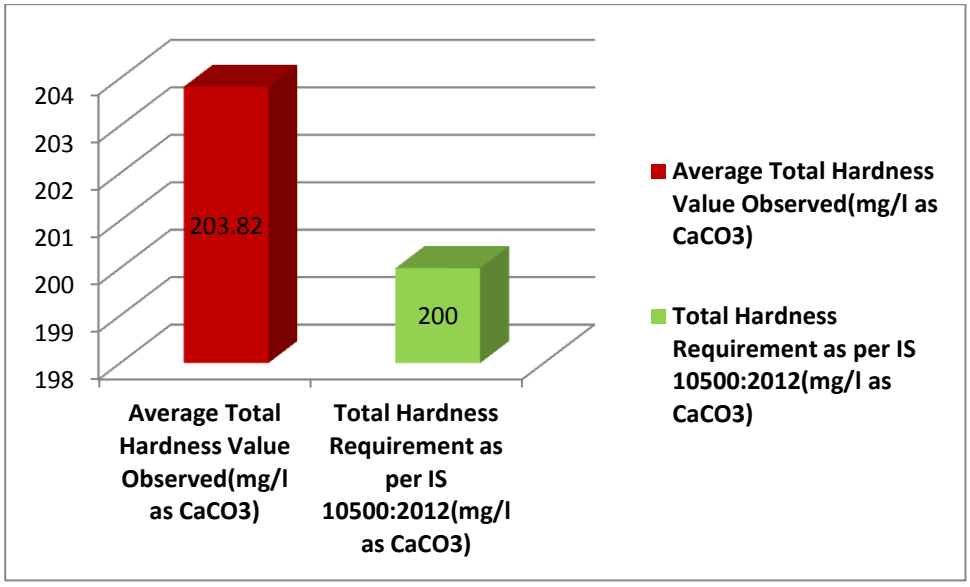


Fig12: Plot of Total Hardness (mg/l as $CaCO_3$) Vs Samples of direct tap water of KMC



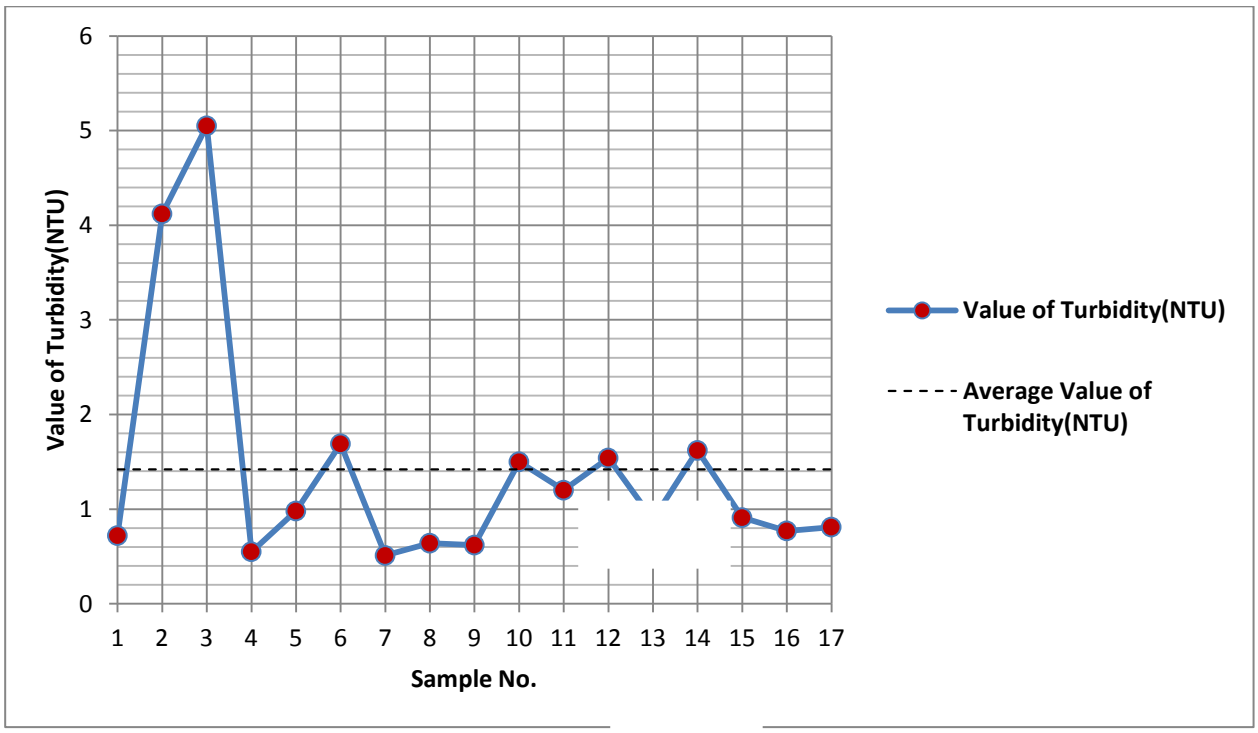
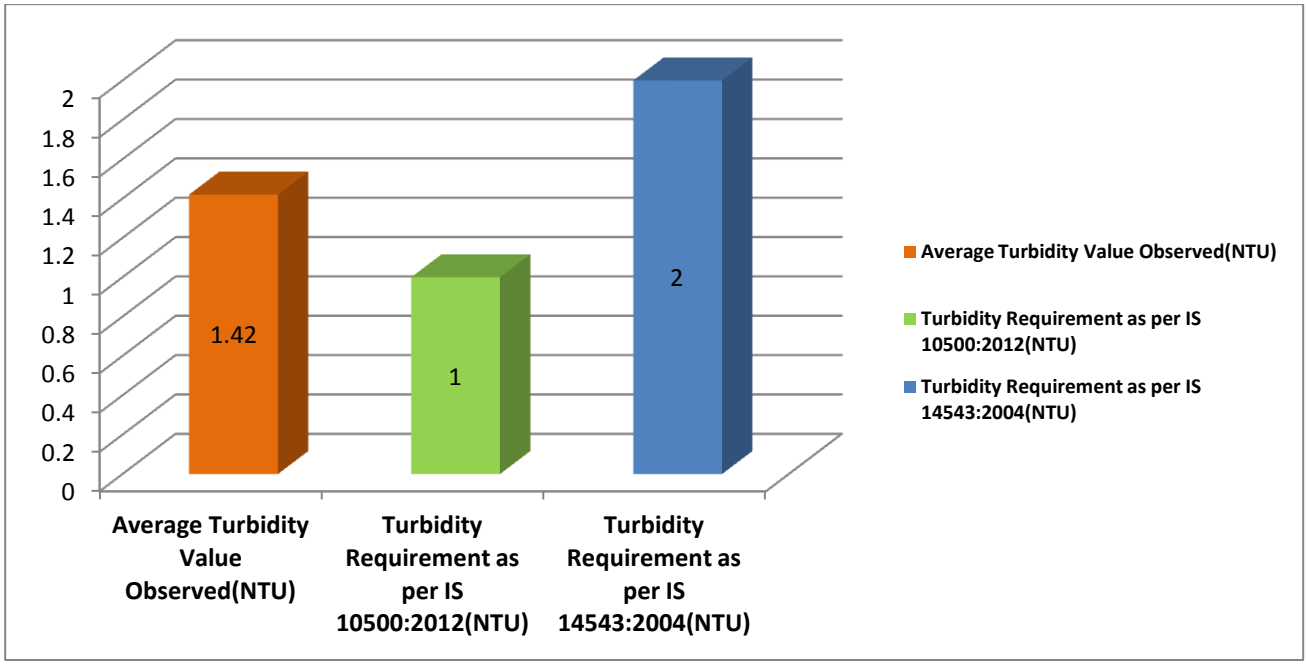


Fig13: Plot of Turbidity (NTU) Vs Samples of direct tap water of KMC



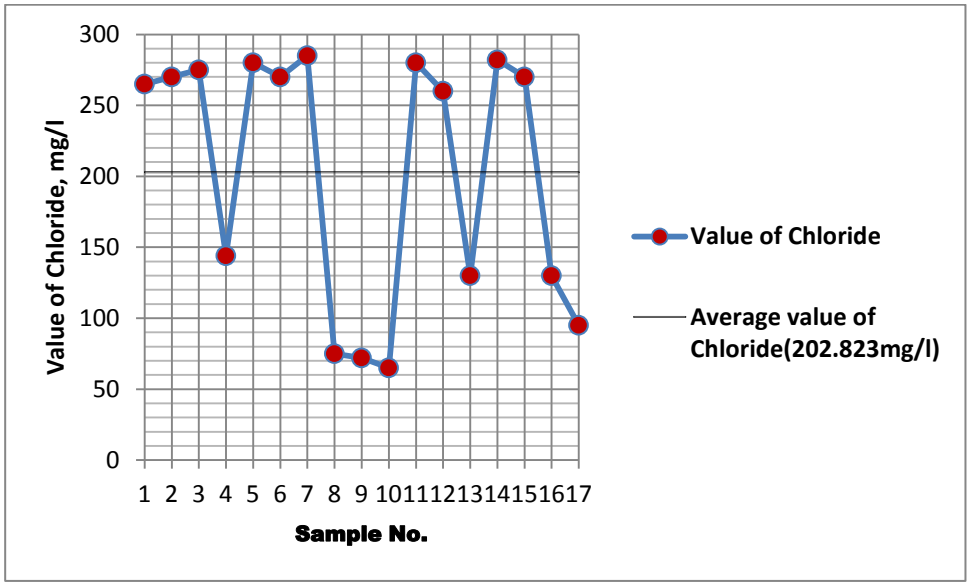
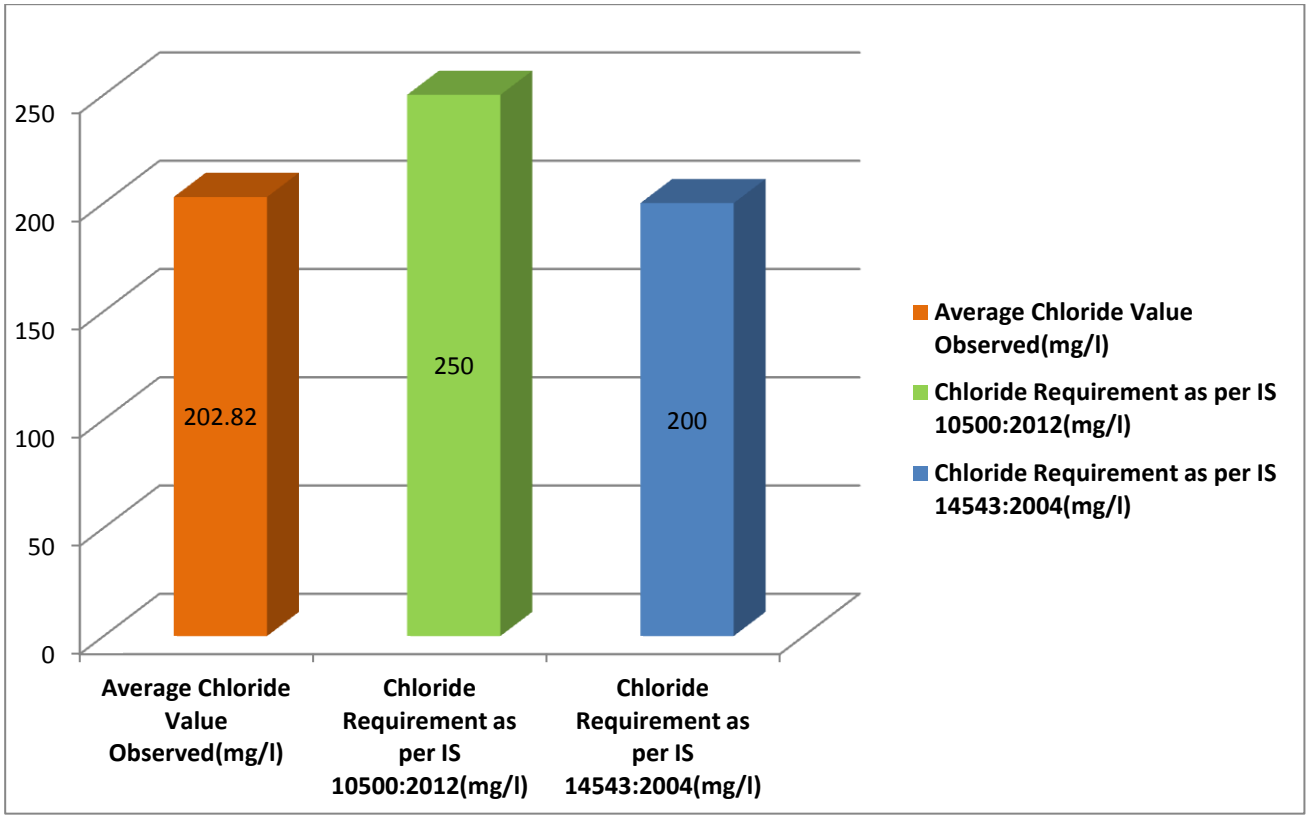


Fig14: Plot of Chloride (mg/l) Vs Samples of direct tap water of KMC


250
200
150
100
50
0
202.82
250
200
Average Chloride Value Observed(mg/l)
Chloride Requirement as per IS 10500:2012(mg/l)
Chloride Requirement as per IS 14543:2004(mg/l)
Average Chloride Value Observed(mg/l)
Chloride Requirement as per IS 10500:2012(mg/l)
Chloride Requirement as per IS 14543:2004(mg/l)

CHAPTER 6

DISCUSSION

6.0 DISCUSSION

As per study conducted to assess the quality of public water supply in Kolkata City and also packaged drinking water sold in the city, the following observations are presented below. As per the obtained results which is in detailed in Chapter-5, the following consideration and review are made on **bottled** packaged drinking water and the water which is supplied by KMC.

6.1 PACKAGED DRINKING WATER

In this study 17 brands of bottled packaged drinking water were collected to analyze the water quality in the laboratory of School of Water Resources Engineering, Jadavpur University. As per calculation of WQI it may be stated that all the samples are in **excellent category (WQI < 50)** and average value is 20 (twenty). Six parameters were analysed for WQI assessment in the laboratory (i.e. pH, TDS, Turbidity, TH, Chloride and coliform organism).

Coliform organism No bacterial contamination was found in all the samples; that means it is safe for the purpose of drinking.

pH: 23% samples have pH value less than 6.5 which means these are acidic and it does not satisfy the standard value which is specified in IS 10500-2012 and IS 14543 -2004. Rest of the Samples have pH value within 6.5-8.5 and it is compliant with the above mentioned IS codes. The lower pH value in PKD is caused by dissolved carbondioxide which is converted to carbonic acid after getting filtered by RO purifiers.

Turbidity: Turbidity value of all the samples are within acceptable limit (i.e. <1 NTU) as described in the above mentioned IS codes.

Total Dissolved Solids: TDS value of all PKD water samples are lies within the acceptable limit (i.e. 500mg/l) as mentioned in the IS codes. 23% samples have TDS value less than 25mg/l and rest are lies within 25 mg/l to 100 mg/l.

It is observed that more than 50% of the samples have TDS value less than 50mg/l that means it contains low mineral concentration.

Total Hardness: As per IS 10500-2012 it is observed that all the samples have hardness very much lower than the acceptable limit 200mg/l. Most of the samples have hardness less than 50mg/l as CaCO3. Total Hardness below 100mg/l refers to soft water and more than 100mg/l refers to hard water.

Chloride: A per the IS code for drinking water IS 14543 -2004 the acceptable limit of chloride is 200mg/l and in this study all the samples are within this limit. More than 80% samples have chloride value less than 20mg/l.

Effects of Low hardness in drinking water:

In this study the results of packaged drinking water have the concentration of all water quality parameters very low than the acceptable limit as mentioned in the IS codes (IS 10500-2012 (Drinking water specification) and IS 14543 -2004 [Packaged Drinking water (other than natural mineral water) specification].As per WQI results it is categorized as excellent , but the concentration of low hardness may affect the cardiovascular system.To stay healthy human needs some mineral.Lower intake of magnesium increases the risk of stroke or hypertension. So long term consumption of packaged drinking water is not good for health.

6.2 EXAMINATION OF WATER QUALITY PARAMETERS OF DIRECT TAP WATER OF KMC SUPPLY

In Kolkata Municipal area many people collect direct tap water early in the morning for the purpose for drinking. Many different food shops, roadside shops also use this water. They think the quality of this water is better than other sources. In this study water samples were collected within first 15 minutes of supply during morning from different key locations (17 samples). The tested results and WQI values of these samples are given in the above Chapter

From these results, it was noted that the water quality parameters like Turbidity, TH, and Chloride of direct supply water of KMC in the early morning (first water) beyond the acceptable limits in most of the cases. It was also found that the water samples had coliform bacteria. But the concentration of pH and TDS are within the limit.

Presence of Coliform bacteria in drinking water may cause various diseases like fever, abdominal cramps, and diarrhea. Therefore, it is better not to consume the tap water just at the stating time.

CHAPTER 7

CONCLUSION

7.1 CONCLUSION

The study has given the details of the water quality of packaged drinking water of different brands and the water supplied by KMC in Kolkata city. To determine the six water quality parameters (Coliform bacteria, pH, TDS, TH, Turbidity, Chloride) the laboratory of School of Water Resources were used. Water Quality Index of all these parameters was also calculated.

7.2 Package Drinking Water (PDW)

This study has given the overall view of the quality of packaged drinking water available in the city and the quality of KMC supply water. In this study it was observed that maximum sample of packaged drinking water was acidic. It contained very low concentration of other minerals. In our daily life consumption of very low-mineralised water may not be considered safe. There is a potential risk to human health as they consume low-mineralised water for a long period of time.

The lower pH value in PKD is caused by dissolved carbondioxide which is converted to carbonic acid after getting filtered by RO purifiers. It is observed that daily consumption of low pH water for long period of time may affect the mucous membranes, eyes and skin.

In this study there is also deficiency of Ca and Mg along with low TDS.Lack of this mineral (Ca and Mg) in PDW the risk of hypertention, chronic gastritis, goitre etc. was increased. It was also observed that the people who lived in soft water areas had low chances of CVD than the people in hard water areas. Inflammatory cytokines, endothelial damage, atherosclerosis might be caused due to low consumption of Mg.

7.3 Water Quality of KMC Supply Collected Directly from Tap:

Most of the samples which were collected at 7:05 a.m contain Coliform bacteria. This was caused due to leakage in pipe lines and post contamination occurred. To avoid this contamination, the leakage in pipe lines must be repaired. Under this situations of contaminated tap water of KMC, municipal supply water after 15 minutes of the initial time can be a great alternative for drinking purpose. For this purpose, KMC should take proper step to ensure the desired quality. It is noted that three parameters like Turbidity, Total Hardness and Chloride Chloride of direct supply water of KMC in the early morning (first water) mainly at 7: 05 a.m. beyond the acceptable limits in most of the cases. But the concentration of pH and TDS are within limit. The WQI results of KMC water is more than 50 in all the cases.

The concentration of turbidity more than 1NTU has no effects on human health but it inidicates disease-causing bacteria, virus which is responsible for nausea, headaches, and diarrhea.

The concentration of low hardness may affect the cardiovascular system. To stay healthy human needs some mineral. Lower intake of magnesium increases the risk of stroke or hypertension. So long term consumption of packaged drinking water is not good for health.

Chloride is mainly found in tap water. Chlorides are not so harmful but high concentration of Chloride may affect the taste of water and it can also destroy the growth of plants.

ANNEXURE

References

1. Majumder. A, Roy. P.K, Ray. S, Packaged drinking water quality in Kolkata City, India and risk to public health, Desalination and Water treatment,2016, DOI: 10.1080/19443994.2016.1196390

2. Sudarsan. J.S. and Renganathan.K, Packaged drinking water quality characteristics at Chennai city, Tamilnadu, Journal of Structural and Civil Engineering, ISSN: 2277-7032, Volume 1 Issue 1.

3. Mihayo I.Z. and Mkoma S.L., Chemical Water Quality of Bottled Drinking Water Brands Marketed in Mwanza City, Tanzania, Research Journal of Chemical Sciences, Vol. 2(7), 21-2, July,2012.
.
4. Brindha. K. and Sangeetha. M, Consumer behaviour towards bottled drinking water with special reference in Coimbatore City, 2017.

5. Patil V. T. and Patil P. R, Groundwater quality status using water quality index in Amalner town, Maharashtra, Journal of Chemical and Pharmaceutical Research, Vol 5(5), pp 67-71, 2013.

6. Mufid al-hadithi, Application of water quality index to assess suitability of groundwater quality for drinking purposes in Ratmao –PathriRao watershed, Haridwar District, India, American Journal of Scientific and Industrial Research, Science Huβ, http://www.scihub.org/AJSIR, 2012.

7. ChoudharyRanjeeta, RawtaniPushpa and Vishwakarma Monika, Comparative study of Drinking Water Quality Parameters of three Manmade Reservoirs i.e. Kolar, Kaliasote and Kerwa Dam, Current World Environment, Vol. 6(1), pp 145-149, 2011.

8. Edema MO, Atayese AOand MO Bankole, Pure water syndrome: bacteriological quality of sachet- packed drinking water sold in Nigeria, African Journal of Food, Agriculture, Nutrition and Development, Vol. 11, No. 1, 2011 pp. 4595-4609.

9. Ramakrishnaiah C.R, Sadashivaiah C and Ranganna G, Assessment of water quality index for the groundwater in TumkurTaluk, Karnataka State, India, E-Journal of Chemistry, Vol6(2), pp 523-530, 2009.

10. Rebecca L. Calderon, Gunther F. Craun, Water hardness and cardiovascular disease: a review of the epidemiological studies, 1957-78 (from google search).

11. APHA (American Public Health Association), Standard Methods for the Examination of Water and Wastewater, 22 edi, 2012.

12. IS 10500: 2012, Indian Standard, Drinking Water- Specification, Second Revision, 2012.

13. IS 14543: 2004, Indian Standard, Packaged Drinking Water (Other Than Packaged Natural Mineral Water) Specification, First Revision, 2004.

14. WHO Guidelines for Drinking Water Quality, 4th edition.

15. Garg, S.K., Environmental Engineering (Vol-I), Water Supply Engineering, Khanna Publishers, New Delhi, 1996.

16. Websites : www.freedrinkingwater.com
www.mapsofindia.com/kolkata

List of Figures

List of Tables