STUDY OF PERFORMANCE EFFICACY OF SERAMPORE WATER TREATMENT PLANT

A thesis submitted towards partial fulfilment of the requirements for the degree of

Master of Engineering in
Water Resources and Hydraulic Engineering
Course affiliated to Faculty of Engineering & Technology
Jadavpur University

Submitted by

SAYANTIKA SAHA

EXAMINATION ROLL NO.: **M6WRP19011**

Under the guidance of

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 and Technology
Jadavpur University
Kolkata-700032
India
2019

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

CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"Study of Performance Efficacy of Serampore Water Treatment plant"** is bonafide work carried out by **Sayantika Saha** under our supervision and guidance for partial fulfillment of the requirement for Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academic session 2018-2019.

THESIS ADVISOR
Prof. (Dr.) Pankaj Kumar Roy
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, Kolkata- 700032

M.E. (Water Resources & Hydraulic Engineering) Course Affiliated to
Faculty of Engineering and 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 pre-requisite 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 a part of my Master of Water Resources & Hydraulic Engineering degree during academic session 2018-2019.

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

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

Name: **Sayantika Saha**

Roll Number: **M6WRP19011**

Thesis Title: **Study of Performance Efficacy of Serampore Water Treatment plant**

Signature:

Date:

ACKNOWLEDGEMENT

I express my sincere gratitude to my Thesis Advisor **Prof. (Dr.) Pankaj Kumar Roy** under whose valuable guidance this work has been carried out. It would have been impossible to carry out this thesis work with confidence without his wholehearted involvement, advice, support and constant encouragement throughout. He has not only helped me to complete my thesis work but also have given valuable advice to proceed further in my life.

I also express my sincere gratitude to all the faculty members **Prof. (Dr.) Asis Mazumdar, Director, Prof. (Dr.) Arunabha Majumder, Dr. Rajib Das & Dr. Subhasis Das** of School of Water Resources Engineering for their valuable suggestion.

I also express my thankfulness to **Dr. Gourab Banerjee,** Assistant Professor, of School of Water Resources Engineering, Jadavpur University for his hard work and support throughout the study.

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

Date : May, 2019

Place : Jadavpur University, Kolkata
(Roll No. - M6WRP19011)

ABSTRACT

The performance efficacy study was undertaken at individual unit of 20 MGD Serampore Water Treatment Plant, West Bengal. Water samples were collected at different stages of treatment units once in a week during study period and analyzed for the major water quality parameters such as pH, turbidity, total dissolved solid, residual chlorine, total hardness, carbonate hardness, magnesium hardness, iron, nitrate, sulphate, total coliform ,fecal coliform. Samples from selective points of distribution mains and consumer's end were also collected to assess the quality of supply water. Sand samples were collected from two filter beds for the analysis of particle size distribution (uniformity coefficient and effective size of Sand).Based on the analysis for physico-chemical parameters, the finished water was conforming to Indian standard for drinking water (IS: 10500,2012) prescribed by APHA guideline in the study period. Result revealed that turbidity removal of clarified water ranging between 81% and 90% have been found. Similarly total coliform and fecal coliform were determined by membrane filter technique.Residual chlorine having 0.2 mg/l was found at the end stage so no bacteria was observed considering post disinfection has been made properly in the treatment system. This research work concludes turbidity values were found satisfactory at different stages except residual chlorine at few points in the distribution system were found less than 0.2 mg/l. Thus it is concluded that proper disinfection need to be done including backwashing of rapid sand filter at regular interval.

List of Figures

List of Tables

TABLE OF CONTENTS

CHAPTER-4

CHAPTER 1

INTRODUCTION

Introduction

1.0 Introduction

1.1 Preamble

The world is fast running out of fresh water, our demand for this "blue gold" is increasing at a faster pace with passing time and thousand more people are compelled to survive in a water-stressed condition. One-half and two-thirds of the global population will be put to severe fresh water crisis within next quarter century(Barlow and Clarke,2003).

River is the main inland water resources for all civilizations on earth. They are used by the people for domestic, industrial and irrigation purpose. It must not be polluted. Coming to India , anga is the longest river basin . The water quality of the river has deteriorated due to discharge of pollution load from different sources. The major sources of pollution of the river Ganga are generally the discharge of untreated and partially treated waste water from cities or towns, discharge of untreated and partially treated wastewater from industries, mixing of surface runoff carrying pesticides, agricultural wastes etc. discharge of cattle-shed liquid waste and bathing of cattle in the river and mainly direct disposal of solid waste in the river or mixing of leachate from solid waste dumps. In order to protect the river from contaminations activities relating to abatement of Ganga pollution was taken up by the National River Conservation Directorate under the programme GAP Phase-I and Phase-II.

1.2 Present Scenario of Water Supply in Kolkata Metropolitan Area(KMA)

Kolkata Metropolitan Area (KMA) has got its twofold water source viz: (a) Surface water from the only source of river Hooghly and (b) Ground water source. Out of these two sources, the water from river Hooghly is being treated and supplied to a very limited areas of KMA through the treatment plants and infrastructures that has so far been constructed leaving the vast majority of remaining KMA to depend on the source (b) i.e. Ground water

1.3 Ground Water Resource

As it has not yet been possible to extend treated surface water supply to the majority of KMA, inhabitants of these areas are forced to depend on ground water. This good quantity of ground water is found to become unpredictable day by day due to over withdrawal by the huge number of haphazardly placed deep tube wells resulting in fall of piezometric level, ground subsidence, trace of arsenic in some places and other adverse effects.

1.4 Surface Water Resource

Though the quality aspect of any source of water generally relates for deciding its suitability for treatment process, KMA has got no other alternative but to accept the only surface water resource as River Hooghly regardless of its quality. To assess the different process of treatment and the degree of treatment required at each stage, it is necessary to have a look at the quality of raw water resource. For this purpose the quality of water of River Hooghly was ascertained through a thorough investigation made by National Environmental Engineering Research Institute (NEERI) in September 2001.

1.5 Major Completed Water Supply Schemes

a) Augmentation of Palta Water Works

The capacity of the Plant, located about 20 km away from the north of the city, has been augmented to 220 MGD to serve the central and northern part of KMC area, Bidhannagar, South Dum Dum and North Dum Dum Municipal areas. Construction of an additional UGR (7 MG) at Tallah is also a part of it.

b) Augmentation of Garden Reach Water Treatment Plant

For serving the Southern part of KMC and Budge Budge, Pujali and Maheshtala Municipal areas, one 60 MGD treatment plant was constructed at Garden Reach within Maheshtala Municipality. The capacity of the Plant has been augmented to 120 MGD. But at present the Plant cannot be run to its optimum capacity for non-completion of secondary storage reservoirs along with necessary Primary Grids, some of which have been taken up and are in advance stage of completion.

c) Howrah Water Treatment Plant

Construction of one 30 MGD treatment plant has been completed at PadmapukurJala in South Howrah for the areas of Southern part of Howrah and part of Bally Municipality.

d) Baranagar-Kamarhati Water Treatment Plant (Phase-1 and Phase-2)

Construction of two 30 MGD treatment plant has been completed in Kamarhati Municipality for supplying water to six municipal areas viz. Baranagar, Kamarhati, Panihati, Khardah, Titagarh (Phase-1) and Dum Dum, South Dumdum and North Dumdum (Phase-2). Phase-2 water treatment plant was commissioned in February 2014. The works (Phase-2) was executed under Jnnurm for supplying treated water on 24 x 7 basis with three underground reservoirs in each of the municipality to be supplied. For facilitating 24 x 7 services 27 nos. elevated service reservoirs have also been constructed. 90% of the population of the municipalities have been successfully converted to treated surface water from ground water. But the full capacity of the plant is not being generated at present for non-completion of the secondary reservoirs at the respective municipal zone for phase-1.

e) Serampore Water Treatment Plant

At Serampore Municipal Area one 20 MGD treatment plant has been completed to cater eight municipal areas viz. Bhadreswar, Champdani, Baidyabati, Serampore, Rishra, Konnagar, Uttarpara-Kotrung and Bally (P).

f) Chandannagar Water Treatment Plant

The 0.48 MGD capacity treatment plant constructed in French regime for Chandannagar Municipal Corporation has been augmented to 1.00 MGD at present.

g) Bansberia Water Treatment Plant

For serving the Bansberia and Hooghly- Chinsurah municipal areas, one 0.6 mgd treatment plant was constructed long back.

h) Bhatpara Water Treatment Plant

Construction of 20 MGD water treatment plant has been completed in Bhatpara Municipality for supplying treated surface water on 24 x 7 basis to the municipality. The project was commissioned in 2013.

i) Kalyani Water Treatment Plant

1st phase of the kalyani water treatment plant of 30 MGD capacity was commissioned in 2007 to supply treated surface water on 24 x7 basis to four municipal areas of Kalyani, Kanchrapara, Gayespur and Halisahar.

j) Garulia Water Treatment Plant

5 MGD water treatment plant was commissioned in Garulia Municipality in 2014 for supplying treated surface water on 24 x 7 basis to the municipal town.

k) Bally Water Treatment Plant

48 MLD water treatment plant on with space saving technology commissioned in the erstwhile Bally Municipality in 2014 on 24 x 7 basis. This is now a part of the water supply system of HMC since Bally Municipality has been merged with HMC.

l) Madhyamgram Water Treatment Plant

A 36 MGD water treatment plant on space saving technology has been commissioned in 2015 for treated surface water on 24 x 7 basis to municipal towns of Madhyamgram, Barasat and New Barrackpore.

m) Panihati Water Treatment Plant

A 20 MGD water treatment plant was completed in Panihati Municipal area in 2016 to supply treated water to the municipal town.

n) Titagarh Water Treatment Plant

70 MLD water treatment completed in Titagarh Municipality for supplying treated surface water to Titagarh and Khardah Municipality.

All above the water works are constructed by either KMDA or KMW&SA (presently KMDA).

1.6Treatment Philosophy

The Hydraulics of the treatment plant is designed in such a way that water flows by gravity from the collecting well to the clear water reservoir and the sludge generated from the inclined plate settler flows by gravity to sludge sump and ultimately in to the nearest drainage canal

Table No: 1.1 Basic Process of Water Treatment

Sl. No.	Process	Types of impurities removed
1	Screening	Big and visible object, such as, trees, dead animals, floating matters,etc.
2	Plain Sedimentation	Coarser suspended impurities, such as, sand, silt, clay, etc.
3	Sedimentation with coagulation	Fine suspended matter
4	Filtration	Micro-organism and colloidal matters
5	Disinfection	Pathogenic bacteria

Water is of fundamental importance in human life. To provide drinking water to the public is one of the most important tasks of communities .Water is treated differently in different communities depending on the quality of the water which enters the plant. The water for drinking must be free from harmful substances that cause adverse effect on human health.

1.7 Objectives

The overall objective of the proposed research work is to assess the performance of individual unit of Serampore Water Treatment Plant through qualitative analysis.

1.8 Scope of Work

The scope of the project are given below

- To evaluate the physico-chemical and bacteriological quality at various stages of treatment.
- To assure quality of the treated water
- To study chemical dosing during study period
- To determine chlorine demand of the treatment system
- To analyse particle distribution curve for sand bed of rapid sand filter
- To calculate effective size and coefficient of uniformity of sand particles.
- To assure quality of the treated water at selected points of the distribution mains.
- To assure quality of the water at selected points of the consumer's end

1.9 Proposed Methodology

Serampore Water Treatment Plant was investigated from all aspects and considerations including engineering, chemical, bacteriologicaland heavy metals to determine water quality. Keeping in view the provision of safe water to the community of Serampore (a sub divisional town under Hooghly District) and it's adjoining six municipalities , the Kolkata Metropolitan Water and Sanitation Authority constructed a water treatment plant of 20 MGD in the western bank of river Hooghly at Serampore with conventional water treatment by using Hooghly river water as raw water source and it started functioning in the year of 1994.This report will deal with the plant performance as well as quality assurance for the Serampore Water Treatment Plant for a period of 5 months. Quality assurance to the selected distribution points has also been presented in this report. This study will help the proper maintenance of the treatment plant and ensure the safe water quality supplied to the consumers

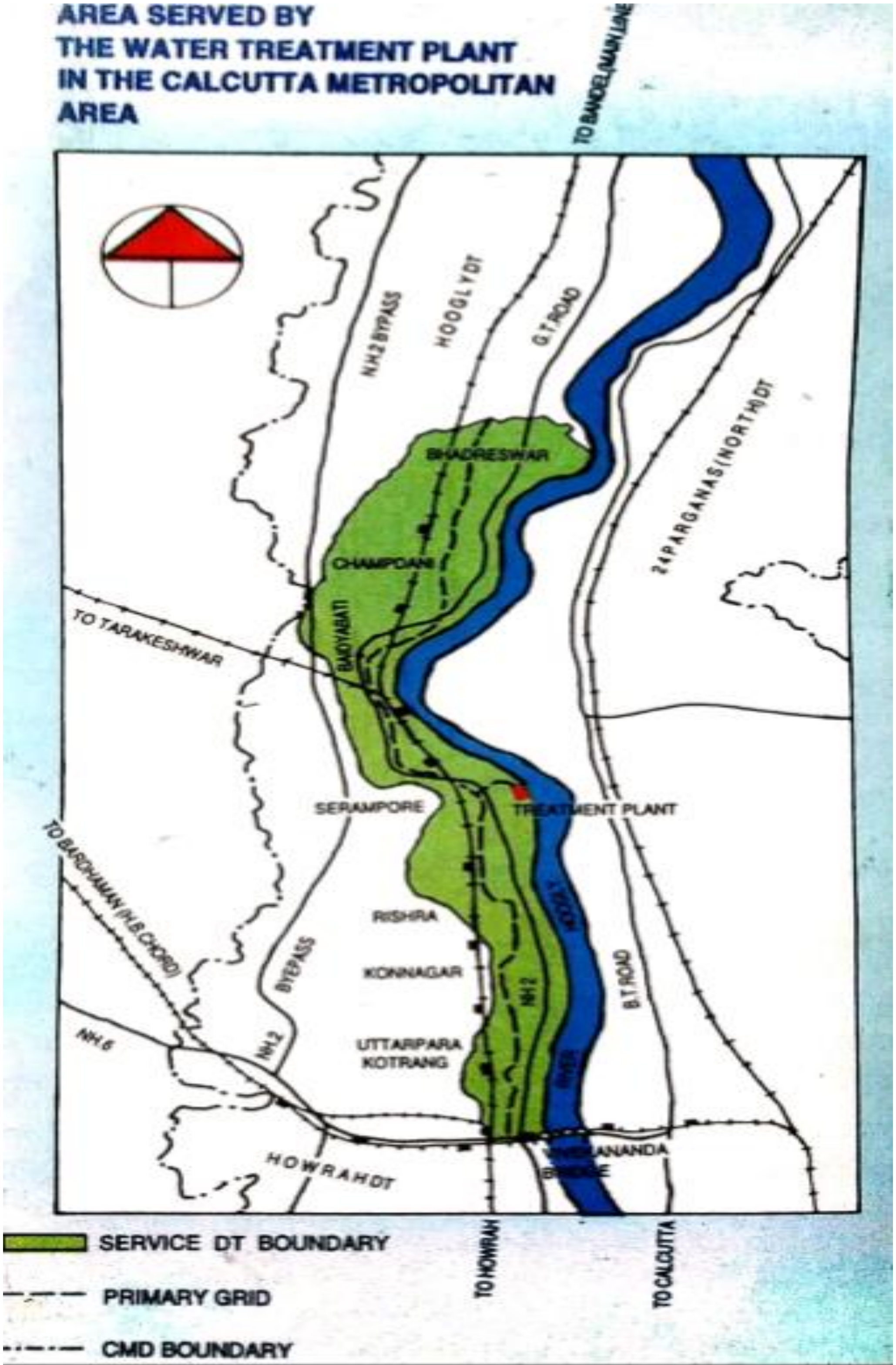


Figure 1.1 Area served by the Water treatment plant*

***Source**: *Report of Serampore Treatment Plant (2004), NEERI*

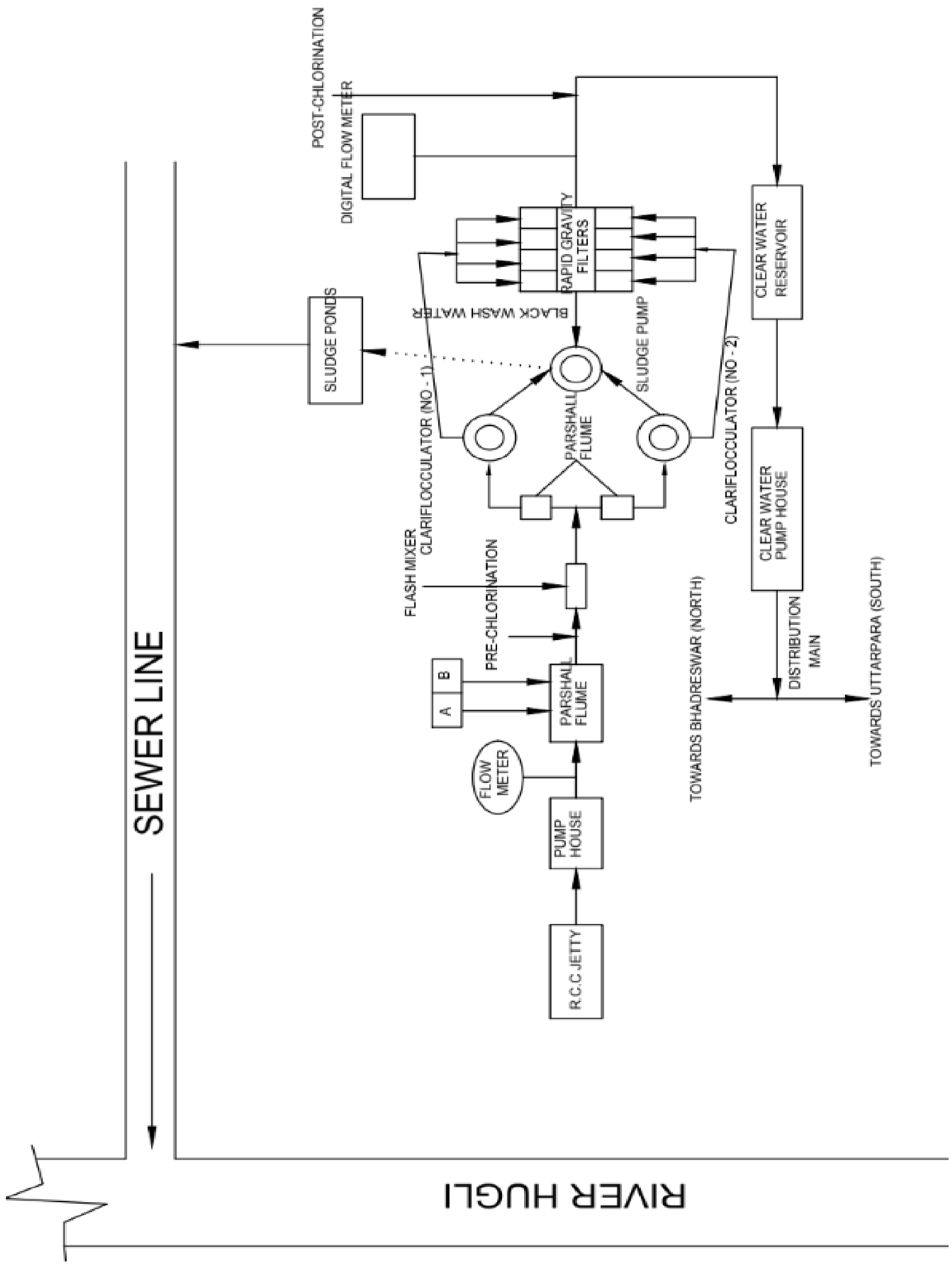


Figure 1.2 Layout of Serampore water Treatment Plant

CHAPTER 2

LITERATURE REVIEW

Literature Review

Kashyape and Jawed (2018) studied about the performance of a clariflocculator of a water treatment plant. They observed significant increase in the turbidity levels in outlet of the clariflocculator than that of the inlet during dry season. After analyzing all inlet and outlet data for both dry season and rainy season it was observed that the cause of ineffective performance of the clariflocculator during dry season is inadequate addition of coagulant doses.

Ray et al.(2016) assessed the bacteriological and physicochemical quality of packaged drinking water(PDW) sold in Kolkata city,India. In this study the quality of PDW and KMC supply have been compared. It was observed that both the PDW and KMC supply water were free from bacteria but at least 41% PDW had pH value less than 6.5 and pH value of KMC water supply was within the acceptable limit. This study shows that municipal corporation supply water having higher values of total dissolved solid (TDS), Calcium (Ca), Magnesium (Mg), Chloride(Cl-) and Fluoride(F-) compare to the PDW .Long-term consumption of low mineralized PDW may lead to potential risk on public health.

Mahajan et al.(2006) study shows that hard water is very dangerous to human health. Natural and treated waters have a wide range of mineral content. The mineral consumption from drinking water and cooking water will vary upon the location, treatment and water source .This study showed that lower value of hardness , TDS, magnesium, potassium. calcium and fluoride than the recommended limits of the WHO indicates the deficiency in essential minerals. It was observed that 10out of 17 samples had sodium content greater than 20mg/l which is maximum limit for the people with hypertension all over the world. Chloride and nitrates were found below the prescribed values of the WHO. 14 out of 20 samples have pH within the range of 7.0- 8.5 and only three samples were slightly acidic. It was observed that all the bottled drinking water had zero chlorine demand which is safe for consumption. In this it was found that zinc and copper concentration is lesser than the WHO recommended lower limit of 5mg/l and 0.05mg/l respectively but lead had been found to be greater than the limit of 0.015mg/l. prescribed by the WHO and USEPA.

Akram and Rehman (2018) studied hard water causes many diseases in human.Polyvalent metallic ions from sedimentary rocks, seepage and runoff from soil are the sources of hardness in water. Excess intakes of calcium and magnesium can increase the risks of osteoporosis, nephrolithiasis, colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Through ion-exchange device these ions can be treated at primary level for household purposes.This study shows that excess intake of magnesium salts may cause a temporary adaptable change in bowel habits but seldom causes hypermagnesaemia in persons with normal kidney function. Most of these disorders have treatments, but not cures.

M. A. ElDib and M. A. Elbayoumy (2003) analyzed the performance of a water treatment plant in Dakahlia (Meet Fares) . Biological, chemical, bacteriological analysis were conducted to evaluate the performance of each unit.It is observed that in coagulation tank 50-cm thick scum is accumulated at top daily. Chemical analysis result shows high concentration of alum in coagulation tank. Heavy metal was present in raw water as well as in final ground water but it's limit was below standard limit .But heavy metal concentration is high in sludge it's discharge to drain is considered a violation to environmental law.These study indicates the presence of organics in the coagulation tank. Continuous maintenance and analysis is required to run a successful operating plant.

Roy et al.(2014)studied to determine an efficient and simple method to remove arsenic from ground water.In these study ground water sample was analyzed in the three blocks(Lalgola, Bahadurpur, Jiaganj) of Murshidabad district located in West Bengal. From these analysis it was observed that these three blocks were arsenic affected areas.Based on laboratory experiment they have designed a unit for the community-based water supply scheme.Four types of coagulant (Ferrous sulphate, Ferric chloride, Aluminiumsulphate, Lime)had been used to analyze the removal efficiency of arsenic ,among them alum and lime showed the best results.The Arsenic Removal Unit is operated under atmospheric pressure and gravity flow.

Shahaby et al.(2015) studied chemical and bacteriological characteristics of drinking bottled and tap water . In this study total 103 bottled water representing 17 brands and 21 tap water were collected from different locations in and around Taif city. The result of this study shows that pH, Electrical conductivity (EC), Total dissolved solid (TDs) of bottled water were highest with respect to tap water. Total coliform and fecal coliform were equal in both tap water 9.5% and in bottled water 2.9%, respectively. E. coli was absent in both tap water and bottled water.Total aerobic microbial count (HPC) was higher in tap water 23.8% than bottled water 1.9%.This study suggested to protect public health, stringent quality control is recommended for the bottled water.

Khan et al. (2012) analyzed chemically and microbiologically 60 drinking water samples from both urban and rural areas of district Kohatin Pakistan. In this study fifty-four samples were collected from hand pumps, streams, tanks, wells and tube wells, at 15 main population zones selected and six bottled water samples were also taken from the open market for analysis.Samples were investigated for various chemical parameters including sodium (Na+), potassium (K+), sulfate (SO42-), phosphate (PO4-3), nitrate (NO3-), and nitrite (NO2-), using standard methods of analysis recommended by American Public Health Association (APHA) and Microbiological analysis was also carried out for Escherichia coli, to find out any fecal contamination. The result of this analysis shows that majority of water sources are not safe to drink.

Pal et al (2016) study shows that water quality of Rudrasagar Lake falls within the _good water' category but marginally. In this study all the water quality parameter examined and the results of pH varied from 6.2 to 9.0, indicating that the water samples are almost neutral to sub-alkaline in nature. The observed average DO concentration level of 6.5 mg/L complies with WHO standards and is considered good to sufficient for human consumption and most aquatic biota. It was observed that lake waters are till not polluted much as most of the cases BOD value is less than 3 mg/L. Turbidity is widely concerned as an important parameter for drinking water. However, the observed values are not within the permissible level recommended by the WHO for drinking water

Mota et.al (2013) carried out research on the method and criteria used for the performance evaluation of conventional water treatment plant and its findings. The results obtained shown the increase in the DO and decrease in the acidity of water and thus confirms proper working of aeration. But in case of high turbid water, the clariflocculator and filtration were failed to produce permissible limits.

Janna and Samawi (2014) studied the performance evaluation of Al-Karkh water treatment plant in Baghdad City. The 1-day average turbidity data of supplied water showed that the WTP was (2%) violate with the Iraqi and WHO standards, 2-day average turbidity data was 99% compliance with the USEPA and 30-day average turbidity result was 32% compliance with the **USEPA**.

Barlow & Clarke (2002) describe the water as a "universal and individual" truth that "the Earth's freshwater belong to the all species, and thereafter must not be treated as a private commodity to be bought, sold, and traded for profit... the global freshwater supply is a shared legacy, a public trust, and a fundamental human right, and therefore, a collective responsibility". The water tariff can be used to management to assist with the reform of the municipal water and sanitation sector (**D. Whittington, 2003**). The pricing of water services is controversial. But despite the controversial nature of municipal water pricing, the pricing policy reforms are possible in most South Asian cities and it will benefit almost everyone. He also mentions the objectives of water pricing such as 'revenue sufficiency', 'economic efficiency', 'equity', 'poverty mitigation'. A simple definition of cost recovery for water services is to recover all of the costs associated with a water system, service to ensure long-term sustainability. A water service is sustainable when it is functioning and being used, it is able to deliver an appropriate level of benefits to all, it continues to function over a prolonged period of time(beyond the life span of structure) and also it does not affect the environment negatively (**R. Cardone and C. Fonseca, 2003**).

Tchobanoglous and Burton (1991) state that raw water colloidal suspension consists of negatively charged particles. When particles are similarly charged, the resulting repulsive forces tend to stabilize the suspension and prevent particle agglomeration. In order to destabilize the colloids, that is to neutralize the negative surface charge positive ions are introduced into it through coagulation process and form a layer around the colloids.

McCave (1984) also found that Brownian motion dominates below 1.5 to 8 µm, but if large particles are present at realistic concentrations, they become important in the removal of fine particles by shear-controlled coagulation. According to **McCave (1984),** turbulent inertial coagulation is only important when particles extremely differ in diameter. For most particles its effect is orders of magnitude less than the effect of turbulent shear. Therefore the effect of turbulent inertia of suspended flocs is not likely to be an important flocculation mechanism in the Dollard estuary.

Stolzenbach &Elimelech (1994) showed that the likelihood of collision between a small particle and a faster settling, but less dense, larger particle is very small. Small particles overtaken by the large settling particle are deflected around the larger particle and collisions are impossible. Only collisions between flocs with a size difference of a factor 10 or more are still able to collide. The density of larger estuarine flocs is generally lower than the density of smaller estuarine flocs (**Dyer, 1989).** Therefore, the findings of **Stolzenbach&Elimelech (1994**) suggest that differential settling is probably hardly important in an estuary. A complicating factor is however the porosity of the flocs, throughflow typical of large marine aggregates increases the collision probability by an order of magnitude. The porosity may partly suppress the deflection of small particles around large particles and still make some collisions, due to differential settling, possible. However, Stolzenbach and Elimelech conclude that aggregation by differential settling is only significant between very small and very large particles.

KshitijaBalwan et al., (**2016)** Conducted a pilot scale model and installed at Ichalkaranji municipal water treatment plant the effect of length and inclination of tube settler the flocculated water was used the multiple tubular channels of tube settlers are used at an angle of about 450 to 600 and adjacent to that with the used of this the increased effective settling area the circular tubes were used with inclination of 450 to 600 of 45 mm diameter the length of tube varied as 60 cm, 50 cm,& 40 cm the four pvc tubes of 4.5 cm diameter was connected to the bottom of base tank representing the tube settler.)

Pereira et al. (2013) tested the effectiveness of free chlorine for the inactivation of fungi present in settled surface water. In addition to that, free chlorine inactivation rate constants of Cladosporiumtenuissimum, Cladosporiumcladosporioides, Phomaglomerata, Aspergillusterreus, Aspergillusfumigatus, Penicilliumgriseofulvum, and Penicilliumcitrinum that were found to occur indifferent source waters were determined in different water matrices (laboratory gradewater and settled water). They also stated the effect of using different disinfectant concentrations (1 and 3 mg/l), temperatures (21°C and 4°C), and pH levels (6 and 7). They found the sensitivity degree of different fungi isolates to chlorine disinfection varied among different general with some species showing a higher resistance to disinfection and others expected to be more prone to protection from inactivation by the water matrix components. When they measured the disinfection efficiency in terms of the chlorine concentration and contact time (CT) values needed to achieve 99% inactivation were compared with the CT values reported as being able to achieve the same degree of inactivation of other microorganisms, they found fungi were to be more resistant to chlorine inactivation than bacteria and viruses and less resistant than Cryptosporidium oocysts.

Somani et al. (2011) used Sodium Chloride (NaCl) and Sodium Hypochlorite (NaOCl) for the disinfection of water. They determined the percentage reduction in bacteria population by using disinfectants NaCl and NaOCl for 10%concentration at different contact times and the percentage reductions in bacteria population by using same disinfectants at different percentage concentration. After the experiment, they observed that for 30 min. contact time percentage reduction in bacterial population was 82.05 % by using Sodium Chloride (NaCl) and 89.74% by using Sodium Hypochlorite (NaOCl) and also observed that maximum percentage reduction in bacterial population at 10% concentration of disinfectants. From the obtained results they concluded that Sodium Chloride (NaCl) and Sodium Hypochlorite (NaOCl) can be effectively used as a disinfectant to remove pathogenic bacteria from the water and make water safe for the user.

Casteel et al. (2008) performed experiments to determine the kinetics of free chlorine inactivation of hepatitis A virus (HAV) and the indicator virus coliphage MS2 on strawberries (SBs), cherry tomatoes (CTs), and head lettuce (HL). The oxidant demands of those produce items also was determined. When they exposed the items to approximately 20 parts per million (ppm) solutions of free chlorine for 5–10 min, HAV and MS2 were inactivated by 90–99% and in some cases virus inactivation was ≥99%. Exposure of strawberries to approximately 200 ppm free chlorine resulted in more rapid and extensive inactivation of both viruses. The items tested in the study exhibited a demand for chlorine which varied by produce type, and chlorine residuals declined over time. The found results demonstrated the potential for chlorine to reduce the levels of infectious viruses on different produce types, but adequate contact time and chlorine residual are required to achieve maximum virus inactivation. After the experiment they commented that the inactivation kinetics of MS2 and HAV were similar and also suggested that MS2 and perhaps other similar bacterial viruses may be used as process indicators and surrogates for determining the disinfection efficacy of produce in the laboratory or in actual practice. From the results they also commented that the difference in chlorine demand between SBs, CTs, and HL suggests that varying disinfection practices are needed for the wide variety of processed fruits and vegetables

Somani and Ingole (2011) Used different methods other than chlorination for disinfection of water as it has been proved that chlorine may produce Trihalomethanes (THM's) that are toxic and classified the methods of disinfection into three categories– Physical Methods; Chemical Methods; and Membrane Processes. They included (a) Boiling (b) Solar (c) TiO_2 films and sunlight (d) U-V radiation (e)Electromagnetic Radiation; (f) Ultra-sonic sound; and (g) Activated Carbon in Physical method category, included (a) Ozone; (b) Hydrogen peroxide; (c) Acid & alkali; (d) Metallic ions; (e) Other Halogens; (f) Lime; (g) Chlorite and Chlorine Dioxide, (h) Anodic Oxidation and (i) Potassium permanganate in the chemical method category and included (a) Microfiltration & Ultra filteration; (b) Reverse Osmosis and (c) Photo sensitizers immobilized on Chitosan membrane in Membrane Process category. After the whole experiment they concluded that the methods of disinfection are attractive in certain specific situations but have disadvantages like cost and no residual effect.

Izadiet al. (2010) Carried out a study on the effects of incubation period and temperature on the Hydrogen sulphide (H_2S) technique for detection of faecal contamination in water. In his research paper he showed that the incubation period of H_2S bottles is highly dependent on temperature and concentration of faecal coliform bacteria. In their study they indicated that incubation period and temperature had significant effects ($P = 0.05$) on the efficiency of H_2S technique. The times when H_2S bottles take to turn black is dependent on the number of faecal bacteria, an indicator of the risk that pathogenic organisms are present. Based on the results obtained in their study, they concluded that H_2S technique is a reliable method that can be used as an alternative for indication of faecal contamination for drinking water quality surveillance. By using this technique at high temperatures, rapid screening of large number of water samples in a short period can be profitable especially when the number of drinking water sources is high. They also concluded by their study that H_2S test is a reliable and alternative indicator of faecal contamination in drinking water quality surveillance and screening of large number of water samples in short duration in the field where laboratory facilities are limited. and H_2S test is a simple and versatile test, that can be carried out in the field within a broad range of incubation temperature and is recommended for the routine monitoring of water for detection of faecal contamination.

Pillai et al. (1999 done a study to analyze the reliability of the H_2S method for detecting faecal contamination in drinking water. For that, they determined the minimum level of faecal coliforms that could be detected and the incubation period required at various levels of contamination. They also determined the range of temperatures at which the method was effective and the incubation period required at various temperatures. After the whole experiment they found the H_2S method to be able to detect contamination down to a level of 1 CFU/100mL of coliform bacteria and observed that the H_2S method can be used at a temperature range of 20 to 44°C, temperatures between 28 to 37°C gave faster results and an incubation period of only 24 hours is required at 37°C, which was found to be the most suitable incubation temperature. They increased incubation period with a decrease or increase in temperature.

Manja et al. (1982) Developed an on-site microbial water testing method based on the detection of hydrogen sulphide producing bacteria. Human faces contain high concentrations of sulphate reducing bacteria, which can be as high as to 10^{10}/g. The hydrogen sulphide paper strip method (H_2SMethod) was developed for testing water in case of an emergency when frequent testing of large numbers of samples becomes essential. They conducted study using natural samples, which may contain H_2S producing bacteria other than those of faecal origin and reported that the H_2S method could detect faecal contamination in drinking water.

Northcott et al. (2005) presented his article about the water treatment in cold region for contaminated water.This research concentrated on coagulation experiments and modeling methods for the water treatment process. The water quality parameters considered were pH, coagulant dosage and flow rate. This research showed that a simple laboratory set up could be used to predict the full scale water treatment process performance. The authors suggested that the laboratory set up can be tested in different operating conditions without affecting the real process.

CHAPTER 3

STUDY AREA

Study Area

3.1 Plant Location

The Serampore Water Treatment Plant is located at Chowdhuri Para Lane under Serampore Municipality. The Plant is located at 2-2.5 km East of Serampore Railway station while its intake point islocated about 0.5 Km North of the plant. Both the plant and the intake point are located by the side of river Hooghly.

3.2 Details of the Plant

The 20MGD Serampore Water Treatment Plant (SWTP) consists of the units which are presented in layout of the plant (Figure 1.2)

- Raw water Intake Point
- Parhsall Flume
- Pre Chlorination
- Flash Mixer
- Chemical House
- Clariflocculators
- Filter Beds
- Post-Chlorination
- Clear water Reservoir
- Clear Water Pump House
- Sludge Pond

3.2.1 Raw Water Intake Point

R.C.C jetty of 60 meters length has been constructed on Hooghly river bank where sufficient draft is available for drawl of raw water from river. It is about 700m from the plant.

The raw water pumping station presently has 4 pumps (2 pumps are standby), each capable of drawing and delivering 2250 m^3 of river water per hour. Diaphragm wall is present as a structural member in Raw Water Pumping Station (RWPS). Water is conveyed to the treatment plant through a 1100 mm dia glass- fiber reinforced pipeline.

3.2.2 Parshall Flume

The parshall flume is set just before the flash mixer. A flow meter is present in the left side of the parshall flume (throat width-60cm) to measure total inflow of water, based on which the coagulant and coagulant aids are to be added in the form of solution before the entry of the water into the flash mixer. Moreover, just at the point of the flume a hydraulic jump occurs where coagulants are added for homogeneous mixing.

3.2.3 Pre- Chlorination

Pre-chlorination is done by mixing chlorine gas with water. This chlorine is applied to raw water before entry of the water into the flash mixer. Plant has two numbers(one standby) about 30 Kg/hour capacity Wallance and Tieman made chlorinators in the chlorination room, which meet the pre- chlorination requirement.

3.2.4 Flash Mixer

The flow from the parshall flume passes into a distribution tank of size 4.2 m dia x 6.16 m. The raw water dosed with coagulant (along with coagulant aid in the monsoon period) flows from the tank to the flash mixer. The flash mixer has provided with 10H.P motor driven propeller type 4 bladed agitator having speed of 1440 rpm and detention time not less than 60 second.

3.2.5 Chemical House

Chemical house is provided with arrangements for chlorination, storage, preparation and distribution of chemicals that are added to the raw water for the treatment .Plant laboratory is located in the first floor of chemical house.

- Six numbers alum tanks each of capacity 17.7 m^3 are provided for solutionizing the alum blocks
- Alum solution(5%) is added to the raw water at the raw water channel.
- Polyelectrolyte, which is cationic polymer and is obtained in liquid form, acts as a Coagulant aid, is also added to raw water in order to enhance the rate of flocculation and setting thereof. This is applied in the form of solution(0.1%).

Figure 3.1 Raw Water

Figure 3.2 Flow Meter

Figure 3. 3 Clariflocculator

3.2.6 Clariflocculator

The object of Clariflocculator is to form settleable flocs during flocculation in the flocculation zone and their removed by gravitation settling in the clarifying zone. The clear water over flows leaving behind the settleable solids.

There are 2 nos of clariflocculator units in Serampore Water Treatment Plant(SWTP). Facing towards sludge ponds, left hand side clariflocculator can be called as clariflocculator No.1 and right hand side can be called as clariflocculator No.2. Each clariflocculator has a volume of 2200m^3. The sizes of the clarifier and flocculator are 47.5 m dia x 4.375 S.W.D. and 17.5m dia X 5.81 m S.W.D. respectively. Each flocculationg zone is having theoretical detention time of 30 minutes and that of clarifying zone is 180 minutes i.e 3hrs.

The clarified water comes out through orifices to the clarifier water collection channel and goes to the Rapid Gravity Sand Filter Beds.

3.2.7 Rapid Gravity Filter

The clarified water fom the clariflocculation is received in the filter inlet channel by gravity. There are 10 nos.filter bed each with a filterarea of 88.10m^3 giving a filter rating of about 5m^3/m^2 /hr.

While filtering 440 m^3 of water per hour.Washwater and air flow rates are 500lit/m^2/min and 750litr/m^2/min respectively.

The filter media consists of sand of effective size varies from 0.45 mm to 0.70mm and uniformity coefficient of 1.3 to 1.7 with depth of 600 mm with supporting gravel of sizes from 5mm to 15 mm with total depth of 500 mm and underdrainage system. Each filter is provided with an inlet and outlet, washwater inlet and wastewater drain outlet. The filter outlet is provided with an automatic rate of flow controller to maintain uniform flow of filtration. The clarified water from the filter inlet channel flows through the filter beds. The clarified water bearing the residual suspended solids passes down the filter media during which the solids are retained on the top of the media . This accumulation of suspended solids causes the choking of media and needs backwashing after periodical interval of 72 hours , in each filter bed by air compressor and water. The diameter of backwash delivery pipe of each filter is 900mm. Backwash water rate according to design is500litre/m^2/min. Sludge washwater is stored in the Sludge Pond through Sludge Pump House (SPH).

Figure 3.4 Rapid Sand Filter

Figure 3.5 Backwashing of Filter Bed

Figure 3.6 Sludge House

Figure 3.7 Control Panel of Backwashing of Filter Bed

3.2.8 Post- chlorination

Post – chlorination is done by chlorine gas mixed with water. This chlorine is applied to filtered water before entry of the water into the Clear Water Reservoir (CWR). Plant has two numbers(one standby) 10kg/hour capacity Wallance and Tieman made chlorination equipment.

3.2.9 Clear Water Reservoir

The treated (i.e filtered and disinfected) Water from Filter house is conveyed to 9 million litres capacity Underground Clear Water Reservoir(UGCWR) for storing through a 1600mm diameter hume pipe.

3.2.10 Clear Water Pumping Station

The filtered and disinfected water is pumped into the 27 km long primary grid by pumps located in the clear water pumping stayion. The station has 6 pumps, each capable of delivering 2100 m^3 of water per hour with a total head of 60metres.

3.2.11 Sludge Pond

The sludge water from the plant is disposed through a pump house and is conveyed through a pipeline to the twin Sludge Pond having total volume of $1800m^3$.

3.3 Distribution Mains

The treated potable water from the Serampore water Treatment Plant (SWTP) caters the water supply to the seven adjoining Municipalities viz. Serampore, Uttarpara, Konnagar, Rishra, Baidyabati, Bhadreshwar and Champdani. Figure shows the location of distribution mains (Take off points) and overhead reservoirs through which treated water is supplied to the consumers of seven adjoining Municipalities at specified timing.

Figure 3.8 Chlorinator

Figure 3 9 Underground Reservoir

Figure 3.10 Sludge Pond

CHAPTER 4

WATER QUALITY PARAMETER

Water Quality Parameter

4.0 Characteristics of Water

The raw or treated water can be checked and analysed by studying and testing their physical, chemical and microscopical characteristics, as explained below.

4.1 Physical Water QualityParameter

Physical parameters define those characteristics of water that respond to the senses of sight, touch, taste or smell. Suspended solids, turbidity, colour, taste and odour and temperature fall into this category.

4.1.1 Suspended solids

Solids can be dispersed in water in both suspended and dissolved forms. Although some dissolved solids may be perceived by the physical senses, they fall more appropriately under the category of chemical parameters.

Solids suspended in water may consist of inorganic or organic particles or of immiscible liquids. Inorganic solids such as clay,siltand other soil constituents are common in surface water. Organic material such as plant fibers and biological solids (algal cells, bacteria, etc.) are also common constituents of surface water. These materials are often natural contaminants resulting from the erosive action of water flowing oversurfaces.

Other suspended material may result from human use of the water. Domestic wastewater usually contains large quantities of suspended solids that are mostly organic in nature. Industrial use of water may result in a wide variety of suspended impurities of either organic or inorganic nature. Immiscible liquids such as oil and greases are often constituents ofwastewater.

Suspended material may be objectionable in water for several reasons. It is aesthetically displeasing and provides adsorption sites for chemical and biological agents. Suspended organic solids may be degraded biologically, resulting in objectionable by-products. Biologically active (live) suspended solids may include disease-causing organisms as well as organisms such as toxin-producing strains ofalgae.

Most suspended solids can be removed from water by filtration. (Reference - Peavy, Howard S. and Rowe, Donald R. , edition 2013, EnvironmentalEngineering).

4.1.2 Turbidity

Turbidity is a measure of the extent to which light is either absorbed or scattered by suspended material in water. Because absorption and scattering are influenced by both size and surface characteristics of the suspended material , turbidity is not a direct quantitative measurement of suspended solids.

Most turbidity in surface water resultfrom the erosion of colloidal material such as clay, silt, rock fragments and metal oxides from the soil. Vegetable fibers and microorganisms may also contribute to turbidity. Household and industrial wastewater may contain a wide variety of turbidity-producing material. Soaps, detergents and emulsifying agents produce stable colloids that result inturbidity.

When turbid water in a small, transparent container, such as a drinking glass, is held up to the light, an aesthetically displeasing opaqueness or “milky” coloration is apparent. The colloidal material associated with turbidity provides adsorption sites for chemicals that may be harmful or cause undesirable tastes and odoursand for biological organisms that may beharmful.

In natural water bodies, turbidity may impart a brown or other colour to water, depending on the light-absorbing properties of the solids and may interfere with light penetration and photosynthetic reactions in streams and lakes.

Fortunately, traditional water treatment process have the ability to effectively remove turbidity when operated properly.

Turbidity is measured by Digital Nephelo Turbidity Meter. (Reference - Peavy, Howard S. and Rowe, Donald R. , edition 2013, Environmental Engineering).

4.1.3 Colour

Pure water is colorless, but water in nature is often coloured by foreign substances. Water whose colourispartly due to suspended matter is said to have *apparent colour*. Colour contributed by dissolved solids that remain after removal of suspended matter is known as *truecolour*.

Coloured water is not aesthetically acceptable to the general public. In fact, given a choice, consumers tend to choose clear, noncoloured water of otherwise poorer quality over treated potable water supplies with an objectionable colour. Highly colored water isunsuitable for laundering, dyeing, papermaking, beverage manufacturing, dairy production and other food processing and textile and plastic production. Thus, the colour of water affects its marketability for both domestic and industrial use.

While true colour is not usually considered unsanitary or unsafe, the organic compound causing true colour may exert a chlorine demand and thereby seriously reduce the effectiveness of chlorine as a disinfectant. Perhaps more important are the products formed by the combination of chlorine with some colour-producing organics. Phenolic compound, common constituents of vegetative decay products,produce very objectionable taste and odour compounds with chlorine. Additionally, some compounds of naturally occurring organic acids and chlorine are either known to be, or are suspected of being carcinogens (cancer-causing agents).

4.1.4 Taste and Odour

The terms taste and odourare themselves definitive of this parameter. Because the sensations of taste and smell are closely related and often confused, a wide variety of tastes and odours may be attributed to water by consumers. Substances that produce an odourinwater will almost invariably impart a taste as well. The converse is not true, as there are many mineral substances that produce taste but noodour.

Many substances with which water comes into contact in nature or during human use may impart perceptible taste and odour. These include minerals, metals and salts from the soil, end products from biological reactions and constituents of wastewater. Inorganic substances are more likely to produce tastes unaccompanied by odour. Alkaline material imparts a bitter taste to water, while metallic salts may give a salty or bitter taste. Organic material, on the other hand, is likely to produce both taste and odour. Biological decomposition of organics may also result in taste and odour producing liquids and gases in water. Principal among these are the reduced products of sulfur that impart a “rotten egg” taste and odour. Also, certain species of algae secrete an oily substance that may result in both taste andodour.

Consumers find taste and odour aesthetically displeasing for obvious reasons.

Because water is thought of as tasteless and odourless, the consumer associates taste and odour with contamination and may prefer to use a tasteless, odourless water that might actually pose more of a health threat.

4.1.5 Temperature

Temperature is not used to evaluate directly either potable water or wastewater. It is, however, one of the most important parameter in natural surface water systems. The temperature of surface water governs to a large extent the biological species present and their rates of activity. Temperature has an effect on most chemical reactions that occur in natural water systems. Temperature alsohas*a* pronounced effect on the solubilities of gases inwater.

The temperature of natural water systems responds to many factors, the ambient temperature (temperature of the surrounding atmosphere) being the most universal. Generally, shallow bodies of water are more affected by ambient temperatures than are deeper bodies. The use of water for dissipation of waste heat in industry and the subsequent discharge of the heated water may result in dramatic, though perhaps localized, temperature changes in receiving streams.

4.2 Chemical Water QualityParameters

Water has been called the universal solvent and chemical parameters are related to the solvent capabilities of water. Total dissolved solids, pH value, alkalinity, hardness, fluorides, metals, organics and nutrients are chemical parameters of concern in water-quality management. The following review of some basic chemistry related to solutions should be helpful in understanding subsequent discussions of chemical parameters.

4.2.1 Total dissolvedsolids

The material remaining in the water after filtration for the suspended solids analysis is considered to be dissolved. This material is left as a solid residue upon evaporation of the water and constitutes a part of total solids. Dissolved material results from the solvent action of water on solids, liquids and gases. Like suspended material, dissolved substances may be organic or inorganic in nature. Inorganic substances which may be dissolved in water include minerals,metals and gases. Water may come in contact with these substances in the atmosphere, on surfaces and within the soil. Materials from the decay products of vegetation, from organic chemicals and from the organic gases are common organic dissolved constituents of water. The solvent capability of water makes it an ideal means by which waste products can be carried away from industrial sites andhomes.

Many dissolved substances are undesirable in water. Dissolved minerals, gases and organic constituents may produce aesthetically displeasing color, tastes, and odours. Some chemicals may be toxic and some of the dissolved organic constituents have been shown to be carcinogenic. Quite often, two or more dissolved substances especially organic substances and members of the halogen group will combine to form a compound whose characteristics are more objectionable than those of either of the originalmaterials.

Not all dissolved substances are undesirable in water. For example, essentially pure, distilled water has a flat taste. Additionally, water has an equilibrium state with respect to dissolved constituents.

A direct measurement of total dissolved solids can be made by evaporating to dryness a sample of water which has been filtered to remove the suspended solids. The remaining residue is weighed and represents the *total dissolved solids (TDS)* in the water.

(Reference - Peavy, Howard S. and Rowe, Donald R. , edition 2013, Environmental Engineering).

4.2.2 pH value ofwater

The pH value of water indicates the logarithm of reciprocal of hydrogen ion concentration present in water. It is thus an indicator of the acidity or the alkalinity ofwater.

Since the pH is the log of reciprocal of H+, the higher values of pH means lower hydrogen ion concentrations and thus represent *alkaline* solutions; whereas, the lower values of pH means higher hydrogen ion concentrations representing *acidic* solutions.

Truly speaking, pure water is a balanced combination of positively charged hydrogen ions (i.e. H^+) and negatively charged hydroxyl ions (i.e.OH^-). In pure or natural waters, their number is equal. Further, it has been found that the product of concentration of H ions and concentration of OH ions in awater solutionisconstant. This constant has been found to be equal to 10^{-14} moles/litre. Therefore, if H ion and OH ion concentrations are equal, virtually each will have a concentration equal to $\sqrt{10^{-14}} = 10^{-7}$ moles per litre. A neutral water will, therefore, have a pH equal to $\log_{10}(1/H^{+}) = \log_{10(1/10}{}^{-7}) = \log_{1010}{}^{7} = 7$.

If an acid is added to the neutral or pure water, the number of hydrogen ions will increase because of the hydrogen contained in the acid. For example, if hydrochloric acid is dissolved in water, the dissociation becomes

$$H_2O \rightleftharpoons H^{+} + OH^{-}$$

$$HCL \rightleftharpoons H^{+} + Cl^{-}$$

Then the net concentration of hydrogen ions will exceed that of hydroxyl ions and will be more than the hydrogen ion concentration of neutral water (i.e. 10^{-7}) and thus decreasing the pH value to less than 7 and thereby making the water acidic.

Similarly, if an alkali is dissolved in pure water, the concentration of hydroxyl ions will exceed the hydroxyl ion concentration of neutral water and thus, reducing the concentration of hydrogen ions to less than 10^{-7}. (Theirproduct being constant = 10^{-14} moles/litre). For example, if sodium hydroxide is added to water, the dissociation willbe

$$H_2O \rightleftharpoons H^{+} + OH^{-}$$

$$NaOH \rightleftharpoons Na^{+} + OH^{-}$$

The net amount of OH ions present in this alkaline water will, therefore, be more than that present in a neutral water and thus reducing the hydrogen ion concentration to less than 10^{-7} and thereby increasing the pH above 7 and making the water alkaline.

Hence, if the pH of water is more than 7, it will be alkaline and if it is less than 7, it will be acidic. The maximum acidity will be at zero value of pH and the maximum alkalinity will be at a value of pH equal to 14.

Testing the pH value of water, therefore, directly tells us as to whether the water is acidic or isalkaline.

However, the permissible pH values for public supplies may range between 6.6 to 8.5.

pH is measured by the Digital pH Meter.

(Reference –Peavy, Howard S. and Rowe, Donald R. , edition 2013, Environmental Engineering and Garg, S.K., twentieth revised edition, 2010, Water SupplyEngineering).

4.2.3 Alkalinity

Alkalinity is defined as the quantity of ions in water that will react to neutralize hydrogen ions. Alkalinity is thus a measure of the ability of water to neutralize acids.

The most common constituents of alkalinity are bicarbonate (HCO_3^-), carbonate ($CO_3^=$) and hydroxide (OH^-). In addition to their mineral origin, these substances can originate from carbon dioxide, a constituent of the atmosphere and a product of microbial decomposition of organic material. These reactions are as follows :

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \text{ (dissolved } CO_2 \text{ and carbonic acid)}$$
$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \text{ (bicarbonate)}$$
$$HCO_3^- \rightleftharpoons H^+ + CO_3^= \text{ (carbonate)}$$
$$CO_3^= + H_2O \rightleftharpoons HCO_3^- + OH^- \text{ (hydroxide)}$$

In large quantities, alkalinity imparts a bitter taste to water. The principal objectiontoalkaline water, however, is the reactions that can occur between alkalinity and certain cationsinthe water. The resultant precipitate can foul pipes and other water-systems appurtenances. (Reference - Peavy, Howard S. and Rowe, Donald R. , edition 2013, EnvironmentalEngineering).

4.2.4 Hardness

Hardness is defined as the concentration of multivalent metallic cations in solution. At supersaturated conditions, the hardness cations will react with anions in the water to form a solid precipitate. Hardness is classified as *carbonate hardness* and *noncarbonate hardness,* depending upon the anion with which it associates. The hardness that is equivalent to the alkalinity is termed carbonate hardness, with any remaining hardness being called noncarbonate hardness.

Carbonate hardness is sensitive to heat and precipitates readily at high temperature.

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 + CO_2 + H_2O$$

$$Mg(HCO_3)_2 \xrightarrow{\Delta} Mg(OH)_2 + 2CO_2$$

The multivalent metallic ions most abundant in natural waters are calcium and magnesium. Hardness may be represented by the sum of the calcium and magnesium ions.

Hard water is undesirable because they may lead to greater soap consumption, scaling of boilers, causing corrosion and incrustation of pipes, making foods tasteless, etc.

$$2NaCO_2C_{17}H_{33} + Cation^{2+} \rightarrow Cation^{2+} + (CO_2C_{17}H_{33})_2 \downarrow + 2Na^{+}$$

Soap Precipitate

Magnesium hardness, particularly associated with the sulfate ion, has a laxative effect on persons unaccustomed to it. Magnesium concentration of less than 50 mg/l is desirable in potable water, although many public water supplies exceed this amount. Calcium hardness presents no public health problem. In fact, hard water is apparently beneficial to the human cardiovascularsystem.

Hardness can be measured by using spectrophotometric techniques or chemical titration to determine the quantity of calcium and magnesium ions in a given sample.

A generally accepted classification is as follows :

Soft < 50 mg/l as $CaCO_3$
Moderatelyhard 50 to 150 mg/l as $CaCO_3$
Hard 150 to 300 mg/l as
$CaCO_3$Veryhard > 300 mg/l as$CaCO_3$

(Reference –Peavy, Howard S. and Rowe, Donald R. , edition 2013, Environmental Engineering and Garg, S.K., twentieth revised edition, 2010, Water Supply Engineering).

4.2.5 Fluoride

Generally associated in nature with a few types of sedimentary or igneous rocks, fluoride is seldom found in appreciable quantities in surface water and appears in groundwater in only a few geographical regions. Fluoride is toxic to humans and other animals in large quantities, while small concentrations can be beneficial

Concentration of approximately 1.0 mg/l in drinking water help to prevent dental cavities in children. During formation of permanent teeth, fluoride combines chemically with tooth enamel, resulting in harder, stronger teeth that are more resistant to decay. Fluoride is often added to drinking water supplies if sufficient quantities for good dental formation are not naturally present.

Excessive intakes of fluoride can result in discoloration of teeth. Noticeable discoloration, called *mottling or dental fluorosis* is relatively common when fluoride concentrations in drinking water exceed 2.0 mg/l, but is rare when concentrations are less than 1.5 mg/l. Adult teeth are not affected by fluoride. Excessive dosages of fluoride can also result in bone fluorosis and other skeletal abnormalities.

4.2.6 Chloride

Chloride is widely distributed in nature, generally as the sodium (NaCl) and potassium (KCl) salts. By far the greatest amount of chloride found in the environment is in the oceans.

Sodium chloride is widely used in the production of industrial chemicals such as caustic soda (sodium hydroxide), chlorine, soda ash (sodium carbonate), sodium chlorite, sodium bicarbonate and sodium hypochlorite. Potassium chloride is used in the production offertilizers.

The presence of chloride in drinking water sources can be attributed to the dissolution of salt deposits, leaching of marine sedimentary deposit, seawater intrusion in coastal areas, effluents from chemical industries, oil well operations, sewage, irrigation drainage, etc. Each of these sources may result in local contamination of surface water and groundwater. The chloride ion is highly mobile and is eventually transported into closed basins or to the oceans.

Chloride is an essential element and is the main extracellular anion in the body. It is a highly mobile ion that easily crosses cell membranes and is involved in maintaining proper osmotic pressure, water balance and acid base balance.

The toxicity of chloride salts depends on the cationpresent, that of chloride itself is unknown. Although excessive intake of drinking water containing sodium chloride at concentration above 2.5g/l has been reported to produce hyper tention, this effect is believed to be related to the sodium ion concentration.

Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, e.g. in congestive heart failure. Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Little is known about the effect of prolonged intake of large amounts of chloride in the diet. As in experimental animals, hypertension associated with sodium chloride intake appears to be related to the sodium rather than the chlorideion.

4.2.7 Metals

All metals are soluble to some extent in water. While excessive amounts of any metal may present health hazards, only those metals that are harmful in relatively small amounts are commonly labeled toxic; other metals fall into the nontoxic group. Sources of metals in natural water include dissolution from natural deposits and discharges of domestic, industrial, or agricultural wastewaters. Measurement of metals in water is usually made by atomic absorption spectro-photometry.

4.2.8 Nontoxic Metals

In addition to the hardness ions, calcium and magnesium, other nontoxic metals commonly found in water include sodium, iron, manganese, aluminum, copper andzinc.

4.2.9 Sodium

Sodium by far the most common nontoxic metal found in natural water is abundant in the earth's crust and is highly reactive with other elements. The salts of sodium are very soluble in water. Excessive concentrations cause a bitter taste in water.

Sodium is also corrosive to metal surfaces and, in large concentrations, is toxic to plants.

4.2.10 Iron andManganese

Iron and manganese quite frequently occur together and present no health hazards at concentrations normally found in natural water. Iron and manganese in very small quantities may cause colour problems. Iron concentration of 0.3 mg/l and manganese concentration as low as 0.05 mg/l can cause colour problems.

Additionally, some bacteria use iron and manganese compounds for energy source and the resulting slime growth may produce taste and odourproblems.

4.2.11 Toxic Metals

Toxic metals are harmful to humans and other organisms in small quantities. Toxic metals that may be dissolved in water include arsenic, barium, cadmium, chromium, lead, mercury and silver. Cumulative toxins such as arsenic, cadmium, lead and mercury are particularly hazardous. These metals are concentrated by the food chain, thereby posing the greatest danger to organisms near the top of the chain.

Fortunately, toxic metals are present in only minute quantities in most natural water systems. Although natural sources of all the toxic metals exist, significant concentration in water can usually be traced to mining, industrial or agricultural sources.

4.3 Organics

Many organic materials are soluble in water. Organics in natural water systems may come from natural sources or may result from human activities. Most natural organics consist of the decay products of organic solids, while synthetic organics are usually the result of wastewater discharges or agricultural practices. Dissolved organics in water are usually divided into two broad categories: biodegradable andnon biodegradable(refractory).

4.3.1 Biodegradable Organics

Biodegradable material consists of organics that can be utilized for food by naturally occurring microorganisms within a reasonable length of time. In dissolved form, these materials usually consist of starches, fats, proteins, alcohols, acids, aldehydes, and esters. They may be the end product of the initial microbial decomposition of plant or animal tissue or they may result from domestic or industrial wastewater discharges. Although some of these materials can cause colour, taste and odour problems, the principal problem associated with bio- degradable organics is a secondary effect resulting from the action of micro- organisms on these substances.

molecule) or by *reduction* (addition of hydrogen to, or deletion of oxygen from elements of the organic molecule). Although it is possible for the two processes to occur simultaneously, the oxidation process is by far more efficient and is pre-dominant when oxygen is available. In *aerobic* (oxygen-present) environments, the end products of microbial decomposition of organics are stable and acceptable compounds. *Anaerobic* (oxygen-absent) decomposition results in unstable and objectionable end products. Should oxygen later become available, anaerobic end products will be oxidized to aerobic endproducts.

The amount of oxygen consumed during microbial utilization of organics is called the *biochemical oxygen demand (BOD).*

4.3.2 Nonbiodegradable Organics

Some organic materials are resistant to biological degradation. Tannic and lignic acids, cellulose and phenols are often found in natural water systems. These constituents of woody plants biodegrade so slowly that they are usually considered refractory. Molecules with exceptionally strong bonds (some of the poly-saccharides) and ringed structures (benzene) are essentially nonbiodegradable.

4.4 Nutrients

Nutrients are elements essential to the growth and reproduction of plants and animals and aquatic species depend on the surrounding water to provide their nutrients. Although a wide variety of minerals and trace elements can be classified as nutrients, those required in most abundance by aquatic species are carbon, nitrogen and phosphorus. Carbon is readily available from many sources. Carbon dioxide from the atmosphere, alkalinity and decay products of organic matter all supply carbon to the aquatic system. In most cases, nitrogen and phosphorus are the nutrients that are the limiting factors in aquatic plantgrowth.

4.4.1 Nitrogen

Nitrogen gas (N_2) is the primary component of the earth's atmosphere and is extremely stable. It will react with oxygen under high-energy conditions (electrical discharges or flame incineration) to form nitrogen oxides. Although a few biological species are able to oxidize nitrogen gas, nitrogen in the aquatic environment is derived primarily from sources other than atmosphericnitrogen.

Nitrogen is a constituent of proteins, chlorophyll and many other biological compounds. Upon the death of plants or animals, complex organic matter is broken down to simple forms by bacterial decomposition. Proteins, for instance.are converted to amino acids and further reduced to ammonia (NH_3). If oxygen is present, the ammonia is oxidized to nitrite (NO_2^-) and then to nitrate (NO_3^-). The nitrate can then be reconstituted into living organic matter by photosynthetic plants.

Nitrate poisoning in infant animals, including humans, can cause serious problems and even death. Apparently, the lower acidity in an infant's intestinal tract permits growth of nitrate-reducing bacteria that convert the nitrate to nitrite, which is then absorbed into the bloodstream. Nitrite has a greater affinity for hemoglobin than does oxygen and thus replaces oxygen in the blood complex. The body is denied essential oxygen and in extreme cases, the victim suffocates. Because oxygen starvation results in a bluish discoloration of the body, nitrate poisoning has been referred to as the "blue baby" syndrome, although the correct term is *methemoglobinemia*. Once the flora of the intestinal tract has fully developed, usually after the age of 6 months, nitrate conversion to nitrite and subsequent methemoglobinemia from drinking water is seldom a problem. Fortunately, the natural oxidation of nitrite to nitrate, occurs quickly so that significant quantities of nitrites are not found in natural water. (Reference - Peavy, Howard S. and Rowe, Donald R. , edition 2013, Environmental Engineering).

4.4.2 Phosphorus

Phosphorus appears exclusively as phosphate (PO_4^{3-}) in aquatic environments. There are several forms of phosphate, however, including orthophosphate. condensed phosphates (pyro-, meta- and polyphosphates) and organically bound phosphates. These may be in soluble or particulate form or may be constituents of plant or animal tissue. Like nitrogen, phosphates pass through the cycles of decomposition and photosynthesis. Phosphate is a constituent of soils and is used extensively in fertilizer to replace and /or supplement natural quantities on agricultural lands. Phosphate is also a constituent of animal waste and may become incorporated into the soil in grazing and feeding areas. Runoff from agricultural areas is a major contributor to phosphate in surface water. The tendency for phosphate to adsorb to soil particles limits its movement in soil moisture and groundwater, but results in its transport into surface water by erosion.Municipal wastewater is another major source of phosphate in surface water.

4.5 Biological Water – QualityParameters

Water may serve as a medium in which literally thousands of biological species spend part, if not all, of their life cycles. Aquatic organisms range in size and complexity from the smallest single-cell microorganism to the largest fish. All members of the biological community are, to some extent, water-quality parameters, because their presence or absence may indicate in general terms the characteristics of a given body of water.

4.5.1 Pathogens

From the perspective of human use and consumption, the most important biological organisms in water are pathogens, those organisms capable of infecting, or of transmitting diseases to, humans. These organisms are not native to aquatic systems and usually require an animal host for growth and reproduction. They can, however, be transported by natural water systems, thus becoming a temporary member of the aquatic community. Many species of pathogens are able to survive in water and maintain their infectious capabilities for significant periods of time. These waterborne pathogens include species of bacteria, viruses, protozoa and Helminths (parasiticworms).

4.5.1.1 Bacteria

The word *bacteria* comes from the Greek word meaning "rod" or "staff," a shape characteristic of most bacteria. Bacteria are single-cell microorganisms, usually colourless, and are the lowest form of life capable of synthesizing protoplasm from the surrounding environment. In addition to the rod shape (bacilli) mentioned above, bacteria may also be spherical (cocci) or spiral-shaped (spirilla). Gastrointestinal disorders are common symptoms of most diseases transmitted by waterborne pathogenic bacteria. Cholera, the disease that ravaged Europe during the eighteenth and nineteenth centuries, is transmitted by *Vibrio comma*. Among the most violent of the waterborne bacterial diseases, cholera causes vomiting and diarrhea that, without treatment, result in dehydration and death. Symptoms of typhoid, a disease transmitted by the waterborne pathogen, *Salmonella typhosa,* include gastrointestinal disorders, high fever, ulceration of the intestines and possible nerve damage. Although immunization of individuals and disinfection of water supplies have eliminated cholera and typhoid in most partsoftheworld,areasofdevelopingcountrieswhereovercrowdingandpoor sanitary conditions prevail still experience occasional outbreaks of these two diseases.

4.5.1.2Viruses

Viruses are the smallest biological structures known to contain all the genetic information necessary for their own reproduction. So small that they can only be "seen" with the aid of an electron microscope, viruses are obligate parasites that require a host in which to live. Symptoms associated with waterborne viral infections usually involve disorders of the nervous system rather than of the gastrointestinal tract. Waterborne viral pathogens are known to cause polio-myelitis and infectious hepatitis and several other viruses are known to be, or suspected of being, waterborne.

Immunization of individuals has reduced the incidence of polio to a few isolated cases each year in developed nations.

4.5.1.3Protozoa

The lowest form of animal life, protozoa are unicellular organisms more complex in their functional activity than bacteria or viruses. They are complete, self-contained organisms that can be free-living or parasitic, pathogenic or nonpathogenic, microscopic or macroscopic. Highly adaptable, protozoa are widely distributed in natural water, although only a few aquatic protozoa are pathogenic. Protozoal infections are usually characterized by gastrointestinal disorders of a milder order than those associated with the bacterial infections. Protozoal infections can be serious nonetheless, as illustrated by an epidemic in Chicago in 1933 in which over 1400 people were affected and 98 deaths resulted when drinking water was contaminated by sewage containing *Entamoebahistolytica*. Many cases of giardiasis, or backpackers disease, have been reported in recent years among persons that drank untreated water from surface streams. This infection is caused by *Giardia lamblia*, a protozoan that may be carried by wild animals living in or near natural water systems. Under adverse environmental circumstance, aquatic protozoa form cysts that are difficult to deactivate by disinfection. Usually complete treatment, including filtration, is necessary to remove protozoacysts.

4.5.1.4 Helminths

The life cycles of helminths, or parasitic worms, often involve two or more animal hosts, one of which can be human and water contamination may result from human or animal waste that contains helminths. Contamination may also be via aquatic species of other hosts, such as snails or insects. While aquatic systems can be the vehicle for transmitting helminthal pathogens, modern water-treatment methods are very effective in destroying these organisms. Thus, helminths pose hazards primarily to those persons who come into direct contact with untreated water. Sewage plant operators, swimmers in recreational lakes polluted by sewage or stormwater runoff from cattle feedlots, and farm laborers employed in agri- cultural irrigation operations are at particularrisk.

4.5.1.5 Pathogen indicators

An *indicator organism* is one whose presence presumes that contamination has occurred and suggests the nature and extent of the contaminant(s). The ideal pathogen indicator would (1) be applicable to all types of water, (2) always be present when pathogens are present, (3) always be absent when pathogens are absent, (4) lend itself to routine quantitative testing procedures without interference from or confusion of results because of extraneous organisms and (5) for the safety of laboratory personnel, not be a pathogen itself.

Most of the waterborne pathogens are introduced through fecal contamination of water. Thus, any organism native to the intestinal tract of humans and meeting the above criteria would be a good indicator organism. The organisms most nearly meeting these requirements belong to the **fecal coliform group**. Composed of several strains of bacteria, principal of which is *Escherichia coli*, these organisms are found exclusively in the intestinal tract of warm-blooded animals and are excreted in large numbers with feces. Fecal coliform organisms are nonpathogenic and are believed to have a longer survival time outside the animal body than do most pathogens**.**

The **total coliform group** is widely used as the indicator organism of choice for drinking water. The major criticism of this group as an indicator is that some of its members (such as Enterobacteraerogenes) are widely distributed in the environment. However, when it is assumed that all of its members originated in feces, a safety factor is provided. This approach is reasonable when applied to provision of safe drinking water but suffers when fecal contamination of a wateris suspected.

4.6 Water – Quality Requirements

Water-quality requirements vary according to the proposed use of the water. Water unsuitable for one use may be quite satisfactory for another and water may be deemed acceptable for a particular use if water of better quality is not available.

Water-quality requirements should not be confused with water-quality standards. Set by the potential user, water-quality requirements represent a known or assumed need and are based on the prior experience of the water user. Water-quality standards are set by a governmental agency and represent a statutory requirement.

4.7 Water Quality Standards

As per **WHO** guidelines, the safe drinking water does not represent any significant risk to health over a lifetime of consumption including different sensitivities that may occur between lifestages.

As per **IS 10500-2012 (drinking water-specification)**, drinking water is defined as the water which is intended for human consumption for drinking and cooking purposes from any source and it includes water (treated or untreated) supplied by any means for human consumption.

According to this code, drinking water shall comply with the specified requirements of physical parameters, chemical parameters.

Table-4.1 Organoleptic and Physical Parameters as per IS 10500-2012

Sl. No.	Characteristic	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 in absence of alternate sources
2	Odour		Agreeable	Agreeable	a) Test cold and when heated b) Test at several dilutions
3	pH value		6.5 – 8.5	No relaxation	-
4	Taste		Agreeable	Agreeable	Test to be conducted only after safety has been established
5	Turbidity	NTU, Max	1	5	-
6	Total Dissolved Soids (TDS)	Mg/l, Max	500	2000	-

Table-4.2 General Chemical Parameters concerning substances undesirable in excessive amounts as per IS 10500-2012

Sl. No.	Characteristic	Unit	Requirement (acceptable limit)	Permissible limit in the absence of alternate source
1	Chloride (as Cl)	mg/l, Max	250	1000
2	Fluoride (as F)	mg/l, Max	1	1.5
3	Total Hardness (as $CaCO_3$)	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, Max	0.2	1.0
9	Iron (as Fe)	mg/l, Max	0.3	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 $CaCO_3$)	mg/l, Max	200	600
15	Zinc (as Zn)	mg/l, Max	5	15

Table – 4.3 Bacteriological quality of drinking water as per IS 10500-2012

Sl. No.	Organisms	Requirements
1	All water intended for drinking : a) E. Coli or thermotolerant coliform bacteria	Shall not be detectable in any 100 ml sample
2	Treated water entering thedistribution system: a) E. Coli or thermotolerantcoliform bacteria b) Total coliform bacteria	a) Shall not be detectable in any 100 mlsample b) Shall not be detectable in any 100 mlsample
3	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 mlsample b) Shall not be detectable in any 100 mlsample

(Reference : Drinking water- Specification, second revision, IS 10500:2012, Bureau of Indian Standards).

CHAPTER 5

METHODOLOGY

Methodology

5.1 Sampling

The samples of water at different stages of treatment system of Serampore Water Treatment Plant were collected. The following information were noted during sampling

- Sample no.
- Date of Collection
- Location from where the sample were collected.

5.1.1. Physico- chemical Parameters

Sample collections for Raw and Finished water from the plant were carried out once in amonth for a period of 5 months (November,2018 to March ,2019) . Samples from clarifier and filter were also collected for the selective physic –chemical parameters during study period.Samples for metals were collected from sludge pocket in month of March,2019.The samples so collected were preserved properly and brought back to laboratory for further analysis.Samples from selective points of distribution mains were collected for physico-chemical parameters in the month of March,2019.Samples from selective points of consumer's end were collected for physico-chemical parameters in the month of March 2019.

Figure 5. 1 Distribution Main atRishra

5.1.2 Bacteriological Parameters

Samples for Bacteriological parameters such as Total Coliform, Fecal Coliform were collected from Raw water(after pre –chlorination), Clarified water, Filtered water and Finished water (after post chlorination) during monthly sampling .

Samples from the selective points of Distribution mains(take off points) were collected for the determination of Total Coliform and Fecal Coliform during supply hours for the month of March,2019.

Samples from the selective points of consumers' end were collected for the monthof March,2019.

Samples so collected were properly preserved and were brought back to School of Water Resources Laboratory for analysis.

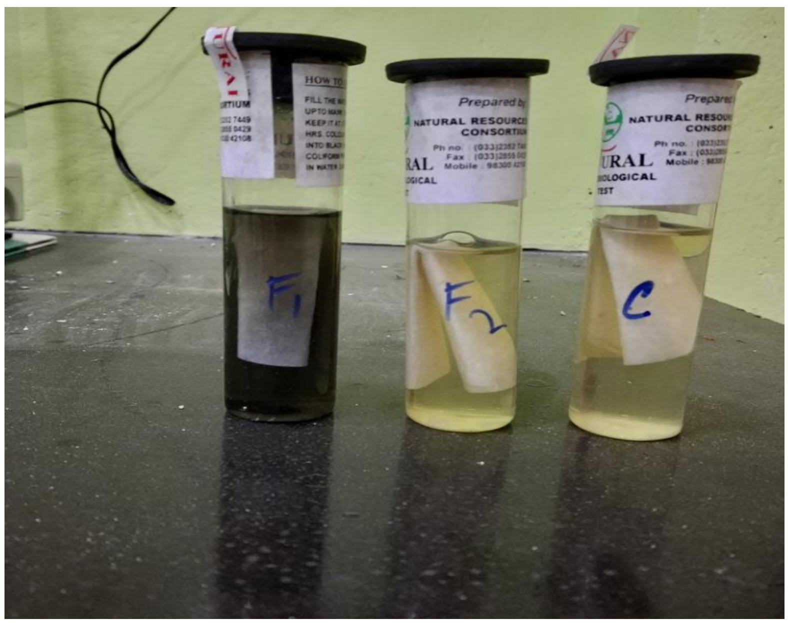


Figure 5. 2 Bacteria Detection at Plant Laboratory

5.1.3 Engineering Parameters

Serampore water Treatment plant has two clariflocculators and the clarified water is distributed to ten numbers of filter beds for filtration.

Sand samples were collected from all the filter beds for the analysis of Particle size Distribution(Uniformity coefficient and effective Size of Sand).

Figure 5. 3 Weighing of Sand sample Collected from Filter Bed

Figure 5. 4 Sieve Analysis

5.1.4 Sludge

For characterization of sludge, the sludgesamples were collected from both the clariflocculator of the treatment plant during study period.

5.2 Analysis

5.2.1 Physico- chemical Parameters

Physico-chemical parameters for all the samples collected from treatment plant as well as distribution mains and consumer point were analyzed in accordance with standard methods for the analysis of water (APHA Guideline). After collection of samples, spot tests (such as pH, Temperature) were carried out at the field. Turbidity and conductivity were carried out at plant laboratory and rest of the samples were brought back to School of Water Resources laboratory,Jadavpur University after preservation for further analysis. Samples were also collected and analyzed from selective distribution points, distribution mains and consumer end during study period.

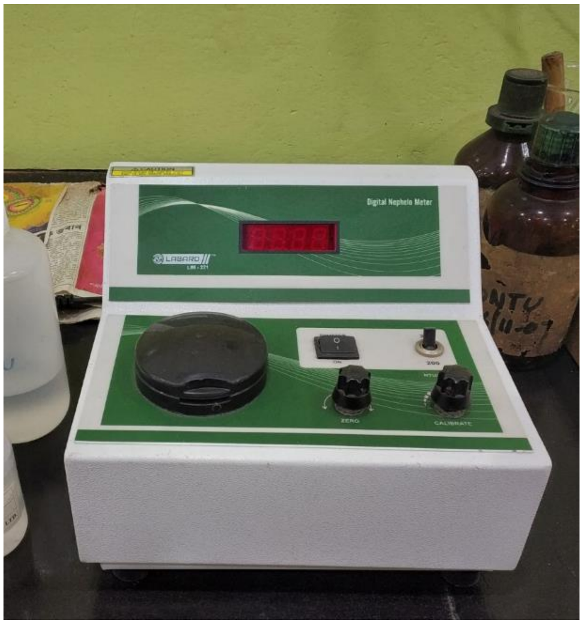


Figure 5. 5 Turbidity Meter at Plant

Figure 5. 6Conductivity and TDS Meter at Plant

5.2.2 Bacteriological Parameters

Bacteriological parameters for all the samples collectedfrom the treatment plant with standard methods for the analysis of water (APHA Guideline).Total coliform and fecal coliform were determined by membrane filter technique and the results were expressed in organisms/100ml. However for distribution mains, Total coliform and fecal coliform were determined.

Figure 5.7 Total and Fecal coliform Test using Membrane Filter Technique

5.2.3 Engineering Parameters

Analysis for particle size distribution (uniformity coefficient and effective size of sand) of sand samples collected from ten filter beds were carried out as per CPHEEO manual.

5.2.4 Laboratory procedures towards the Estimation of Optimal Dose for Coagulant Aids (Polyelectrolyte) Dose

Jar test is conducted in laboratory to determine the optimal dosing of coagulant aids to be applied in raw water for removing suspended and colloidal particles present in raw Water.

The procedure for Jar Test is described here under:

- Raw Water turbidity is measured.
- Raw water (one liter) is taken in each of the 6 beakers
- Coagulant Aids(1% coagulant aids solution) in small increments are added to the beakers
- After each addition 2 minutes rapid mixing followed by 3 minutes slow mixing is continued until visible floc is formed
- This process of slow mixing is continued for another 5 minutes for complete flocculation.
- Allow to settle for 30 minutes
- Measure the turbidity of clear water

The minimum turbidity or maximum percent removal of turbidity is the optimal dose for coagulant aids.

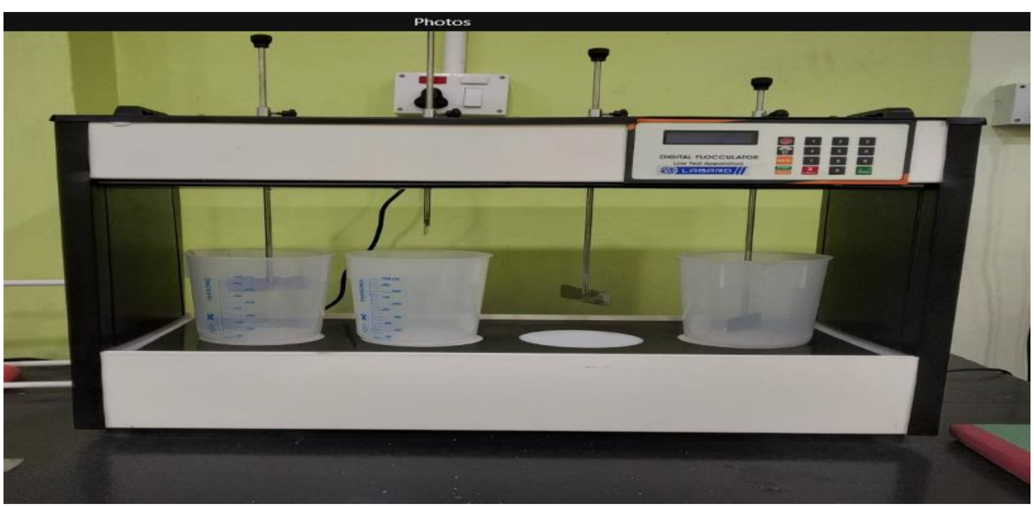


Figure 5. 8 Jar Test

5.2.5 Estimation of chlorine demand according to the stated Laboratory Process

Estimation of chlorine demand both for raw and filtered water were done by means of prepared bleaching powder solution of known strength and distributing different dose to the raw and filtered water and finally determine the available chlorine content in the raw and filtered water after a contact time of 30 minutes.

Figure 5. 9 Determination of Chlorine Demand

5.2.6 Sludge

Sludge samples collected from both the clariflocculator were analyzed for selective parameters and for metals. Analyses were done in accordance with standard Methods for the analysis of water (APHA guideline).

CHAPTER 6

RESULT AND DISCUSSIONS

Result and Discussions

6.0 Results and Discussions

Raw water , clarified water, filter water before chlorination and filter water after chlorination were collected from Serampore Water Treatment Plant for each month and also twice in every month during the study period (from November,2018 to April,2019) for estimation of physic-chemical and bacteriological quality. These results reflects the overall performance of the plant and assure the drinking water quality .

Water sample from distribution mains and consumer point were also collected to assure the drinking water quality .

Physico –chemical and Bacteriological quality of Raw Water (RW), Clarified Water (CW), Filter water Before Chlorination (FWBCL) and Filter water after Chlorination (FW) are summarized in Table 6.1. through 6.10

Table:6.1Physico – chemical Characteristics of Raw Water, Clarified Water and Filter Water ,Serampore Water Treatment Plant

Date of Collection: 16.11.2019		Month: November, 2018	
PARAMETERS	**RW**	**CW**	**FWBCL**
Turbidity,NTU	46	8.1	0.8
pH	8.2	7.6	7.5
Conductivity,µmhos/s	338	357	354
Temp.,^{0}C	22	21.9	21.8
Residual chlorine,mg/l	-	<0.2	<0.1
TDS,mg/l	169	178.5	177

Table:6.2 Physico – chemical and Bacteriological Characteristics of Raw Water, ClarifiedWater and FilterWater ,Serampore Water Treatment Plant

Date of Collection:29 .11.2019		Month: November, 2018	
PARAMETERS	**RW**	**CW**	**FWBCL**
Turbidity,NTU	28	4.3	0.3
pH	8.9	7.6	7.5
Conductivity,µmhos/s	226	342	329
Temp,^{0}C	24.8	24.8	24.8
Residual chlorine,mg/l	-	<0.2	<0.1
Total Hardness,mg/l	100	120	120
Calcium Hardness, mg/l	50	60	60
Iron(as Fe), mg/l	0.05	-	0.05
Chloride(as Cl), mg/l	10	10	10
Alkalinity, mg/l	70	80	80
TSS, mg/l	500	400	300
TDS,mg/l	113	171	164.5
Total Coliform	690/100ML	<1	<1

Table:6.3 Physico – chemical Characteristics of Raw Water, Clarified Water and Filter Water Serampore Water Treatment Plant

Date of collection: 25.01.2019		Month:January,2019	
PARAMETERS	**RW**	**CW**	**FWR**
Turbidity, NTU	132	7.6	0.8
pH	7.55	7.5	7.5
Conductivity, µmhos/s	348	360	360
Temp., ^{0}C	22	22	21.9
Residual chlorine, mg/l	-	<0.1	0.8
Total Hardness, mg/l	95	115	110
Calcium Hardness, mg/l	55	60	70
Chloride, mg/l	10	30	30
Alkalinity, mg/l	100	200	200
TDS, mg/l	174	180	180

Table:6.4 Physico – chemical and Bacteriological Characteristics of Raw Water, Clarified Water and Filter Water Serampore Water Treatment Plant

Date of collection: 02.01.2019			Month:January,2019	
PARAMETERS	**RW**	**CW**	**FWBCL**	**FWR**
Turbidity,NTU	24	8	0.5	0.5
pH	7.8	7.5	6.5	6.5
Conductivity,µmhos/s	455	705	455	423
Temp.,^{0}C	25	25	25	25
Residual chlorine,mg/l	-	<0.2	<0.1	0.8
Nitrate, mg/l	-	Nil	Nil	Nil
Sulphate, mg/l	-	0.2	0.2	0.2
Hardness,mg/l	110	100	104	104
TDS, mg/l	83	63	67	66
TC ,MPN/100mL	$14x10^4$	$5x10^4$	<1	<1
FC ,MPN/100mL	$10x10^4$	$4x10^4$	<1	<1

Table:6.5 Physico – chemical and Bacteriological Characteristics of Raw Water, Clarified Water and Filter Water Serampore Water Treatment Plant

Date of collection: 07.01.2019		Month:January,2019		
PARAMETERS	**RW**	**CW**	**FWBCL**	**FWR**
Turbidity,NTU	24	7	0.5	0.5
pH	7.9	7.8	7.5	7.5
Conductivity,µmhos/s	460	477	456	450
Temp.^{0}C	21	22	20	20
Residual chlorine, mg/l	-	<0.2	<0.1	0.8
Nitrate, mg/l	-	Nil	Nil	Nil
Sulphate, mg/l	-	Nil	Nil	Nil
Hardness, mg/l	120	110	124	124
TDS, mg/l	89	87	88	85
TC, MPN/100mL	$16 x10^4$	$5 x10^4$	<1	<1
FC, MPN/100mL	$11 x10^4$	$4 x10^4$	<1	<1

Table:6.6 Physico – chemical and Bacteriological Characteristics of Raw Water, Clarified Water and Filter Water Serampore Water Treatment Plant

Date of collection: 22.01.2019		Month:January,2019		
PARAMETERS	**RW**	**CW**	**FWBCL**	**FWR**
Turbidity,NTU	49	8	0.6	0.6
pH	7.9	7.3	6.8	6.8
Conductivity, µmhos/s	465	436	432	433
Temp.^{0}C	25	25	23	22
Residual chlorine,mg/l	-	<0.2	<0.1	0.8
Nitrate, mg/l	-	Nil	Nil	Nil
Sulphate, mg/l	-	0.2	-	0.2
Hardness,mg/l	121	120	124	124
TDS,mg/l	102	96	94	94
TC, MPN/100mL	$16x10^{4}$	$6x10^{4}$	<1	<1
FC, MPN/100mL	$12x10^{4}$	$40 x10^{4}$	<1	<1

Table:6.7 Physico – chemical and Bacteriological Characteristics of Raw Water, Clarified Water and Filter Water Serampore Water Treatment Plant

Date of collection: 01.02.2019		Month:February,2019		
PARAMETERS	**RW**	**CW**	**FWBCL**	**FWR**
Turbidity,NTU	40	8	0.7	0.7
pH	8.1	7.9	7.2	7.2
Conductivity µmhos/s	375	350	341	340
Temp.^{0}C)	25	25	25	25
Residual chlorine,mg/l	-	<0.2	<0.2	0.8
Nitrate, mg/l	-	-	Nil	Nil
Sulphate, mg/l	342	340	336	324
Hardness,mg/l	121	107	102	102
TC, MPN/100mL	$8x10^{4}$	$4 x10^{4}$	<1	<1
FC, MPN/100mL	$2x10^{4}$	$1x10^{4}$	<1	<1

Table:6.8 Physico – chemical and Bacteriological Characteristics of Raw Water, Clarified Water and Filter Water Serampore Water Treatment Plant

Date of collection: 26.02.2019		Month: February,2019		
PARAMETERS	**RW**	**CW**	**FWBCL**	**FWR**
Turbidity(NTU)	46.1	8	0.8	0.7
pH	8	7.8	7.2	7.2
Conductivity, µmhos/s	355	346	323	321
Temp.^{0}C)	23.1	23	22	22
Residual chlorine,mg/l	-	<0.2	<0.2	0.7
Nitrate mg/l	-	NIl	NIl	Nil
Sulphate, mg/l	-	NIl	NIl	Nil
Hardness,mg/l	178	162	154	152
TDS,mg/l	150	150	150	150
TC, MPN/100mL	8 x10^4	4 x10^4	<1	<1
FC, MPN/100mL	2 x10^4	1 x10^4	<1	<1

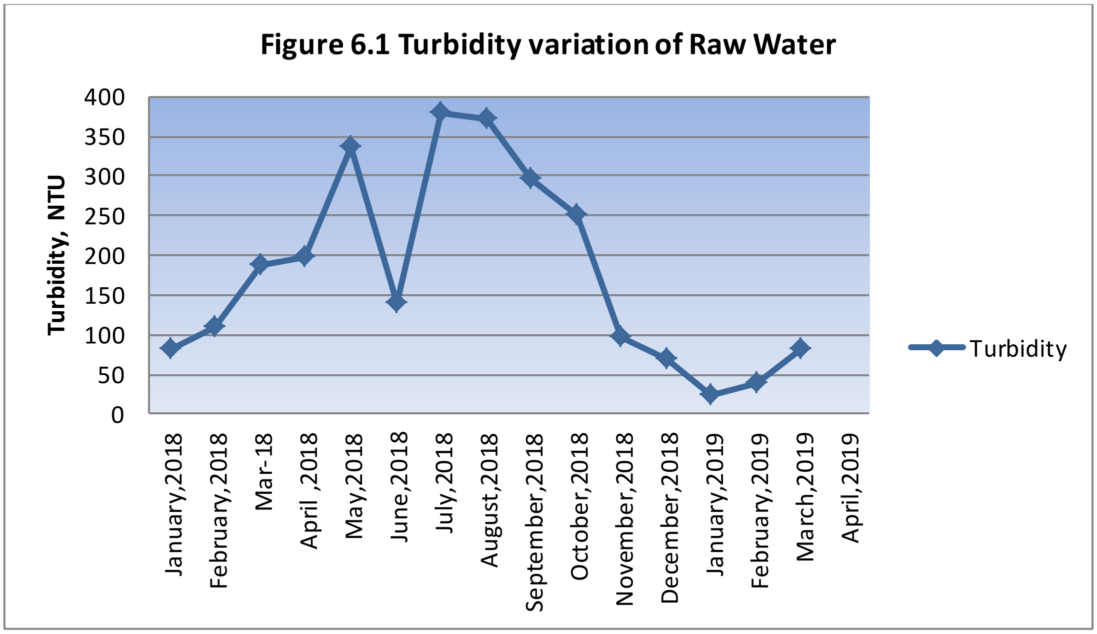
Table:6.9 Physico – chemical and Bacteriological Characteristics of Raw Water, Clarified Water and Filter Water Serampore Water Treatment Plant

Date of collection: 19.03.2019		Month: March,2019		
PARAMETERS	**RW**	**CW**	**FWBCL**	**FWR**
Turbidity,NTU	52	8	0.7	0.7
pH	7.9	7.3	7	7
Conductivity, µmhos/s	305	321	301	304
Temp.^{0}C	30	30	29	29
Residual chlorine, mg/l	-	<0.2	<0.2	0.7
Nitrate, mg/l	-	NIL	NIL	NIL
Sulphate, mg/l		NIL	NIL	NIL
Hardness, mg/l	125	120	122	122
TDS, mg/l	120	107	102	102
TC, MPN/100mL	6x10^4	3x10^4	<1	<1
FC, MPN/100mL	<1	<1	<1	<1

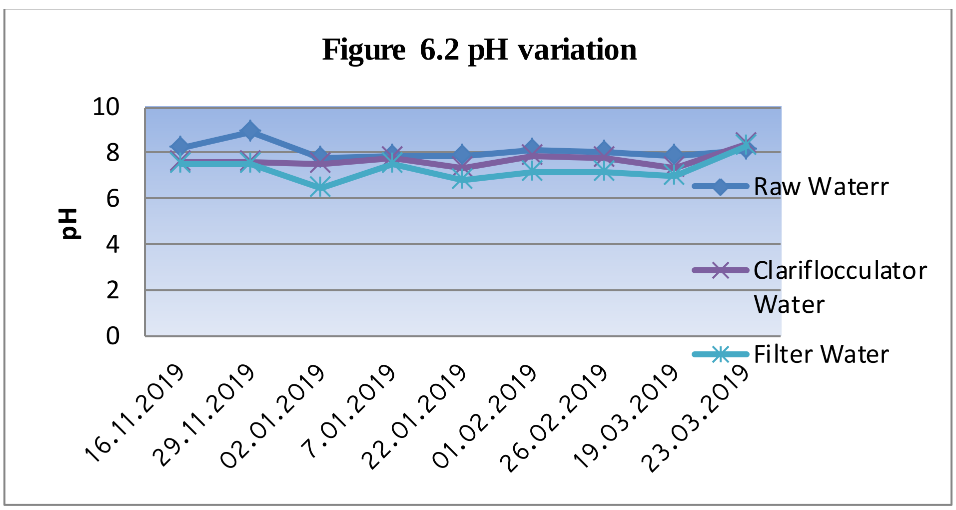
Table:6.10 Physico – chemical and Bacteriological Characteristics of Raw Water, Clarified Water and Filter WaterSerampore Water Treatment Plant

Date of collection:23 .03.2019		Month: March,2019	
PARAMETERS	**RW**	**CW**	**FWBCL**
Turbidity,NTU	82	8	0.7
pH	8.15	8.36	8.31
Conductivity,µmhos/s	357	353	356
Temp.^{0}C	25	25	25
Calcium(as $CaCO_3$), mg/l	74.5	70.6	78.4
Chliride(as Cl),mg/l	19.2	21.2	23.1
Magnesium(as $CaCO_3$),mg/l	51	51	47
Nitrate, mg/l	2.21	1.17	1.6
Sulphate, mg/l	17	20.3	18.5
Iron(as Fe),mg/l	7.71	0.18	0.1
Hardness, mg/l	125.4	121.5	129.4
TDS, mg/l	198	194	196
TC, MPN/100mL	4900	<1	<1
FC, MPN/100mL	<1	<1	<1

- On the basis of secondary data which are collected from the plant laboratory(Jan,2018 to Oct,2018) and some primary data which is collected throughout the study period (from Nov,2018 to March,2019), Turbidity values of Raw water were observed in the range of 35 - 380 NTU Throughout the study period it was observed that during monsoon turbidity value is increases as well as coagulant dosing also increased and during dry season Turbidity level is decreased as well as dosing also decreased. Jar test is conducted to know the dosing value once in a month for dry season and weekly for rainy season.

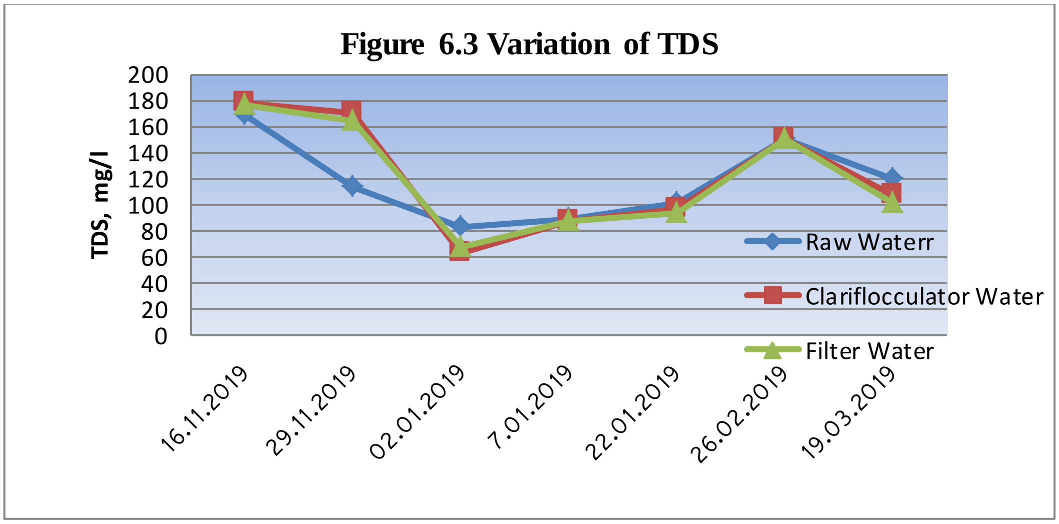


- pH values for Raw Water were observed to be in the range of 8.2 to 7.8 and filter water were 6.5 to 8.31 throughout the study period. It is observed that pH level is increased after coagulant dosing but pH values are under acceptable limit as per IS :10500:2012 specified limit.

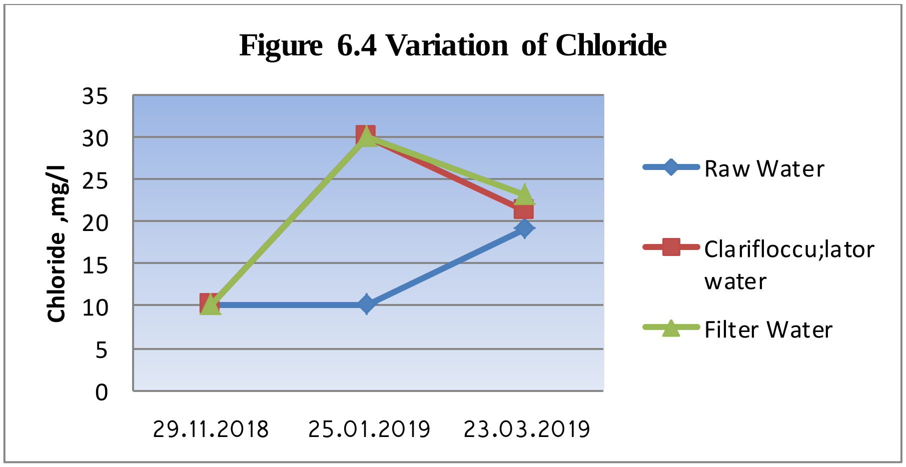


- Conductivity values for Raw water were observed to be in the range of 465 to 226 µmhos/s and filter water were 456-301 µmhos/s throughout the study period. Conductivity indicates the concentration of ions present in water. These conductive ions come from dissolved salts and inorganic materials present in the water. It is observed that when turbidity value is increased , dosing of chemical is also increased, simultaneously conductivity is also increased.

- TDS values for Raw Water were observed to be in the range of 198-89 mg/l and filter water were 196-85 mg/l throughout the study period. TDS is a measure of the dissolved combined content of all organic and inorganic substances present in the water. All values were well below the IS :10500:2012 specified limit.



- Chloride values for Raw Water of Serampore Water Treatment Plant were in the range of 19.2 to 10 mg/L throughout the study period. Chloride values for filter water were 23.1 to 30 mg/L. Chloride increases the electrical conductivity of water .Chloride concentrations in excess of about 250 mg/litre can give rise to detectable taste in water .All values were well within IS:10500 2012 specified limit.



- Alkalinity values for Raw Water were observed to be ranging from 70 -100 mg/L throughout the study period and filter water shows the alkalinity values in the range of 80 -200 mg/L. Alkalinity as $CaCO_3$ in excess of about 200mg/L is not suitable for drinking as per IS 10500:2012.But these study indicates all values were within IS:10500:2012 specified limit.

- Total Hardness values of Raw water were observed to be in the range of 100-133 mg/L throughout the study period and for finished water were in the range of 120-129 mg/L. These range of values are well below the ISI prescribed limit of 200mg/L.

- Nitrate and sulphate values for Raw Water were observed to be very low for Serampore Water Treatment Plant.

- Total coliform and fecal coliform were determined by membrane filter technique.Residual chlorine having 0.2 mg/l was found at the end stage so no bacteria was observed.

Table:6.11 Physico – Chemical and Bacteriological Characteristics of Water at Distribution Mains of Serampore Water Treatment Plant

Date of collection: 06.04.2019	Month:April,2019			
PARAMETERS	**TS-3**	**TS-9**	**TN-3**	**TN10**
Turbidity,NTU	1.6	2.3	1.6	1.6
pH	7.97	7.97	7.96	8.06
Conductivity,µmhos/s	359	360	363	352
Calcium(as $CaCO_3$), mg/l	34.6	29.8	34.6	29.8
Chloride(as Cl),mg/l	27	25.1	25.1	25.1
Magnesium(as $CaCO_3$),mg/l	11.4	13.3	9.5	11.4
Nitrate, mg/l	1.1	1.06	1.1	1.01
Sulphate, mg/l	16.7	18.2	17	15.7
Iron(as Fe),mg/l	<0.1	<0.1	<0.1	<0.1
Hardness, mg/l	133.3	129.4	125.4	121.5
TDS, mg/l	212	208	214	204
TC, MPN/100mL	<1	5	<1	5

Location of Distribution Points

TS-3: NazrulPark,Rishra

TS-9: Uttarpara

TN-3: Sitalatala, Baidyabati Municipality

TN-10: Bhadreswar

- Table: 6.11 shows the physico-chemical and bacteriological characteristics of treated water at selected distribution mains for the month of April,2019.Data shows that turbidity level is higher than the prescribed limit in IS-10500-2012.Other physico-chemical quality conforms to ISI drinking water standard . presence of coliform organisms were detected in TS-9 and TN-10.

Table:6.12 Bacteriological Characteristics of Water at Consumer Points of Serampore Water Treatment Plant

PARAMETERS	CONSUMER POINTS	
	CS-1 (near TS-3)	CS-2(near TN-10)
TC, MPN/100mL	9	9
FC, MPN/100mL	<1	<1

- Two points at the consumer's end were selected covering two distribution points under study. Presence of coliform were detected in the consumer's end for the month of April, 2019.

Table:6.13 Physico – Characteristics of sludge of Serampore water treatment Plant

PARAMETERS	SLUDGE
Turbidity, NTU	76250
pH	7.04
Conductivity, µmhos/s	938
Total Dissolved Solids, mg/kg	640
Chloride(as cl), mg/kg	80.7
Nitrate(as NO_3), mg/kg	1.48
Sulphate(as SO_4), mg/kg	<2.5
Total Hardness,mg/kg	400
Aluminium (as Al), mg/kg	<0.01
Zinc (as Zn), mg/kg	14.18
Cadmium(as Cd), mg/kg	0.545
Lead(as Pb), mg/kg	7.7
Chromium (as Cr), mg/kg	6.84
Total Coliform, MPN/100 ml	$34x10^2$
Fecal Coliform, MPN/100 ml	<1

- From the metal accumulation data (mg/kg) in the clariflocculators it was observed that heavy metals , Cadmium(Cd), Zinc (Zn), Lead (Pb), Chromium (Cr) were present in the sludge but Aluminium (Al) content is very low. Total coliform also observed in sludge generated form clariflocculator .

Figure No:6.5 Particle Size Distribution Curve For Bed No:01

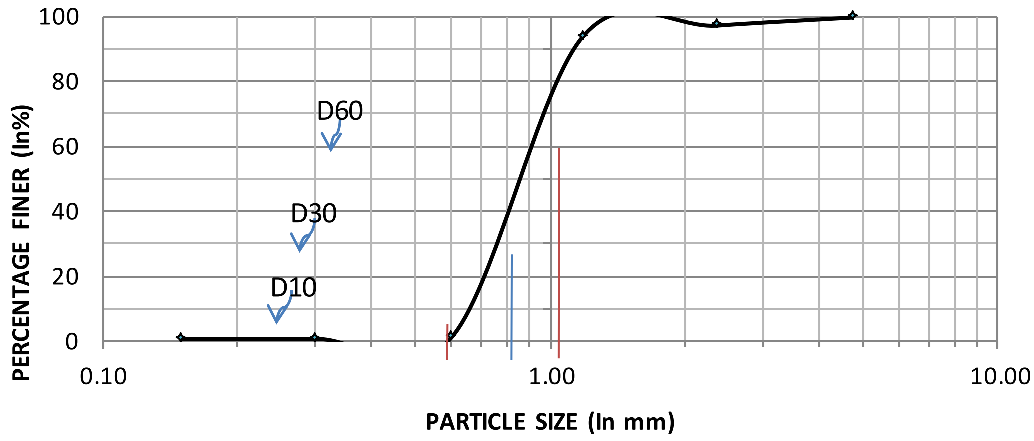


Table No: 6.14 Sieve Analysis of Sand for Rapid Sand Filter

BED NO		DATE			
1		11.05.2019			
TOTAL AMOUNT OF SAMPLE TAKEN FOR SIEVING:- 1000 gm					
IS SIEVE NO.	SIEVE SIZE	MASS RETAINED	% RETAINED	CUMULATIVE % RETAINED	% FINER
-	(mm)	(gm)	(%)	(%)	(%)
4	4.75	2.5	0.250	0.250	99.750
8	2.36	25	2.500	2.750	97.250
16	1.18	35	3.500	6.250	93.750
30	0.60	927.5	92.750	99.000	1.000
50	0.30	2.5	0.250	99.250	0.750
100	0.15	1.25	0.125	99.375	0.625
PAN	-	6.25	0.625	100.000	0.000
TOTAL		**0.0**		**=406.875**	

Uniformity Coefficient = $(D_{60}/D_{10}) = 1.58$,
where $D_{60} = 0.9$ and $D_{10} = 0.57$

The value of Cu is less than 4, hence it is falls under poorly graded or uniformly graded category & for Rapid gravity filter the range of Uniformity Co-efficient is 1.3 to 1.7 & it falls within the range of the above mentioned value.

Figure 6.6 Particle Size Distribution curve for Bed No 10

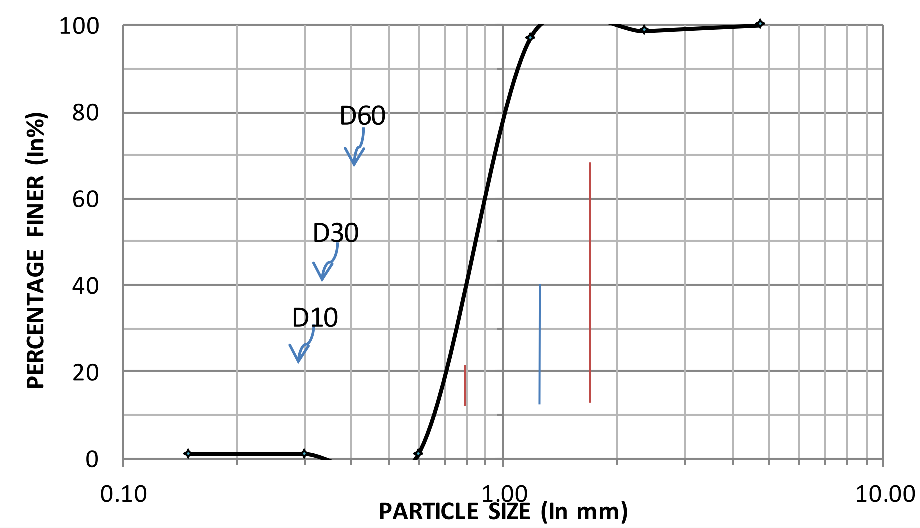


Table No: 6.15 Sieve Analysis of Sand for Rapid Sand Filter

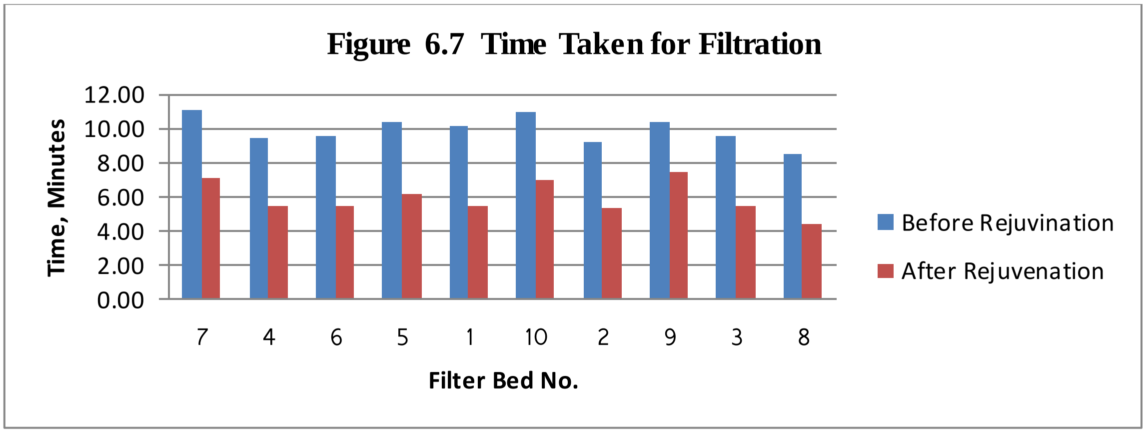
BED NO		DATE			
10		11.05.2019			
TOTAL AMOUNT OF SAMPLE TAKEN FOR SIEVING:- 1000gm					
IS SIEVE NO.	SIEVE SIZE	MASS RETAINED	% RETAINED	CUMULATIVE % RETAINED	% FINER
-	(mm)	(gm)	(%)	(%)	(%)
4	4.75	0.7	0.070	0.070	99.930
8	2.36	13.3	1.330	1.400	98.600
16	1.18	16	1.600	3.000	97.000
30	0.60	960	96.000	99.000	1.000
50	0.30	0.27	0.027	99.027	0.973
100	0.15	0.67	0.067	99.094	0.906
PAN	-	9.06	0.906	100.000	0.000
TOTAL		**0.0**			

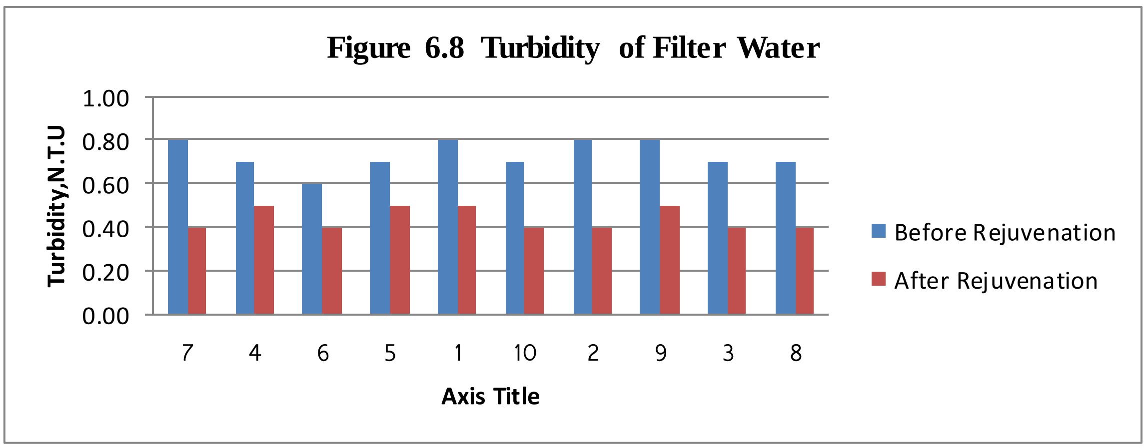
Uniformity Coefficient = (D_{60}/D_{10})= 1.52,
where D_{60}= 0.88 and D_{10}=0.58

The value of Cu is less than 4, hence it is falls under poorly graded or uniformly graded category & for Rapid gravity filter the range of Uniformity Co-efficient is 1.3 to 1.7 & it falls within the range of the above mentioned value.

Table No: 6.16 Records of Quality of Filter Water

Bed No.	Time taken for Filtration		Turbidity of Water	
	Before Rejuvenation	After Rejuvenation	Before Rejuvenation	After Rejuvenation
	(Mins)	(Mins)	(N.T.U.)	(N.T.U.)
7	11.10	7.06	0.80	0.40
4	9.43	5.50	0.70	0.50
6	9.58	5.44	0.60	0.40
5	10.42	6.13	0.70	0.50
1	10.13	5.49	0.80	0.50
10	11.02	7.01	0.70	0.40
2	9.23	5.37	0.80	0.40
9	10.38	7.41	0.80	0.50
3	9.54	5.49	0.70	0.40
8	8.57	4.43	0.70	0.40





- After Re**juvenat**ion of filter beds efficiency of filter bed was increased. Result of sieve analysis of sand material shows that clay particles have present in sand bed after backwashing.

Table:6.17 Particle Size Distribution Curve, Serampore Water Treatment Plant

Date of sampling	Bed No	Uniformity coefficient	Effective size
09.11.2019	1	1.58	0.57
09.11.2019	10	1.52	0.58

- As per CPHEEO Standard Range of effective size of particles varies between 0.45 – 0.70(mm) and Coefficient of Uniformity should not more than 1.70 and not less than 1.3. Table no 5.17 shows the range of uniformity coefficient and effective size of particles for two filter bed among ten bed.

Table:6.18 Estimation of Chlorine Demand for Raw Water, Serampore Water Treatment Plant

Dateof Experiment	Type of Sample	Dosing	Residual chlorine
09-05-2019	Raw Water	2 mg/l	0.2 mg/l
		2.5 mg/l	0.3 mg/l
		3 mg/l	0.4 mg/l
		3.5 mg/l	0.5 mg /

- Estimation of chlorine demand were carried out for raw water . The values of chlorine demand are presented in the table The pre and post chlorination dose were observed to be in the range of 2- 2.5 mg/l and 0.8-1.0 mg/l respectively

CHAPTER 7

OBSERVATION

Observation

7.0 Observation

The observations during field visits throughout the study-period, are summarized below

- Flow meter for Raw and Filtered water units were observed to be working satisfactorily.
- Flow meter for Coagulant Aids were working satisfactorily
- Pre-chlorination is applied to the Raw Water after addition of Coagulant at the rate of 2.5mg/l
- Both pre and post chlorinator were working satisfactorily during study period
- Backwash water and accumulated sludge from the clariflocculators was setting into the Sludge Pond.
- Laboratory facilities for checking the water quality were adequate. Modern Technology based instruments/equipments in the plant laboratory was observed.
- Facilities for conducting Bacteriological analysis in the plant laboratory were observed
- Polyelectrolyte is utilized as coagulant aids in the Serampore Water Treatment Plant.
- Residual Chlorine at the distribution mains was observed during study period ranging between 0.2 mg/l and 0.5 mg/l
- Residual Chlorine in the selective points at consumer's end was studied and was observed to be less than 0.2 mg/l. Coliforms was detected in the water samples at consumer's end during study period.

CHAPTER 8

CONCLUSION AND RECOMMENDATIONS

Conclusion and Recommendation

8.0Conclusion and Recommendation:

- Based on the analysis for physico-chemical parameters, the finished water was conforming to Indian standard for drinking water (IS: 10500,2012) in the entire study period.
- Bacteria was present in Raw water above permissible limit which is prescribed in IS: 10500,2012,though it can be used safely with adequate treatment followed by disinfection in appropriate dose. Total coliform and fecal coliform were determined by membrane filter technique.Residual chlorine having 0.2 mg/l was found at the end stage so no bacteria was observed. Pre-chlorination @ 2.5 mg/l is usually applied in the plant.
- These studies were carried out to evaluate the performance of different units of water Treatment Plant and these are summarized hereunder

    - Though Pre-chlorination is being done at a rate of 2.5 mg/l to the raw water, residual chlorine was observed 0.2 mg /l. No coliform was found at clarifier water.
    - All rate of Flow water measuring devices in a plant should be checked periodically
    - Turbidity removal ranging of clarified water is 81 % to 90 % and coliform reduction ranging for clarified water is 99% to 100 %. Hence it was confirmed that clariflocculatorsin the Serampore Water Treatment Plant are working properly.
    - Reuse of filter washwater has to be adopted
    - Bacteria was not found in filter water before post chlorination.
    - Residual chlorine at filtered water after post chlorination was observed between 0.7 mg/l to 0.8 mg/l.
    - Clear water Reservoir has to be cleaned periodically to remove algae growth and other sediments accumulated inside the reservoir.
    - Serampore Water Treatment Plant is supplying potable water to Serampore and adjoining six Municipalities through distribution mains. Data reveal that residual chlorine is below 0.1 mg/l in distribution mains far away from the plant and Total Coliform was found in 2 nos distribution mains out of 4 nos selected distribution mains. Total coliform was also found in two selected consumer end.It indicates post chlorination dosing should be revised.
    - Test of chlorine demand may be carried out regularly at plant laboratory for both Raw and filter water.
    - Sieve analysis result shows that sand bed was carrying clay particles which should not be present in a proper sand filter bed.

- As sludge contain heavy metals it should be treated before disposal. To overcome the issue with release and treatment of low cost sludge treatment systems like waste stabilization pond, waste water storage reservoir, constructed wetlands may be built. The dry sludge may be used for making of bricks, cement manufacturing.
- SCADA system is required to run the plant properly.

REFERENCES

References

1. P.A. Kashyape and M. Jawed (2018), Performance Assessment of Clariflocculator of A Water Tieatment Plant-A Case Study, Conference Paper
2. S. Ray, P. K. Roy and A. Majumder (2016), Quality of packaged drinking water in Kolkata city, India and risk to public health, Desalination and Water Treatment ,
3. R. K Mahajan , T. P. S. Walia , B. S. Lark and Sumanjit (2006), Analysis of physical and chemical parameters of bottled drinking water, International Journal of Environmental Health Research
4. S. Akram and F. Rehman (2018), Hardness in Drinking-Water, its Sources, its Effects on Humans and its Household Treatment, Avens Publishing Group, J Chem Applications
5. M. A. ElDib and M. A. Elbayoumy (2003), Evaluation of a Water Treatment Plant Performance – Case Study, Seventh International Water Technology Conference IWTC7
6. P. K.Roy , A.Majumder , G. Banerjee , M.B. Roy , S. Pal and A,Mazumdar (2014), Removal of arsenic from drinking water using dual treatment process,Clean Technologies and Environment Policy, Springer-Verlag Berlin Heidelberg
7. A. Shahaby, A. Alharthi , A. Tarras (2015), Bacteriological Evaluation of Tap Water and Bottled Mineral Water in Taif, Western Saudi Arabia, International Journal of Current Microbiology and Applied Sciences
8. N.Khan, S.Hussain, J.Hussain, N.Jamila, S.Ahmed, RiazUllah, ZainUllah, S.Ali, AbdusSaboor(2012), Chemical and microbial investigation of drinking water sources from Kohat, Pakistan, International Journal of Physical Sciences
9. M. Pal, N.R. Samal, M. B. Roy , P. k. Roy (2016), Fresh Water Lake Model Application For Seasonal Variation Of Latent And Sensible Heat Fluxes From The Water Surface Of RudrasagarLake,Tripura , Imperial Journal of Interdisciplinary Research
10. M.H. Mota, S.Chougule and Y.S.Vatkar(2013), “Performance Evaluation of Urban Water Treatment Plant”, International Journal of Science and Research
11. Indian Standard (IS) 10500: 2012, Indian Standard, Drinking Water- Specification, Second Rev, 2012.
12. World Health Organization, Guidelines for Drinking water Quality, fourth ed., Geneva, 2011.
13. Manual on water supply and treatment ; third edition, Central Public Health and Environmental Engineering Organization, Ministry of Urban Development, New Delhi, May, 1999
14. Peavy, Howard S. and Rowe, Donald R. , edition 2013, Environmental Engineering
15. APHA, AWWA, WPCF “Standard Methods” (13th Edition)

16. Casteel MJ1, Schmidt CE, Sobsey MD(2008), Chlorine disinfection of produce to inactivate hepatitis A virus and coliphage MS2, Int J Food Microbial. 2008
17. Pereira, V.J. (2013) New insights concerning the occurrence of fungi in water sources and their potential pathogenicity. Water Research
18. Performance and water quality assurance of Serampore water treatment plant(2004),National Environmental Engineering Research Institute
19. H. Janna and A. Al-Samawi (2014); Performance Evaluation of Al- Karkh Water Treatment Plant in the City of Baghdad, Int. J. of Adv. Res. 2 (10). 0] (ISSN 2320-5407).
20. K. A. Northcott, I. Snape an, P. J. Scales, G. Stevens (2005), Dewatering behaviour of water treatment sludges associated with contaminated site remediation in Antarctica, Chemical Engineering Science,
21. Manja, K.S., M.S. Maurya, K.M. Rao(1982), A simple field test for the detection of faecal pollution in drinking water.,Bulletin of the World Health Organization. 60:797-801
22. Pillai, J.,Mathew, K., Gibbs, R. and Ho, G. E. (1999). H2S paper strip method-A bacteriological test for faecal coliforms in drinking water at various temperatures, Water Science and Technology, 40(2): 85-90
23. M. Barlow and T. Clarke (2002), Blue Gold: The Fight to Stop the Corporate Theft of the World's Water
24. G.Tchobanoglous and F.LBurton (1991), Wastewater Engineering Treatment and Reuse.