Effect of Storage Tanks on Water Quality Within NUST

By

Tafheem Fatima

Nayyera Farooq

Zunaira Khalil

Nuaman Ishfaq Mughal

Institute of Environmental Science and Engineering (IESE)
School of Civil and Environmental Engineering (SCEE)
National University of Sciences and Technology (NUST)
Islamabad, Pakistan
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This is to certify that the Thesis titled

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Submitted by

Tafheem Fatima

2012-NUST-SCEE-ENV-078

Nayyera Farooq

2012-NUST-SCEE-ENV-080

Zunaira Khalil

2012-NUST-SCEE-ENV-064

Nuaman Ishfaq Mughal

2012-NUST-SCEE-ENV-897

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____

Professor Dr. Imran Hashmi

IESE, SCEE, NUST

(Supervisor**)**

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY (NUST)

ISLAMABAD, PAKISTAN

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APPROVAL SHEET

This dissertation submitted by **Ms. Tafheem Fatima, Ms. Nayyera Farooq, Ms. Zunaira Khalil, and Mr. Nuaman Ishfaq Mughal** is accepted in its present form, by the Institute of Environmental Sciences and Engineering (IESE), School of Civil and Environmental Engineering (SCEE), National University of Sciences and Technology (NUST), Islamabad as satisfying the requirement for the degree of **Bachelors in Environmental Engineering.**

Supervisor ________________________

Professor Dr. Imran Hashmi

HOD (Associate Prof. Dr Sher Jamal Khan)

____

Associate Dean (Professor Dr. Imran Hashmi)

____

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Table of contents

CHAPTER 4– Results and Discussion

List of Abbreviations

APHA	American Public Health Association
AWWARF	American Water Works Association Research Foundation
BGLB	Brilliant Green Bile Broth
CDC	Center for Disease control and prevention
CWS	Continuous Water Supply
DO	Dissolved Oxygen
DWDS	Drinking Water Distribution System
EC broth	Escherichia coli broth
EC	Electrical Conductivity
GI	Galvanized Iron
IWS	Intermittent Water Supply
k_w	Wall decay constant
LTB	Lauryl Tryptose Broth
mg/l	Milligram per liter
MPN	Most Probable Number
MGD	Million Gallons per Day
NaOH	Sodium Hydroxide
OCl	Hypochlorite ion
PCRWR	Pakistan Council of Research in Water Resources
PPR	Polypropylene
PSDWQ	Pakistan Standard of Drinking Water Quality
PVC	Polyvinyl Chloride
RCC	Reinforced Cement Concrete
TA	Total alkalinity
TDS	Total Dissolved Solids
THM	Tri Halomethane
UV	Ultra Violet

List of Tables

List of Figures

ABSTRACT

The public health significance of water quality cannot be over emphasized. Water is vital for our existence in life and its importance in our daily life makes it imperative that thorough physicochemical and microbiological examinations be conducted on water. As individuals, we use water for sanitation, drinking and many other human needs. Water constitutes one of the important environmental elements of humans and it has a direct bearing on his health and physiological activities. This study was carried out to highlight the emerging concerns related to drinking water quality and to assess the effect of storage tanks (Polyvinyl chloride and Reinforced cement concrete) on drinking water. A total of 41 sites were selected for sampling. These samples were analyzed for both physicochemical parameters (temperature, pH, free chlorine, total chlorine, salinity, dissolved oxygen, electrical conductivity, and total dissolved solids) and microbiological parameter (MPN).

All the results for physicochemical parameters were satisfactory and were within the range proposed by World Health Organization and Pakistan Standard of Drinking Water Quality. However, it was observed that the values of RCC tanks were higher as compared to the values of PVC tanks.

Bacteriological contamination measured by MPN test revealed that samples collected from PVC tanks were not contaminated except for the month of November than those of RCC tanks which were found to be contaminated. RCC tanks revealed higher number of microorganisms (MPN Index/100ml) as compared PVC tanks. Storage capacity in RCC tanks was higher as compared to storage capacity of PVC tanks, so storage of water in RCC tanks for longer periods results in higher values in comparison to PVC tanks having lower storage capacity.

Further sensors were also developed and calibrated for pH, temperature and electrical conductivity.

Chapter 1

INTRODUCTION

1.1 BACKGROUND

Access to safe and clean drinking water is a basic human right. A major portion of the world population suffers from health problems either due to lack of ample availability of drinking water or its microbial contamination. Contamination of water due to anthropogenic activities is a major issue which poses serious threat to human health and environment.

Approximately 70% of the population of Pakistan relies on ground water for their household water supply. The water bodies are contaminated due to the discharge of domestic and industrial wastewater (approx. 4 Million Acre Feet (MAF) per year. Faulty drainage system accompanied by poor supply lines result in the supply of unsafe drinking water to households (Mohsin *et al*., 2013).

Water supply through piped networks is an advancement in the drinking water distribution. As of 2012, water supply through piped networks in developing countries contributed to 73% urban and 24% rural water supply (Haydar *et al*., 2009). Change in the microbial processes within the distribution network can have significant impact on the water quality supplied at the households. Growth of microorganisms in the distribution system lead to corrosion and roughness of the pipes and impart bad taste and odor to the water. According to a research by Pakistan Council for Research on 3 Water Resources (PCRWR), water supplies in 21 cities of Pakistan are found bacteriological contaminated (Kalim *et al*., 2007).

Bio stability of water implies that concentration and composition of the microbial community in the distribution system should remain unchanged (Lautenschlager *et al*., 2013). Various factors in the distribution network limit the growth of microorganisms in the water such as low nutrient concentrations, adequate disinfectant residuals, short residence times and low temperatures. However, drinking water distribution systems have been reported to cause major changes in water quality during transportation which results in contamination at taps and subsequent outbreak of water borne illnesses.

In the premise plumbing, water is used or supplied at varying frequencies as a result of which water stagnates in pipes overnight or even for days (Haider *et al*., 2002). More than half of the water supply in Asia and approximately one third in Africa is supplied intermittently. When the supply is turned off, pressure is reduced in the pipes which results in the inflow of contaminants from the surrounding environment (Kumpel *et al.*, 2013).

Generally there are two approaches to minimize bacterial regrowth during distribution. First, maintain effective disinfectant residual. Second, limit growth supporting nutrients (Lu *et al*., 2014). Addition of disinfectants is the most widely used technique (Berry *at al*., 2010).

Chlorine is the most widely used disinfectant. However, the disinfectant residual reacts with the substances left in the water after treatment resulting in decay. Chlorine decay is dependent upon its residence time in the distribution system. Longer residence times, particularly in the extremities of the distribution system, result in higher chlorine decay (Blokker *et al*., 2014). Disinfectant residuals decay in the distribution system due to interaction with the pipe material, biofilm or the tubercles formed in the pipe walls, resulting in increased microbial concentration (Clark *et al.*, 1994; Al-Jasser, 2007).

Decline in disinfectant residual followed by increased microbial concentration promote the formation of biofilm which protect and nourish many microorganisms (van der Kooij, 2003; Parsek and Singh, 2003; Lethola *et al*., 2007). Most microbes that enter the water during stagnation in the distribution system come from the biofilms formed on the inner surface of the pipes. Thus, pipe material tends to play a key role in the extent of bacterial regrowth (Inkinen *et al*., 2014). The age and maturity of biofilms increase with the increase in service age of the pipes.(Martiny *et al.*, 2003; LeChevallier *et al.*, 1987; van der Wende *et al.*, 1989).

1.2 THE PRESENT STUDY

In the present study, water samples were collected from the drinking water distribution network of National University of Sciences and Technology (NUST) and analyzed for changes in the physicochemical and microbiological parameter. Most probable number (MPN) technique was performed to evaluate bacterial growth

1.3 OBJECTIVES OF STUDY

Indicator organisms are bacteria such as non-specific coliforms, *Escherichia coli* and *Pseudomonas aeruginosa* that are very commonly found in the human or animal gut and which, if detected, may suggest the presence of wastewater contamination. The main objective of this study was to carry out the standard Membrane Filtration technique to detect the presence of coliform bacteria and *E.coli* that might lead to serious health issues, in the drinking water supply at NUST.

The specific objectives of the study are given below:

1. Monitor physicochemical and microbiological analysis of drinking water within NUST storage tanks (UGT & OHT).
2. Check effect of storage period and tank material on water quality.
3. Calibrate sensors for online water quality monitoring.

Chapter 2

LITERATURE REVIEW

2.1 Waterborne Diseases

Water is an important vector for the transport of waterborne diseases, which are generally caused by pathogenic microbes that can survive and often grow in water. Most waterborne diseases cause diarrheal illness and disproportionally affect children. Access to safe water and sanitation facilities as well as knowledge of proper hygiene practices, can reduce the risk of illness and death from waterborne diseases, leading to improved health, poverty reduction, and socio-economic development (CDC, 2010). Water can be contaminated by various pathways such as lack of hygiene, inadequate treatment or poorly maintained infrastructure.

Numerous studies have found that the consumption of poor quality water is responsible for higher diarrheal incidence (Semenza et al., 1998). However, unlike typhoid fever and Cholera, which is each caused by a specific organism; numerous pathogens are responsible for causing diarrhea. As a result, low levels of indicator bacteria may correspond to high numbers of diarrhea cases and high levels of indicator bacteria may not always correspond to an increased number of cases of diarrhea (Gundry et al., 2004). This may be due to indicator bacteria not being a good measure of pathogens; this has been shown to be the case with thermotolerant coliforms (Gleeson and Gray, 1997; Hamer et al., 1998; Gundry et al., 2004). Additionally, diarrhea is a symptom of many illnesses, which makes the association with improved water quality and a reduction of diarrhea incidence difficult to prove (Gundry et al., 2004).

The United Nations' World Health Organization estimates that more than 3 billion cases of illness and 5 million death, the majority children, can be attributed annually to unsafe water. The death rate for children alone is estimated at one every 8 seconds.

The presence of *E.coli* in water can cause deadly outbreaks as in this case. From May through December of 2000, seven people died from an outbreak of *E. coli* O157:H7 in Walkerton, Ontario, Canada. The city reported 160 confirmed cases of *E.coli*, more than 400 unconfirmed cases, and more than 2,300 people ill with gastrointestinal illness. The Walkerton *E. coli* O157:H7 outbreak is a chilling reminder that communities take high-quality drinking water for granted. Keeping in view the importance of safe drinking water, drinking water is routinely examined to ensure safety. It is not practicable to monitor drinking water for every possible pathogen. Therefore, normal intestinal organisms are used as indicator of fecal pollution. These include coliform group of organisms. They are considered as suitable indicators because they are easy to detect and enumerate in water.

2.2 Drinking water distribution system:

Drinking water distribution system (DWDS) comprises of a complex network of pipelines, storage tanks and treatment plants that are used to carry potable water to consumers. The integrity of these systems is vital in supplying clean water to end users (Whittle *et al.*, 2013). In addition to leaks and bursts, bacterial regrowth in drinking water distribution systems is a problem that can affect large water supply utilities. Regrowth is said to occur when treated water that enters the distribution system with very few bacteria is found to have high amount of bacteria which makes water in a distribution system unstable. (Srinivasan and Harrington, 2007).

The potential for the water in the distribution system to transport microbial pathogens is found in different countries (Shakya *et al*., 2012). Although the presence of a water distribution system is often seen as a sign of improved water quality, it does not imply that the water is free of pathogens and therefore adequate for human consumption (Lee and Schwab, 2005). WHO requires that water that enters the distribution system should be microbiologically safe and biologically stable (WHO, 2006).

2.3 INDICATORS OF WATER QUALITY

Many kinds of bacteria can grow in the drinking water distribution systems which include general heterotrophic plate count bacteria e.g. *Aeromonas* and *Pseudomonas* etc and indicator bacteria such as E. *coli* termed as coliforms.

2.3.1 Coliform

The coliform group includes a broad diversity in terms of genus and species, whether or not they belong to the Enterobacteriaceae family. Most definitions of coliforms are essentially based on common biochemical characteristics. In Standard Methods for the Examination of Water and Wastewater (Part 9221 and 9222; APHA 2012), coliform group members are described as:

1. All aerobic and facultative anaerobic, Gram-negative, non-spore-forming, rod shaped bacteria that ferment lactose with gas and acid formation within 48 h at 35ºC.

2. All aerobic and many facultative anaerobic, Gram-negative, non-spore-forming, rod-shaped bacteria that develop a red colony with a metallic sheen within 24 h at 35ºC on an Endo-type medium containing lactose.

The definition of coliform bacteria differs slightly depending on the country or on the organization in charge of the microbiological monitoring regulations. In Canada, the definition is the same as in the US, and differs in some European countries. (Elmund *et al.,* 1999).

For example, the French Standardization Association (NFT90-413 and NFT90-414; AFNOR, 1990), which may be considered as a representative model for European legislation, defines Total Coliforms (TC) as:

"Rod-shaped, non-spore-forming, Gram-negative, oxidase-negative, aerobic or facultative anaerobic bacteria that are able to grow in the presence of bile salts or other replacement surface active agents having an analogous growth inhibitory effect and that ferment lactose with gas and acid (or aldehyde) production within 48 h at 37 ± 1"

Coliform bacteria are present in the environment and in the feces of all warm-blooded animals and humans.

Coliform bacteria will not likely cause illness. However, their presence in drinking water indicates that disease-causing organisms (pathogens) could be in the water system. Most pathogens that can contaminate water supplies come from the feces of humans or animals. In 1914, the U.S. Public Health Service adopted the enumeration of coliforms as a more convenient standard of sanitary significance.

Total coliform, fecal coliform, and *E. coli* are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria.

Fecal coliforms are types of total coliform that mostly exist in feces. *E. coli* is a sub-group of fecal coliform.

Total coliform bacteria are commonly found in the environment (e.g., soil or vegetation) and are generally harmless. Fecal coliform bacteria are a sub-group of total coliform bacteria. They appear in great quantities in the intestines and feces of people and animals.

E. coli is a sub-group of the fecal coliform group. Most *E. coli* bacteria are harmless and are found in great quantities in the intestines of people and warm-blooded animals. Some strains, however, can cause illness.

2.3.2 Escherischia coli

Escherichia coli, originally known as *Bacterium coli* commune, was identified in 1885 by the German pediatrician, Theodor Escherich. *E. coli* is a coliform bacterium and has historically been regarded as the primary indicator of faecal contamination of both treated and untreated water. As a coliform bacterium it is a member of the family Enterobacteriaceae, and is capable of fermenting lactose or mannitol at 44 °C, usually 8 within 24 hours, and produces indole from tryptophan. Most of the *E. coli* strains possess the enzyme β-glucuronidase, which can be detected using specific fluorogenic or chromogenic substrates.

AFNOR (1990) defines *E. coli* as:

"*E. coli* is a thermotolerant coliform which, among other things, produces indole from tryptophane at a temperature of 44 ± 0.5, gives a positive methyl red test result, is unable to produce acetyl–methyl carbinol and does not use citrate as its sole carbon source."

Several different types of pathogenic *E. coli* are capable of causing disease. A particularly dangerous type is referred to as enterohemorrhagic *E. coli*, or EHEC. The first such strain was identified in the United States in 1982. Since then, EHEC strains have been associated with food-borne outbreaks traced to undercooked hamburgers, unpasteurized apple juice or cider, salad, salami, and unpasteurized milk.

In 1892, Shardinger proposed the use of *E. coli* as an indicator of fecal contamination. This was based on the premise that *E. coli* is abundant in human and animal feces and not usually found in other niches. Furthermore, since *E. coli* could be easily detected by its ability to ferment glucose (later changed to lactose), it was easier to isolate than known gastrointestinal pathogens. Hence, the presence of *E. coli* in water became accepted as indicative of recent fecal contamination and the possible presence of frank pathogens.

In 1986, the United States Environmental Protection Agency (US-EPA) recommended that *Escherichia coli* or enterococci replace fecal-coliform bacteria in State water-quality standards (US-EPA, 1986). The recommendation was based upon a study that demonstrated a statistically significant relationship between the rate of swimming-related illness and the concentrations of *E. coli* and enterococci at freshwater beaches (Dufour, 1984). *E. coli* was determined to be a good indicator of fecal contamination in water and wastewater because it has met a number of important criteria, including:

1. It is present in the feces of humans and warm-blooded animals at numbers exceeding those of pathogens;
2. It shows minimal growth in aquatic systems and at slower rates than pathogens;

3. It is readily detectable by simple procedures that result in unambiguous identification of the fecal-coliform group;
4. It is consistently present when pathogens are present; and
5. It shows increased resistance to disinfectants as opposed to pathogens (Elmund *et al.*, 1999).

2.3.3 CHLORINE DISINFECTION

Disinfectants are added in the distribution system to prevent water borne diseases. In addition to removing pathogens, disinfectants also serve to prevent bacterial regrowth. Chlorine is the most widely used disinfectant due to its low cost, stability and effectiveness against many pathogens.

Chlorine reacts with water to form hydrochloric acid (HCL) and hypochlorous acid (HOCL).

$$. \ Cl^2 + H_2O \leftrightarrow HOCl + HCl$$

HOCL is a weak acid and further dissociates to H+ and OCL^+.

$$HOCl \leftrightarrow H^+ + OCl^-$$

HOCL and OCl^- species are commonly referred to as free chlorine and are highly reactive with numerous components of the bacterial cells. HOCL is much stronger than OCl^- and a much stronger disinfectant. It can result in oxidation, hydrolysis and deamination reactions with a variety of chemical substrates, and produces physiological lesions that may affect several cellular processes.

High chlorine is added in the distribution system to maintain a detectable level at the end points. . Chlorine concentration at stand points and wells should be about 1 mg/L so that sufficient chlorine remains in distribution system pipes to minimize the effects of recontamination by killing or inactivating microbes. A dead end chlorine residual should be maintained at 0.2 to 0.5 mg/L (Blokker *et al*., 2014; Pickard, 2006).

However, high amount of chlorine may result in taste and odor problems (Ohar and Ostfeld, 2014; Song *et al.,* 2014). Disinfectants have been known to oxidize the natural organic matter present in water and as a result provide more substrate for bacterial regrowth to occur. Thus, a trade off exists between ensuring a high amount of disinfectant residual and a low substrate for bacterial regrowth (Liu *et al.*, 2002, Harrington *et al.*, 2003).

2.4 PREMISE PLUMBING

The portion of the drinking water distribution system between water main and the point of use in buildings is termed as ‘’premise plumbing’. Disease causing bacteria are often present in the distribution system water as well as the pipe walls where they 10 can reside in biofilms. Thus, premise plumbing serves as an ideal ecological niche for opportunistic pathogens and also as source from where various negative issues impacting human health arise (Wang *et al.*, 2013).

2.4.1 Stagnation of water

Due to varying frequencies with which water is used in different buildings, longer retention times are known to occur in premise plumbing (Haider *et al.,* 2002). Low velocity of water during higher retention times lead to biofilm detachment, negative pressures and subsequent microbial regrowth. In addition intermittent supply also lead to storage of water in tanks which also promotes bacterial regrowth (Ayoub and Malaeb, 2006).

Kumpel *et al.* (2013) compared the microbial water quality in intermittent and continuous water distribution networks. Higher concentration of indicator bacteria were observed in intermittent water supplies where 31.7% samples were found E.*coli* positive while 0.7% were found positive in continuous water supplies.

Andy and Kelkar (2007) evaluated the impact of intermittent water supply in four cities of India. Water samples collected from various locations receiving either continuous or intermittent supply were tested for total coliform. 90 to 100% of the samples were found coliform negative in case of CWS while for IWS the number of coliform negative samples varied from 24 to 73%.

Pepper *et al.* (2004) carried out a study to find the background HPC concentrations from source to tap. Samples were collected from kitchen and bathroom taps from the 11 first drawn water at 7 a.m in the morning. HPC in kitchen and bathroom taps were consistently above 500 CFU/mL in 68% of the samples. First drawn samples in house 1 had mean HPC 2.4×10^3 CFU/mL while after flushing for 30 seconds HPC reduced to 1.5×10^2 CFU/mL representing a reduction of one order of magnitude.

Siebel *et al.* (2008) carried out a study to determine correlations between total cell concentration, total adenosine tri-phosphate concentration and HPC during microbial monitoring of drinking water. Highest CFU/mL i.e. approx. 1.4×10^3 were found at 8 a.m in the morning indicating bacterial regrowth during night and it fell down to approximately 0.1×10^3 CFU/mL by 10 a.m after the tap used regularized.

Lautenschlager *et al.* (2010) while working on the effect of overnight stagnation on the microbial growth in drinking water quality reported upto 600 folds increase in HPC counts after overnight stagnation associated with significant changes in microbial community composition.

2.5 ENVIRONMENTAL FACTORS AFFECTING STORED WATER QUALITY IN TANKS

2.5.1 TEMPERATURE

Temperature of the stored water is an important influence on the growth rate of bacteria that have survived treatment processes. Various field studies have shown that significant bacteria growth can occur in water of 15°C or higher (Fransolet et al., 1985; Donlan and Pipes, 1988; Smith et al., 1989; Donlan et al., 1994 – From LeChevallier et al., 1996). For example, Fransolet et al. (1985) showed that a temperature increase from 7.5°C to 17.5°C reduced the lag phase of growth for *Pseudomnas putida* from 3 days to 10 hours.

(From LeChevallier et al.,1996). Another study found that coliform bacteria occurred more frequently and in higher concentrations at water temperatures greater than 15°C (LeChevallier et al., 1996). Results from that study indicate that for a temperature increase from 5°C to greater than 20°C, there was an 18-fold increase of coliform occurrence in free-chlorinated systems ($p < 0.0001$) (LeChevallier et al., 1996).

2.5.2 STORAGE PATTERNS

Water is usually stored in the tanks that are made up of different materials and act as reserves during variable water supply periods. Overhead tanks are usually made up of steel and have inner lining of asbestos, coal tar, PVC, epoxy resin, acrylic or silicon while underground tanks are usually lined be concrete, asphalt, gunite or a plastic sheet. These coatings tend to cause bacterial growth problems during storage. Bituminous coatings cause the problem of organic polymer intrusion in water which serves as nutrient source for heterotrophic bacteria (Geldreich, 1996). Bacterial regrowth increases in slowly circulating and hot water tanks (Bagh *et al*., 2004)

2.5.3 FLOW RATE

Cloete *et al*. (2003) carried out a study to evaluate the effect of fluid velocity on biofilm development. It was concluded that as the fluid velocity increased biofilm formation was limited. ±3 m/s and 4 m/s were observed as detaching velocities. Thus, velocities within this range would be helpful in reducing the biofilm formation. As the flow rate increases, the rate of wall decay increases.

2.5.4 DISINFECTANT RESIDUALS

Chlorine is depleted at a faster rate by reaction with a corroded tank material. Bacterial regrowth is higher in such systems because the rust on the tank material can alter the organic matter in water making it more available for bacterial growth and nourishment.

The ferrous ion or hydrogen ion can also be utilized by the bacteria for their growth (Morton *et al.*,2005; Zhang and Liu, 2014).

2.5.5 TURBIDITY

Turbidity in water is usually caused by suspended matter such as clay, silt, organic and inorganic matter, plankton and other microorganisms and is a useful water quality indicator (LeChavallier et al., 1981). These particles can provide either nutrients for bacteria or other pathogens, or they may protect microorganisms themselves from chlorination (LeChavallier et al., 1981). A study by LeChavallier et al. (1981) showed that coliforms in high turbidity water (13 NTU) were reduced from their original concentration after chlorination, while coliforms in low turbidity water (1.5 NTU) were undetectable after chlorination. Their results also showed that given constant chlorine dose a turbidity increase from 1 to 10 NTU results in an eightfold decrease in disinfection efficiency.

2.5.6 RESIDENCE TIME

Residence time has major impact on water quality. Many studies have shown that water quality degrades as the water travels through the distribution system and in some cases is stored before use (e.g., Evison and Sunna, 2001; Tokajian and Hashwa, 2003).

2.5.7 PIPE MATERIAL

Types of pipe material can play a key role in the bacterial regrowth by affecting the corrosion processes and biofilm formation. Owing to the high porosity and the corrosion induced in iron pipes due to the reaction between pipe wall and disinfectant residual they are reported to support highest bacterial biomass as compared to PVC and are favorable for biofilm establishment because pipe sediments serve as a nutritional source for bacteria. Biofilms serve as source ofbacteria entering the distribution system (Inkinen *et al.,* 2014; Wang *et al.,* 2014). Norton *et al.* (2000) reported that bacterial densities in the biofilm formed in iron pipes is much higher (>100-fold) as compared to polyvinyl chloride pipes (PVC).

Niquette *et al.* (1999) carried out a study to examine the impacts of pipe materials on densities of fixed bacterial biomass in a drinking water distribution system. Densities of bacterial biomass in iron pipes were found 10 to 45 times higher than in plastic based pipes. The corrosion tubercles in the iron pipes provide increased surface area and cracks and crevices to protect bacteria from disinfectant residual (LeChevallier *et al.*, 1996).

2.6 REGULATIONS

Some existing bacterial contamination regulations and guidelines for drinking water

1. US Environmental Protection Agency, 2009
2. Ministe`re de la sante´
3. World Health Organization, 2012
4. National Drinking Water Quality Standards Pakistan, 2010

Table 2.1 National and International Standards

Country	**Total Coliform**	***E.coli***
United States	0/100 ml samples from the same site must be coliform free	0/100 ml (100%)
Canada	0/100 ml (90%) none should contain more than 10 CFU/100 ml. A consecutive sample from the same site must be coliform free	0/100 ml (100%)
World Health Organization	0/100 ml	0/100 ml (100%)
Pakistan	0/100 ml	0/100ml

2.7 RELATED STUDIES

A study was carried out in the Bholakpur area, Hyderabad, India regarding the assessment of drinking water quality. The study was conducted to determine the physicochemical properties and microbial quality of the drinking water. The microbial quality of water was tested using standard plate count, membrane filtration technique, thermotolerant coliform (ITC), and most probable number (MPN) methods. All the water samples of the study area exceeded the permissible counts of WHO guidelines. Excessively high colony numbers .indicated that the water is highly contaminated with microorganisms and is hazardous for drinking purposes. Bacteriological 15 pollution of drinking water supplies caused diarrheal illness in Bholakpur, in May 2009 which is due to the infiltration of contaminated water (sewage) through cross connection, leakage points, and back siphoning (Rasheed *et al*., 2011).

Assessment of water quality of rural Punjab was done in a study to analyze water pollution and its impact on the public health. The results showed that almost 90% samples were detected with microbial contamination (Azizullah *et al.*, 2011).

Drinking water quality in Rohri City, Sindh, Pakistan was assessed in a study. The samples were analyzed for the presence of total coliform (TC), *E. coli* (EC) and heterotrophic plate count (HPC). The bacteriological analysis was carried out by membrane filtration and spread plate count (SPC) technique. Both surface and ground water samples were detected with microbial contamination. The quality of surface water was poor as compared to ground water (Abdul Hussain *et al.,* 2010).

A study was carried out on the microbial and chemical analysis of potable water in public water supply within Lagos University, Ojo. Water samples were collected especially into sterile containers and were immediately subjected to both chemical and microbiological analysis in order to evaluate the quality of potable water in circulation within the university and identify its sources of contamination. Coliform contamination was detected which was far above the WHO permissible limits. It was anticipated that there is presence of biological agents in the water distribution network (Ojo *et al*., 2007).

A study was carried out on the manipulation of different media and methods for the cost effective characterization of *Escherichia coli* strains collected from different habitats. They utilized three types of selective and differential agar media (MacConkey, Eosin Methylene Blue: EBM and Endo agar) for the successful identification of *E.coli* using membrane filtration (MF), culture media and biochemical methods. It was anticipated that by using such methods, isolation and identification of *E. coli* can be done effectively without importing expensive diagnostic kits, which is most often difficult especially in the developing countries and thus becomes limiting factor for microbiological investigations (Rubina *et al.,* 2004).

The accuracy of Colilert-18 as a test for coliforms and *Escherichia coli* in subtropical freshwater was evaluated by using API 20E strips and fatty acid methyl ester analysis in a study (Kuo-Kuang *et al.,* 2003). This technique is just a presence/absence test so the study was not useful when the enumeration of coliform and *E.coli* is required and these kits are expensive as well.

Evaluation of *Escherichia coli* as the main indicator of fecal pollution was carried out. The assessment confirmed advantages when compared with assessment of total coliforms and fecal coliforms because (a) *E. coli* survives in river water for shorter period than other coliforms and fecal coliforms and (b) its occurrence in a stream (in an area without any significant point sources of pollution), in particular when compared with total coliforms, is more stable. Significant differences appear especially in the summer period 17 when the elevated temperature allows development of non-fecal bacteria (Baudišová, 1998).

Comparison of membrane filtration and auto analysis Colilert presence-absence techniques for analysis of total coliforms and *Escherichia coli* in drinking water samples was carried out in a study. Over a 4-month period, 950 samples of treated drinking water were analyzed for total coliforms (TC) and *Escherichia coli* by both membrane filtration (MF) and Auto analysis Colilert presence-absence (AC) techniques. The two tests agreed 97% of the time on the basis of presumptive TC results and 98.5% of the time on the basis of verified TC results. Samples which produced disagreement between the two tests were most often TC positive by MF and TC negative by AC. *E. coli* was recovered four times: twice by MF only, and twice by AC only but without the diagnostic fluorescence reaction. In two samples, *E. coli* could not be isolated from fluorescence-positive AC tests. On the basis of these results, the AC test was implemented as the routine analytical procedure for TC but not for *E. coli* (Lewis and Mak, 1989). This study showed that both the techniques have given almost the same probability in results so Membrane filter technique is better than the other one because it's less expensive.

A study was carried out regarding the development and evaluation of a membrane filter procedure for enumerating *Escherichia coli*. The method quantified *E. coli* within 24 h without requiring subculture and identification of isolates. It incorporated a primary selective-differential medium for gram-negative, lactose-fermenting bacteria; resuscitation of weakened organisms by incubation for 2 h at 35ºC before incubation at 44.5 ºC for 18 to 22 h; and an in situ urease test to differentiate *E. coli* from other thermotolerant, lactose-positive organisms. The recovery of *E. coli* from marine, estuarine, and freshwater samples exceeded 90%. Of the presumptively positive colonies, 91% were verified as *E. coli*. Less than 1% of all of the verified *E. coli* colonies failed to react typically (Dufour *et al.,* 1981).

E.coli is considered worldwide an indicator of fecal contamination in water. Some studies have been summarized here regarding the physicochemical and microbiological analysis of water supplies using *E.coli* as an indicator organism.

Chapter 3

Materials and Methods

3.1 STUDY SITE

National University of Sciences and Technology, Pakistan was taken as the study site. NUST was established in 1991. It's new campus was established in 2008 in H-12 sector, Islamabad. It covers an area of 707 acres, over 20 departments, faculty and staff residential area as well as hostels for both female and male students.

Water supply within NUST relies upon ground water supply. Water is pumped by means of tube wells which are 10 in number out of which all tube wells are functional except 1 tube well which is near student centre. Tube wells have total pumping capacity of 397600 gallons.

Table 3.1: Tube wells and their pumping capacity

S. NO.	Tube well No & Location	Capacity Gallons per Hour	Physically pumping per Hour	Total pumping per hour
1	T-1 L-I Gate No. 1	5000	16	80000
2	T-2 L-I TIC Building	4000	16	64000
3	T-3 L-I Student Centre	2000	Water level Down	Pull On
4	T-4 L-II NIT Back Side	2000	16	32000
5	T-5 L-I Gate No. 14	3950	16	63200
6	T-6 L-II Back Side	4000	16	64000
7	T-7 L-II Package-IV	3000	16	48000
8	T-8 L-I Near Lake	4100	16	65600
9	T-9 L-I Ghazali-I	1200	4	4800
10	T-10 L-2,3 Near Location 3	4000	16	64000
				397600 gallons

Water from tube wells is transferred to 3 main storage tanks which include both underground storage tank as well as overhead storage tank. Storage capacity of storage tanks is 1,850,000 gallons per day. Storage time can extend upto 2-3 days. These storage tanks have reached their optimum level of pumping out water, any further pumping will deplete water availability. From these tanks water is supplied to all departments, residential areas and hostels.

Table 3.2: State of Water Storage in NUST

1	**Main Water Supply L-I**	**Number of Tanks**	**Capacity**	**Storage (Gallons)**
	Under Ground Tank	2	300,000	600,000
	Over Head Tank	1	100,000	100,000
2	Main Water Supply L-II			
	Under Ground Tank	3	300,000	900,000
	Over Head Tank	1	100,000	100,000
3	Main Water Supply L-III			
	Under Ground Tank	1	150,000	150,000
	Over Head Tank	-	-	
Total Storage				1,850,000

There are total of 227 tanks with a total of capacity of 450600 gallons per day. These are composed of 2 types PVC (Polyvinyl Chloride) and RCC (Reinforced Concrete Cement). RCC tanks are underground as well as overhead tanks while PVC tanks are mostly overhead tanks. Mostly PVC Tanks have capacity of 500-800 gallons while RCC tanks have capacity of 2000 gallons and above. Water is regularly filled in these tanks. Tanks in hostels and residential areas are filled thrice a day while tanks in schools are filled twice a day in morning and evening. Details of tanks at NUST are as under:

Table 3.3: Details of Storage Tanks in NUST

S/N0	**Buildings**	**Quantity of Tanks**	**Type**	**Capacity (gallons)**

1	SMME	1	RCC	3000
2	SMME (East, Central & West wing)	3	RCC	3000
3	SNS	4	RCC	1000
4	NIT(500 Glns)	6	PVC	500
5	NIT(200 Glns)	6	PVC	200
6	NICE	2	RCC	1000
7	Exam Branch	1	RCC	3000
8	CIE TIC	4	PVC	2000
9	HBL Bank	2	PVC	500
10	Admin Office	4	PVC	500
11	Jamia Masjid	2	RCC	2000
12	Jamia Masjid Wazo Khana	1	PVC	500
13	RCMS	1	RCC	10000
14	RIMMS	1	RCC	10000
15	IGIS	1	RCC	2000
16	Academic I (C3A)	4	RCC	5000
17	Academic II (RCMS,ASAB)	4	RCC	5000
18	Café I & II	2	RCC	1000
19	Café I & II (U/G)	2	RCC	2000
20	IESE	8	PVC	200
21	SCME	10	RCC	1000
22	NBS	2	RCC	10000
23	SEECS	8	PVC	10000
24	SEECS (U/G)	2	RCC	10000
25	S3H	1	RCC	5000
26	HQ Building	2	RCC	2000
27	CIPS	1	RCC	10000

28	NMC (Medical Center)	1	RCC	2000
29	NMC for Kitchen	1	PVC	500
30	Gate 1 & 10	2	PVC	500
31	Filter Plants	6	PVC	200
32	Central Workshop	2	RCC	2000
33	PMO	1	RCC	2000
34	NUST Villas (1-23)	23	RCC	2000
35	Catt-II 32 Apartments	8	RCC	2000
36	Catt-III 48 Apartments	12	RCC	3000
37	Cat-V 32 Apartments	6	RCC	2000
38	Cat-V 24 Apartments	6	RCC	2000
39	Iqra Apartments-64	32	PVC	500
40	Ghazali Hostel Block-I & II	2	RCC	5000
41	Kitchen for Ghazali Hostel	2	PVC	500
42	Razi Hostels Block-I & II	2	RCC	5000
43	Kitchen for Razi Hostel	2	PVC	500
44	Attar Hostel Block-I & II	2	RCC	5000
45	Kitchen for Attar Hostel	2	PVC	500
46	Attar Hostel (U/G)	1	RCC	10000
47	Rumi Hostel Bl0ck-I,II&III	3	RCC	5000
48	Kitchen for Rumi Hostel	2	PVC	500
49	Rumi Hostel (U/G)	1	RCC	10000
50	Fatima Hostel-I &II	2	RCC	5000
51	Fatima Kitchen	2	PVC	500
52	Fatima Hostel (U/G)	1	RCC	10000
53	Zainab Hostel	1	RCC	5000
54	Kitchen Zainab Hostel	1	PVC	500
55	Ayesha Hostel	1	RCC	5000
56	Kitchen Ayesha Hostel	1	PVC	500

57	U/G Tank Zainab & Ayesha Hostel	1	RCC	10000
58	SM BK I, II & III	3	RCC	3000
59	Printing Press	4	PVC	200
60	MT Yard	2	PVC	500
Total Tanks		227		189500

Prior to distribution water is treated with chlorine. University has a total of 6 water filtration plants which are located at various points throughout the campus. Electric water filtration coolers are installed throughout the campus.

We selected 41 sampling sites for our study .Details of these sites along with the number of tanks and their capacity is shown in table below:

Table 3.4: Selected Sampling Sites

S/No	Hostels/Building Name	No. of Water Tanks	Capacity (Gln)
1	Fatima Hostel 1-2	2	5000
2	Fatima Kitchen	2	500
3	Zainab Hostel/ kitchen	2	6000
4	Ayesha Hostel	1	5000
5	Rumi hostel-I,II&III/kitchen	3	5500
6	Ghazali Hostel-I&II/kitchen	3	5500
7	Razi Hostel-I&II/kitchen	3	5500
8	Attar Hostel-I&II/kitchen	3	5500
9	Iqra Appt-8 X Blocks	32	500
10	NBS	2	10000
11	SEECS RCC Water Tank	2	10000
12	SEECS PVC Water Tank	12	500

13	IGIS	1	5000
14	IAEC	1	5000
15	RIMMS	1	5000
16	SCME	10	1000
17	IESE	1	3000
18	Academic Block-I-II	6	4000
19	Student center	4	500
20	NICE	2	1000
21	SCEE PVC Water Tank	8	500
22	SCEE RCC Water Tank	1	4000
23	SNS New	3	500
24	SNS Old	3	500
25	SMME old	1	3000
26	SMME New Block	1	5000
27	SM BK 1,2 & 3	3	3000
28	Main Office	2	3000
29	CIPS	1	10000
30	GYM	3	400
31	MRC	1	3000
32	PRESS	2	400
33	MT Yard	2	500
34	NUST Mosque	2	2500
35	NV1-23 B	23	2000
36	Cat 3-4 Block 48 Houses	12	3000
37	Catt-2	6	2000
38	NMC	1	2000
39	Cat-IV 04-Block	8	2000
40	Cat-IIV 03 Block	6	2000
41	Gate 1 &10	3	500

	Total	185	133300

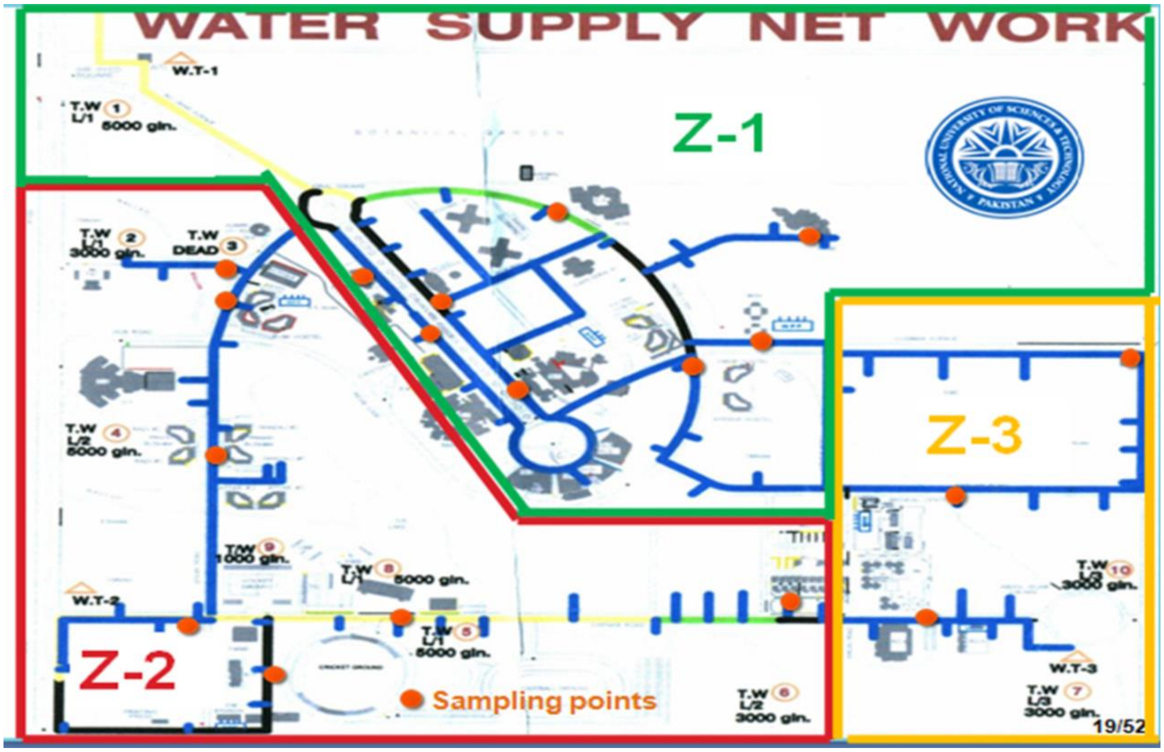

Figure 3.1: Layout of NUST

3.2 SAMPLING

3.2.1 PREPARATION OF GLASSWARE

250ML glass bottles were used for sampling. All the bottles were washed with detergent and then rinsed with distilled water and autoclaved at 121°C, 15 psi for 15 minute. Then these bottles were oven dried for 1 hour at 105^0C. After this the bottles were tightly capped and wrapped.

3.2.2 SAMPLE COLLECTION, TRANSPORTATION AND STORAGE

Samples were collected carefully to avoid any sort of contamination. Samples were collected from both PVC as well as RCC tanks of all 41 sites. All the samples bottles were labeled after collection of sample from the respective sites After collection of Samples, they were analyzed immediately or within 1 hour of their collection or they were stored in refrigerator and analyzed within 4 All this collection, transportation and storage procedures were carried out as prescribed in the Standard Methods for the Examination of Water and Wastewater (APHA, 2012).

3.3 WATER QUALITY ANALYSIS

3.3.1 PHYSICOCHEMICAL ANALYSIS

Water samples were tested for physicochemical parameters. Onsite as well as laboratory analysis of sample was performed.

3.3.1.1 ON SITE ANALYSIS

Temperature, pH, dissolved oxygen, free chlorine and total chlorine were measure onsite. Analysis of these parameters was performed as per the Standard Methods for the Examination of Water and Wastewater (APHA, 2012).

3.3.1.2 LABORATORY ANALYSIS

Total Dissolved solids (TDS), Electrical Conductivity (EC), Salinity of the collected samples was measured in laboratory by using multimeter analyzer. Analysis of all the parameters was performed as per the Standard Methods for the Examination of Water and Wastewater (APHA, 2012).

3.3.2 MICROBIOLOGICAL ANALYSIS

3.3.2.1 MOST PROBABLE NUMBER TECHNIQUE

MPN is a Three Phase test:

1. Presumptive test for Coliform

2. Confirmatory test for Coliform
3. Completed test for Fecal Coliform

Three types of media are involved in MPN technique which are:

1. Lauryl Tryptose Broth (selective for gram-negative bacteria)
2. Brilliant Green Broth(selective and differential for Coliforms)
3. EC Broth(selective for Fecal Coliforms)

3.3.2.2 PREPARATION OF MEDIA

Laural Tryptose Broth (LTB):

For each sample, 10 tubes of LTB were prepared. For preparation of LTB tubes, 8.9 g of media was mixed in 250ml distilled water. 10 mL of the mixture was added in 10 tubes in which there was an inverted durham tube.The tubes were then autoclaved at 121°C and 15 psi for 15 minutes After that they were placed in incubator to check sterility at 37^{o}C for 24 hours.

Brilliant Green Bile Broth (BGLB):

For each sample, 10 tubes of BGLB were prepared. For preparation of BGLB tubes, 10 g of media was mixed in 250ml distilled water. 10 mL of the mixture was added in 10 tubes in which there was an inverted durham tube.The tubes were then autoclaved at 121°C and 15 psi for 15 minutes After that they were placed in incubator to check sterility at 37^{o}C for 24 hours.

Escherichia coli (EC) Broth:

For each sample, 10 tubes of EC were prepared. For preparation of EC tubes, 9.25 g of media was mixed in 250ml distilled water. 10 mL of the mixture was added in 10 tubes in which there was an inverted durham tube. The tubes were then autoclaved at 121°C and 15 psi for 15 minutes After that they were placed in incubator to check sterility at 37^{o}C for 24 hours.

3.3.3 ENUMERATION OF TOTAL COLIFORM AND E. COLI

Total coliforms and E.*coli* were enumerated using Most Probable Number (MPN) or Multiple Tube Fermentation Technique. In the presumptive phase, 10 fermentation test tubes each containing 10 mL LTB and an inverted durham tube were used. After vigorously shaking, the sample 10 mL was added to each tube and the tubes were kept at 37°C for 24 hours. Production of gas in the tubes showed a positive presumptive reaction and gave an indication of presence of total coliforms.

Positive tubes were further subjected to confirmation phase. Positive LTB tubes were shaken slightly and a small inoculum using wire loop was transferred to BGLB tubes. BGLB tubes were then placed in an incubator at 37°C for 24 hours. Production of gas after 24 hours in BGLB tubes confirmed presence of total coliforms.

Positive tubes from previous phase were taken and after gently shaking a small amount using wire loop was added to EC broth tubes and incubated at 37°C for 24 hours. Production of gas confirmed the occurrence of fecal coliforms (E. *coli)*. (APHA, 2012).

3.4 EQUIPMENT

All the equipment required for physicochemical as well as microbiological analysis were available within the Environmental Microbiology Teaching Laboratory, these include:

- Aluminum foil
- Autoclave manufactured by Biotech
- Beakers manufactured by ABBOT
- Colorimeter manufactutred by Consort
- Distilled water
- Flasks manufactured by ABBOT
- Incubator manufactured by Labtech
- Laminar Flow Hood manufactured by Labequip.
- Multimeter manufactured by Consort

- pH meter manufactured by HACH 156
- Pipettes, micro pipettes
- Test tubes, Durham tubes
- Schott Glass Bottles
- Weighing Machine manufactured by Essae

Figure 3.2: pH meter

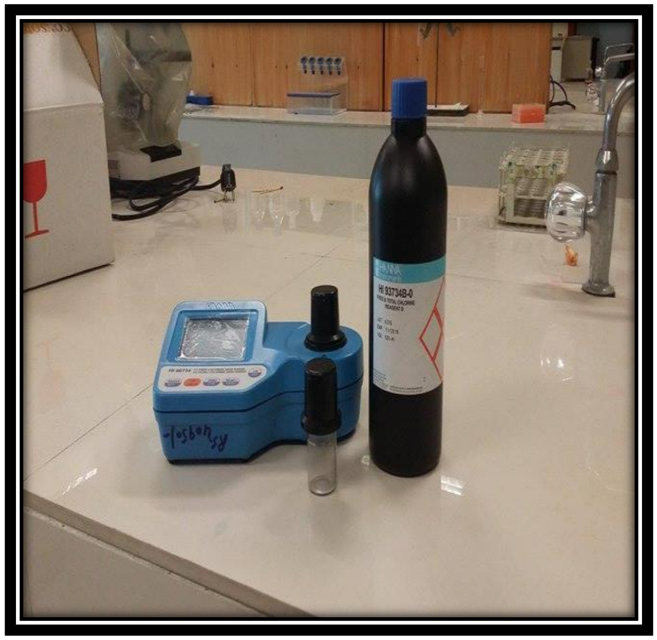

Figure 3.3: Colorimeter

Figure 3.4: Multimeter

Figure 3.5: Autoclave

Figure 3.6: Incubator

Figure 3.7: Weighing Machine

Figure 3.8: Laminar Flow Hood

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 PHYSICOCHEMICAL Analysis

Physicochemical parameters of water samples collected from the university distribution network compared with World Health Organization and Pakistan Standards for Drinking Water Quality are listed in Table 4.1. All the parameters were found within limits proposed by WHO and PSDWQ.

Table 4.1: Physicochemical parameters compared with WHO and PSDWQ

Parameters	**WHO**	**PSDWQ**
pH	6.5-8.5	6.5-8.5
Residual chlorine (mg/L)	0.2-0.5	0.2-0.5
DO (mg/L)	<13-14	-
EC (µS/cm)	<2500	<2500
TDS (mg/L)	<1000	<1000

4.1.1 WATER QUALITY CHARACTERISTICS

4.1.1.1 TEMPERATURE

The quality of water samples was tested by analyzing different physical and chemical parameters. Temperature was observed at the time of collection of water samples Temperature of water samples ranged for PVC tanks from 18.1 to 30.1^{0}C whereas for samples collected from RCC, values of temperature ranged from 18.5 to 30.2^0 C at all sampling stations.

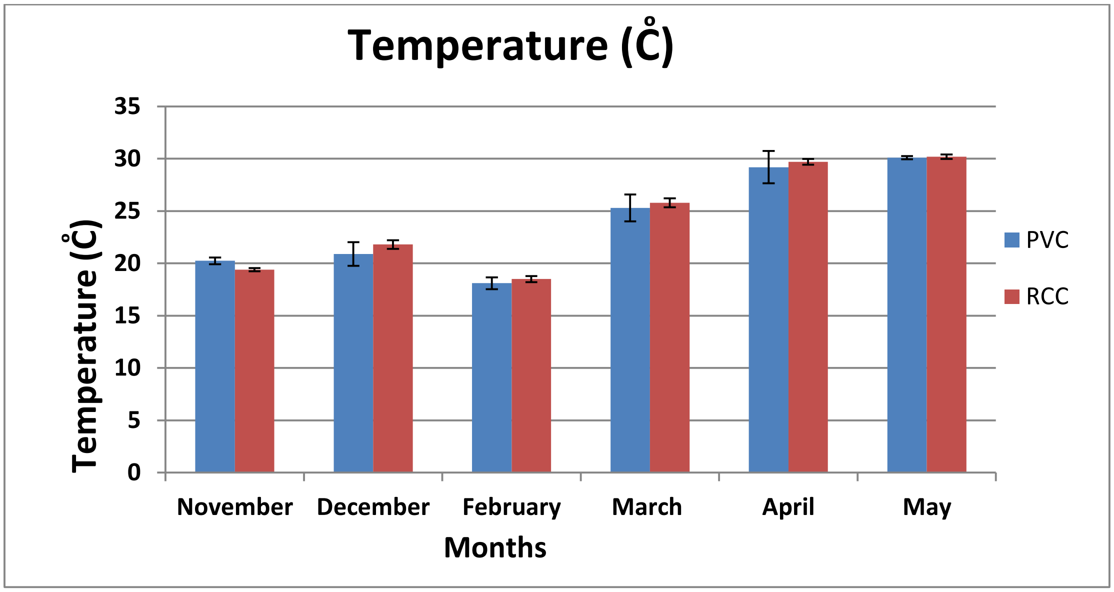

Figure 4.1: Average Temperature for RCC and PVC Tanks

4.1.1.2 pH

The mean values of pH at 41 sampling stations is between from 6.86-7.23 for PVC tanks whereas for samples collected from RCC, values ranged from 6.9 to 7.1 which are well within WHO permissible limits 6.5-8.5 (BUREAU OF INDIAN standards IS 10500-1991 Drinking Water Standards). pH values higher than 8.5 are not suitable for effective disinfection while values less than 6.5 enhance corrosion in water mains and household plumbing system. Therefore, WHO proposes a desirable range of 6.5 to 8.5 for pH of drinking water. PSDWQ has also proposed permissible range of 6.5-8.5 Increased values of pH, temperature and turbidity were associated with increased concentrations of microorganisms.

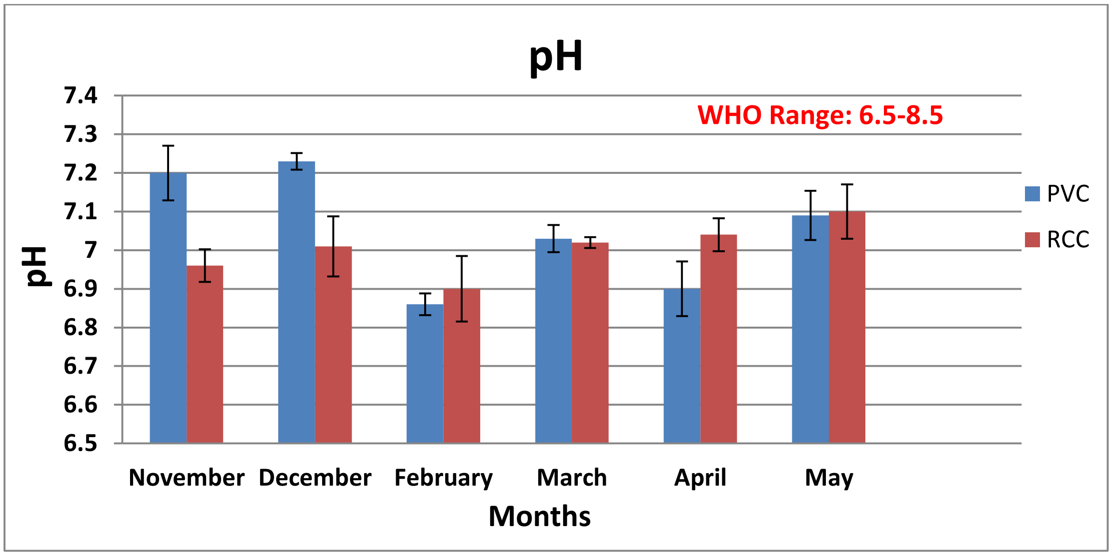

Figure 4.2: Average pH for RCC and PVC Tanks

4.1.1.3 TDS

TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter that are dissolved in water. TDS in drinking-water originate from natural sources, sewage, urban runoff and industrial wastewater. Salts used for road de-icing in some countries may also contribute to the TDS content of drinking-water. Concentrations of TDS in water vary considerably in different geological regions.

The solubility of minerals represents the amount of inorganic substances (e.g. iron, salts) that are dissolved in the water. High total dissolved solids (TDS) can reduce the palatability of water or cause health problems if specific constituent elements are at high levels. Water containing TDS concentrations below 1000 mg/L is usually acceptable to consumers, although acceptability may vary according to circumstances. However, the presence of high levels of TDS in water may be objectionable to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household. The values of TDS for all samples were within the range proposed by WHO and PSDWQ of 1000mg/l. Mean values of TDS for RCC tanks throughout the sampling was 445 to 542mg/L whereas for PVC tanks it ranged from 435 to 518mg/. However, USEPA has proposed permissible limit of 500 mg/l.

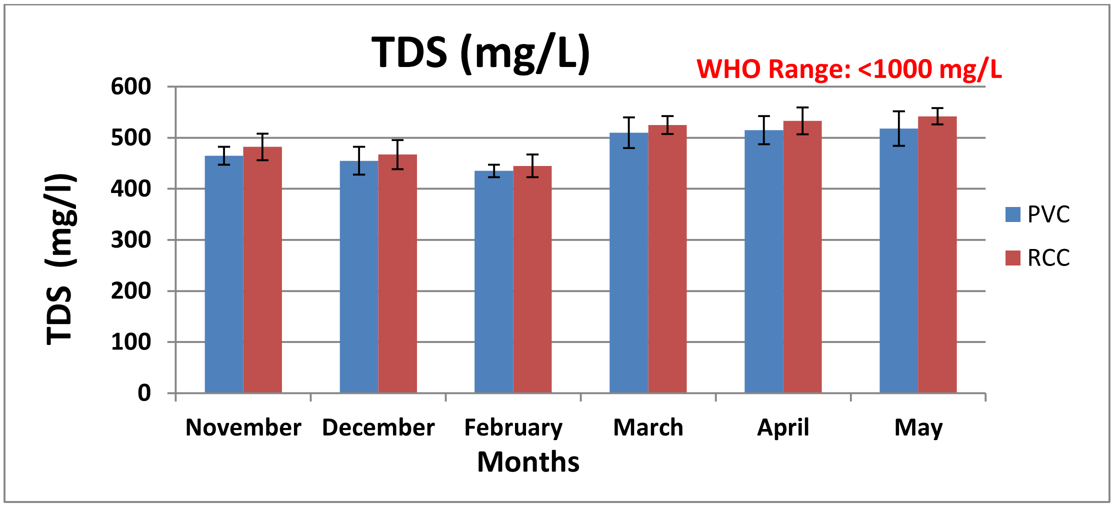

Figure 4.3: Average TDS for RCC and PVC Tanks

4.1.1.4 CONDUCTIVITY

Mean values of conductivity for PVC tanks ranged from 780 to 976µS/cm and for RCC tanks it ranged from 830 to 1002 µS/cm. There is a direct relationship between TDS and conductivity as it is evident from the results. More dissolved solids cause more conductivity. The electrical conductivity is higher for water that has more dissolved ionic species. Temperature also affects the electrical conductivity, as increase in temperature increases dissolution of ionic species. Thus it was observed that with increase in temperature conductivity also increased.

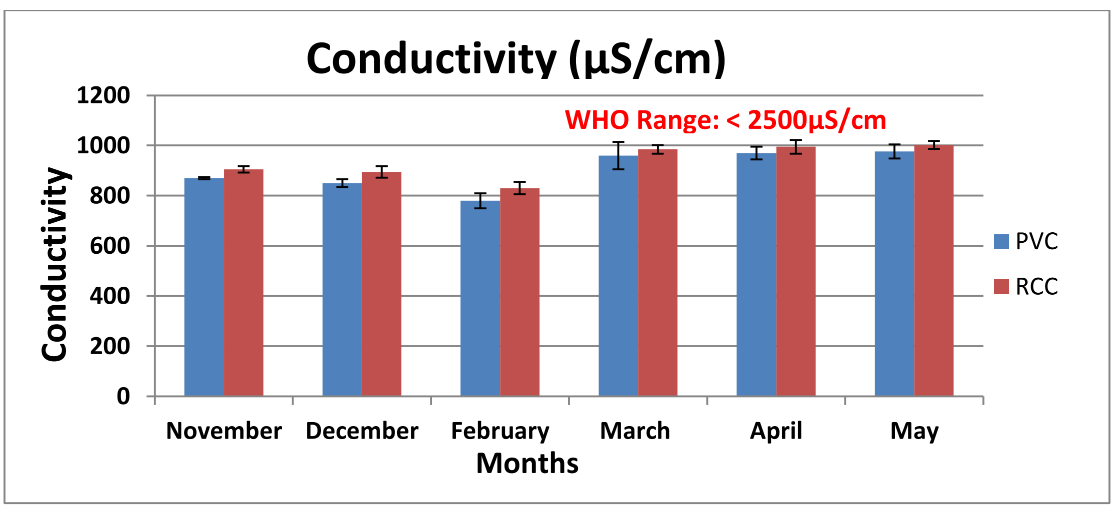

Figure 4.4: Average Conductivity for RCC and PVC Tanks

4.1.1.5 SALINITY

Salinity is the measure of all the salts dissolved in water. Salinity is usually measured in parts per thousand (PPT). The salinity in our water sample ranged from 0.4-0.5.

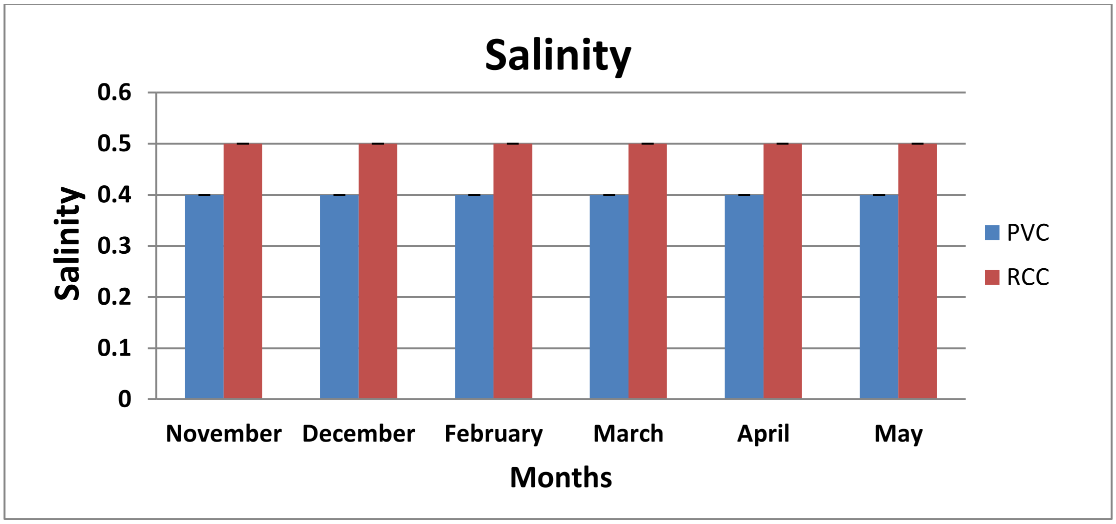

Figure 4.5: Average Salinity for RCC and PVC Tanks

4.1.1.6 FREE CHLORINE

Chlorine residual is a low level of chlorine remaining in water after its initial application. It constitutes an important safeguard against the risk of subsequent microbial contamination after treatment—a unique and significant benefit for public health.

Free chlorine for RCC tanks observed varied from the lowest value of 0.2 to the highest value of 0.26mg/L.

4.1.1.7 TOTAL CHLORINE

The values of total chlorine for PVC tanks observed was 0.25 to 0.35 mg/l. and the values of total chlorine for RCC tanks observed was 0.27 to 0.34 mg/L.

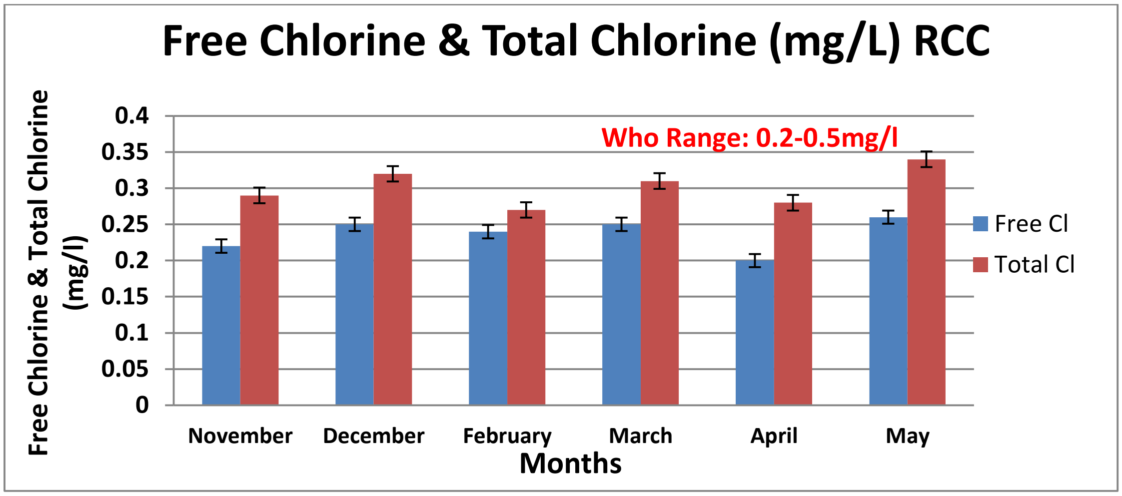

Figure 4.6: Average Values of Free and Total Chlorine for RCC tanks

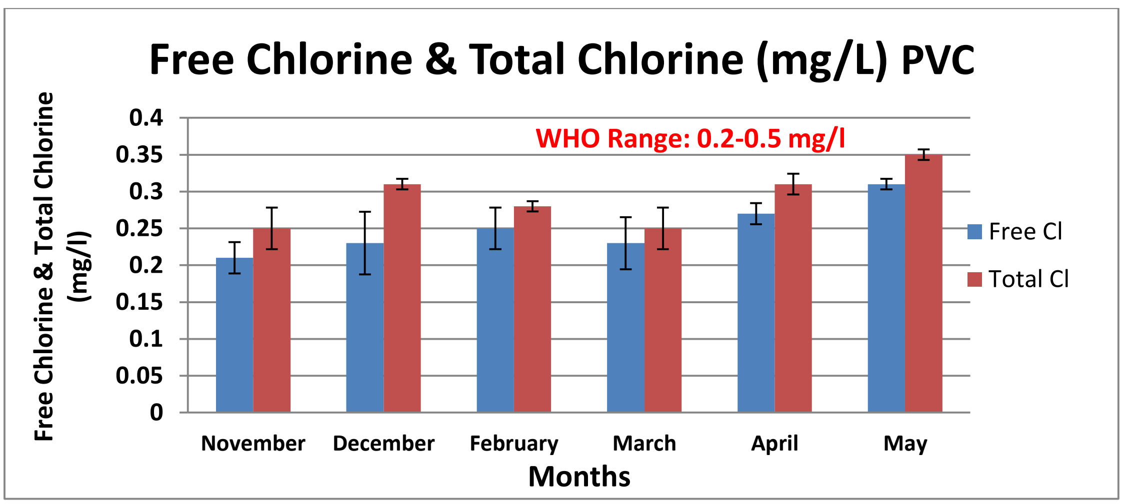

Figure 4.6: Average Values of Free and Total Chlorine for PVC tanks

4.1.1.8 DISSOLVED OXYGEN

Dissolved oxygen (DO) is the amount of oxygen that is present in the water. It is measured in milligrams per liter (mg/L), or the number of milligrams of oxygen dissolved in a liter of water. The DO in our sample ranges from 5.46 to 5.98mg/L for RCC tanks and for PVC tanks it varied from 5.4 to 5.93 mg/L. It was observed that DO shows an inverse relation with temperature. With increased temperature DO reduced.

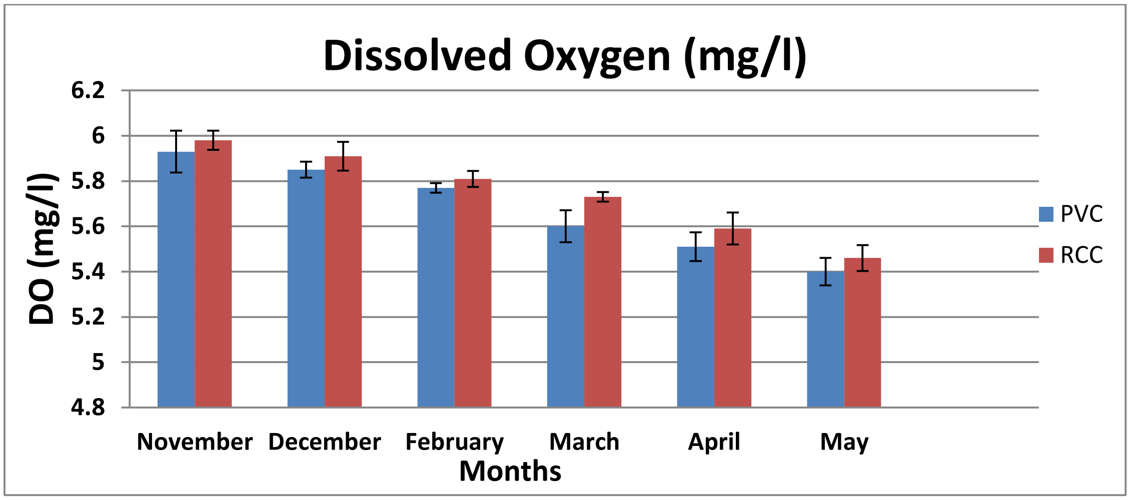

Figure 4.8: Average Values of DO for RCC and PVC Tanks

4.2 BACTERIOLOGICAL ANALYSIS

4.2.1 FECAL COLIFORM

E. coli has been demonstrated to be a specific indicator for the presence of fecal contamination. Mostly it is because of human or animal waste The presence of *E.coli* in water is a potentially dangerous situation. Immediate steps need to be taken to disinfect the water, remove the source of contamination or find an appropriate alternate source. Even brushing your teeth with contaminated water can pose a significant health risk. Zero fecal coliform per 100ml of water sample defines clean water and is a part of all the water quality standards (Essential Bacteriological Standard ISI & WHO).

Samples collected from PVC were not contaminated with fecal coliform than those of RCC tanks were contaminated. For samples collected from PVC tanks the value of MPN/ 100 mL for total coliform was 0 for all the months accept November and probability ranged from 0 to 3% while other sampling periods showed MPN index of 1.1 for RCC tanks in the month of December to May with probability ranged from 0.03 to 5.9%

Highest MPN index was found in the month of November for RCC tanks depicting a value of 3.6 with probability ranging from 0.91 to 9.7%

ALL samples of RCC tanks were above who guidelines and (PSDWQ) Pakistan standard of drinking water quality.

It was observed that, as the distance increased from the main source, disinfectant concentration was significantly reduced causing microbial contaminants to recover to very high levels at places far from the main source of supply where disinfectant is introduced.

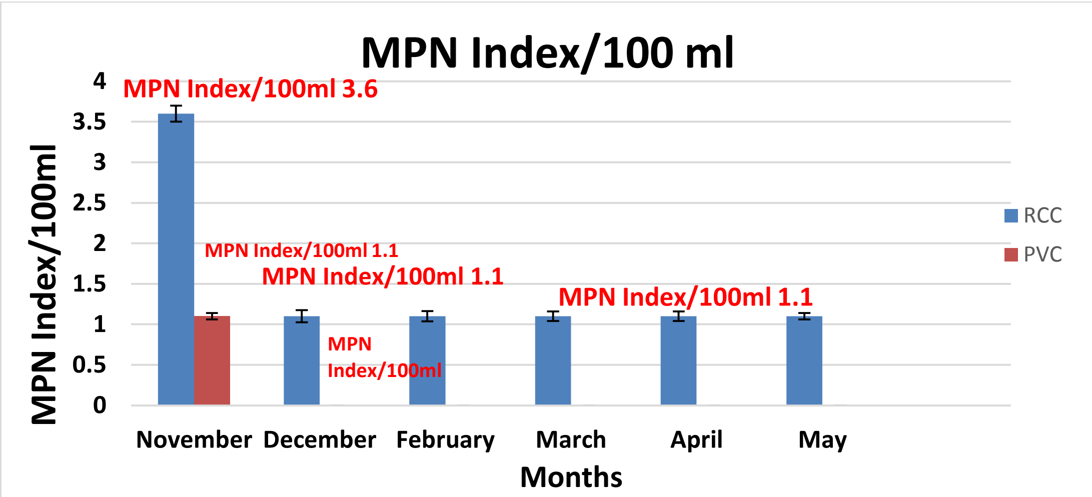

Figure 4.9: MPN Index/100mL for RCC and PVC Tanks

4.3 ANALYSIS BY CALIBRATED SENSORS

4.3.1 TEMPERATURE

Temperature of sample collected from PVC tanks ranged from 25.5 to 30.2^{0}C whereas for RCC it ranged from 26 to 30.4^0 C which was same as the temperature measured during on site analysis.

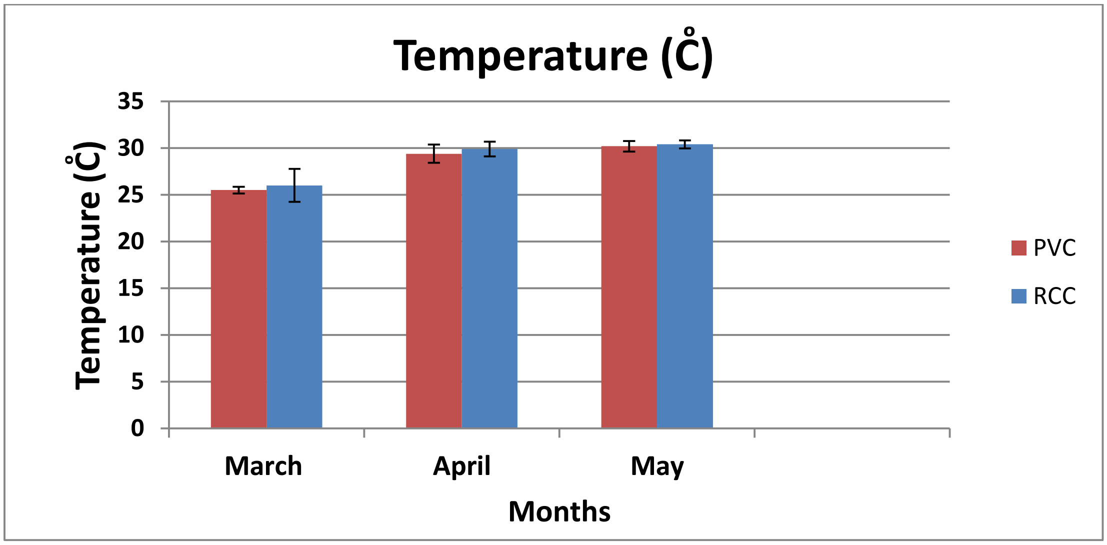

Figure 4.10: Average Values of Temperature by Calibrated Sensors

4.3.2 pH

pH of all the samples ranged from 6.91-7.05 for PVC tanks whereas for the samples collected from RCC tanks, values of pH ranged from 7.04 to 7.1. These values were identical to the values taken by pH meter.

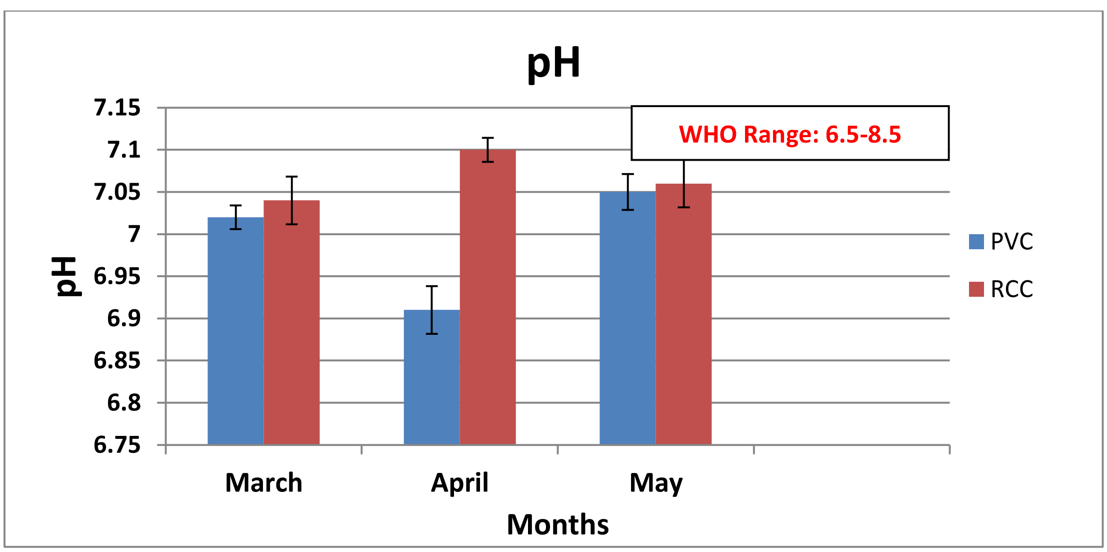

Figure 4.11: Average Values of pH by Calibrated Sensors

4.3.3. CONDUCTIVITY

Mean values of conductivity for PVC tanks ranged from 960 to 976µS/cm and for RCC tanks it ranged from 985 to 1002 µS/cm.

The readings of conductivity taken from sensors were same as other readings taken at laboratory, which showed sensors were appropriately calibrated.

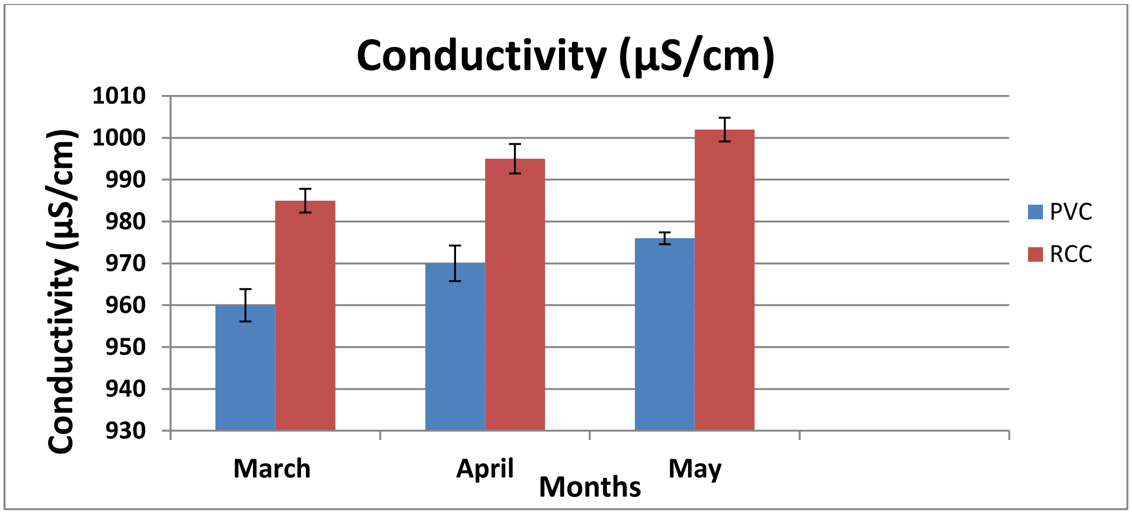

Figure 4.11: Average Values of pH by Calibrated Sensors

Table 4.2: Values in month of November for PVC Tanks

Sites	pH	Temp (^{0}C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	6.96	19.4	0	952	522	6.86	1.1
SNS (PVC)	6.96	19.4	0	950	520	6.9	<1.1
SEECS	7.01	19.8	0.02	951	521	6.91	<1.1
ZAINAB MESS	7	20	0.03	955	525	6.87	<1.1
RUMI HOSTEL	7.05	20	0.02	960	550	6.90	<1.1
FATIMA Mess	6.9	19.9	0.01	950	540	6.84	<1.1
IGIS	6.5	19.8	0.02	952	523	6.83	<1.1
NBS	6.8	19.9	0	950	540	6.92	<1.1
IQRA APT	7.02	20	0.08	970	560	6.82	<1.1
NUST VILLAS	7.05	20.5	0.06	950	523	6.82	<1.1
ATTAR MESS	6.99	20.5	0.4	900	490	6.84	<1.1
MAIN OFC	7.01	19.9	0.2	890	480	6.91	<1.1
AYESHA	7.02	19.8	0.19	890	482	6.84	<1.1
GHAZALI	6.9	20	0.12	870	460	6.9	<1.1
MI ROOM	6.99	20	0.11	950	540	6.83	<1.1
BHITTAI MESS	6.7	21	0.43	950	540	6.82	<1.1
BARRACK	7.1	22	0.32	890	480	6.93	1.1
CIE BUILD	7.05	19.8	0.1	899	490	6.86	<1.1
PRINTING	7.05	19.6	0.57	850	450	6.82	<1.1
RIMMS	7.04	20	0.55	980	570	6.82	<1.1
SCME	7.02	19.4	0.26	958	526	6.9	<1.1
GYM	7.1	19.5	0.06	950	540	6.83	<1.1
MOSQUE	6.98	19.5	0.43	970	560	6.84	<1.1
CIPS	6.9	19.8	0.17	890	480	6.88	<1.1
CAT-III	6.8	20.5	0.12	890	489	6.9	<1.1
HBL	7.06	20.7	0.52	970	560	6.87	<1.1
H.Q BUILD	7.05	21	0.65	950	520	6.9	<1.1
S3H	6.99	21.7	0.6	850	450	6.9	<1.1
C-1	7.03	20.1	0.11	880	470	6.86	<1.1
C-2	7.06	19.1	0.45	952	522	6.86	1.1
ASAB	6.99	21	0.23	880	470	6.9	<1.1
NIT	7.01	21.8	0.36	890	480	6.86	<1.1
EXAM CELL	7.05	20.5	0.11	956	546	6.83	<1.1
CAT-IV	6.5	21	0.32	950	540	6.94	<1.1
RCMS	7.1	22	0.34	890	480	6.85	<1.1
PMO OFC	7.04	20.8	0.45	970	560	6.86	<1.1
CAT-V	7.01	21.8	0.36	890	480	6.86	<1.1

Table 4.3: Values in month of November for RCC Tanks

Sites	pH	Temp (^{0}C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7.05	21.2	0.31	850	425	6.51	1.1
SNS (PVC)	7.1	21.2	0.30	870	435	6.6	2.2
SEECS	7.0	21.4	0.41	880	440	6.53	1.1
ZAINAB MESS	7.09	21.5	0.42	880	440	6.56	1.1
RUMI HOSTEL	7.08	21.0	0.44	870	435	6.6	1.1
FATIMA MESS	7.07	21.1	0.46	876	437	6.59	1.1
IGIS	7.04	21.6	0.44	850	425	6.6	1.1
NBS	7.1	21.1	0.42	890	445	6.6	<1.1
IQRA APT.	7.04	21.4	0.36	850	425	6.55	<1.1
NUST VILLAS	7.05	21.2	0.11	870	435	6.6	<1.1
ATTAT HOSTEL	7.05	21.4	0.42	890	445	6.6	<1.1
MAIN OFC	7.03	21.1	0.43	880	440	6.5	<1.1
AYESHA MESS	7.05	21.1	0.45	887	445	6.6	1.1
GHAZALI	7.02	21.2	0.33	888	445	6.6	<1.1
MI ROOM	7.0	21.3	0.45	890	440	6.52	1.1
BHITTAI MESS	7	21.3	0.36	870	435	6.6	1.1
BARRACK	7.01	21.4	0.2	898	450	6.6	3.6
CIE BUILD	7.05	21.4	0.21	898	450	6.53	1.1
PRINTING	7.03	21.1	0.24	879	440	6.6	1.1
RIMMS	7.03	21.4	0.24	870	435	6.6	<1.1
SCME	7.02	21.2	0.32	890	445	6.55	<1.1
GYM	7.03	21.4	0.32	897	446	6.6	1.1
MOSQUE	7.04	21.4	0.32	895	443	6.57	<1.1
CIPS	7.01	21.5	0.36	870	435	6.6	<1.1
CAT-III	7.03	21.6	0.00	869	430	6.53	<1.1
HBL	7.03	21.7	0	874	435	6.6	<1.1
H.Q BUILD	7.02	21.6	0.31	860	430	6.56	1.1
S3H	7.04	21.5	0.4	890	445	6.6	<1.1
C-1	7.05	21.5	0.43	870	437	6.5	1.1
C-2	7.06	21.4	0.35	899	445	6.6	<1.1
ASAB	7.01	21.3	0.32	900	440	6.5	<1.1
NIT	7.01	21.8	0.36	890	480	6.5	1.1
EXAM BRANCH	7.05	21.4	0.32	870	435	6.6	1.1
CAT-IV	7.04	21.8	0.4	880	440	6.51	1.1
RCMS	7.03	21.4	0.5	890	445	6.6	<1.1
PMO OFC	7.02	21.8	0.3	899	456	6.52	<1.1
CAT-V	7.01	21.8	0.36	890	480	6.5	<1.1

Table 4.4: Values in month of December for PVC Tanks

Sites	pH	Temp (^0C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7.05	28.7	0.21	980	515	6.26	<1.1
SNS(PVC)	7.06	29.5	0.23	967	540	6.21	<1.1
SEECS	7.07	28.5	0.28	980	480	6.22	<1.1
ZAINAB MESS	7.06	29.1	0.25	994	498	6.26	<1.1
RUMI HOSTEL	7.01	27.9	0.24	995	555	6.21	<1.1
FATIMA MESS	7.06	29.2	0.29	957	490	6.27	<1.1
IGIS	7.07	28.6	0.24	995	500	6.20	<1.1
NBS	7.03	28.7	0.25	1002	485	6.23	<1.1
IQRA	7.05	29.2	0.20	1015	513	6.24	<1.1
NUST VILLAS	7.06	29.2	0.17	980	480	6.22	<1.1
ATTAR MESS	7	28.5	0.26	997	495	6.25	<1.1
MAIN OFC	6.99	29.3	0.18	993	485	6.24	<1.1
AYESHA MESS	7.07	28.7	0.22	987	470	6.23	<1.1
GHAZALI	7.08	28.5	0.19	956	465	6.24	<1.1
MI ROOM	7.05	28.9	0.20	991	505	6.26	<1.1
BHITTAI MESS	7.06	28.7	0.28	987	495	6.21	<1.1
GATE 1	7.07	28.9	0.33	992	503	6.22	<1.1
BARRACK	7.07	28.4	0.23	982	485	6.24	<1.1
CIE BUILD	7.03	28.8	0.27	1006	505	6.22	<1.1
PRINTING	7.01	28.9	0.29	977	485	6.25	<1.1
RIMMS	7.05	29.3	0.23	933	480	6.24	<1.1
SCME	7.1	28.1	0.2	1005	490	6.24	<1.1
GYM	6.99	27.4	0.20	1017	515	6.23	<1.1
MOSQUE	7	28.7	0.20	1001	495	6.24	<1.1
CIPS	7.07	29.6	0.16	1025	535	6.26	<1.1
CAT-III	7.07	28.4	0.31	985	495	6.21	<1.1
HBL	7.02	28.3	0.28	993	505	6.27	<1.1
H.Q BUILD	7.07	29.1	0.23	1007	510	6.20	<1.1
S3H	7.06	28.3	0.30	897	494	6.22	<1.1
C-1	7.04	28.8	0.21	979	467	6.25	<1.1
C-2	7.06	28.9	0.20	982	499	6.24	<1.1
ASAB	7.07	28.8	0.22	1021	512	6.24	<1.1
NIT	7.1	27.7	0.23	997	507	6.21	<1.1
EXAM BRANCH	7.06	28.8	0.23	983	517	6.20	<1.1
CAT-IV	7.09	28.7	0.32	984	495	6.22	<1.1
RCMS	7.06	29.1	0.21	985	505	6	<1.1
PMO OFC	7.07	29.2	0.2	1027	517	6.24	<1.1
CAT-V	7.21	28.8	0.18	1031	514	6.23	<1.1

Table 4.4: Values in month of December for RCC Tanks

Sites	pH	Temp (^0C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7.08	28.4	0.22	970	510	6.21	1.1
SNS (PVC)	7.08	28.3	0.12	985	550	6.20	1.1
SEECS	7.06	28.8	0.20	990	480	6.22	1.1
ZAINAB MESS	7.08	28.9	0.12	989	495	6.24	<1.1
RUMI HOSTEL	7.08	27.6	0.31	1022	550	6.23	1.1
FATIMA MESS	7.07	29.1	0.23	990	480	6.24	1.1
IGIS	7.05	28.7	0.14	940	490	6.22	1.1
NBS	7.09	28.6	0.20	989	490	6.25	<1.1
IQRA APT.	7.08	29.2	0.19	992	510	6.24	1.1
NUST VILLAS	7.07	29.1	0.18	990	470	6.23	<1.1
ATTAR HOSTEL	7.08	28.6	0.25	990	490	6.24	1.1
MAIN OFC	7.08	29.2	0.2	980	490	6.26	1.1
AYESHA MESS	7.08	28.8	0.22	995	480	6.21	1.1
GHAZALI	7.08	28.4	0.20	980	495	6.27	1.1
MI ROOM	7.06	28.8	0.22	1005	500	6.20	1.1
BHITTAI MESS	7.07	28.5	0.22	990	505	6.22	1.1
BARRACK	7.06	28.6	0.19	995	495	6.25	1.1
CIE BUILD	7.06	28.2	0.19	980	495	6.24	1.1
PRINTING	7.06	28.6	0.18	1002	500	6.23	1.1
RIMMS	7.06	28.8	0.15	920	470	6.24	1.1
SCME	7.06	29.3	0.30	897	470	6.22	1.1
GYM	7	28.8	0.26	995	480	6.25	<1.1
MOSQUE	6.99	27.6	0.25	1022	510	6.24	1.1
CIPS	7.07	28.9	0.21	970	490	6.23	1.1
CAT-III	7.08	29.2	0.19	1039	540	6.24	1.1
HBL	7.06	28.1	0.18	1005	490	6.26	1.1
H.Q BUILD	7.06	28.9	0.20	985	490	6.21	1.1
S3H	7.10	29.2	0.21	990	500	6.26	1.1
C-1	7.06	29.2	0.29	890	480	6.21	<1.1
C-2	7.03	27.9	0.21	910	450	6.27	<1.1
ASAB	7.06	29.2	0.26	980	490	6.20	1.1
NIT	7.05	28.2	0.20	980	505	6.22	<1.1
EXAM BRANCH	7.06	27.7	0.19	970	495	6.24	<1.1
CAT-IV	7.08	29.2	0.21	1025	520	6.23	1.1
RCMS	7.06	29.3	0.25	985	480	6.24	1.1
PMO OFC	7.07	28.4	0.15	1020	500	6.22	<1.1
CAT-V	7.04	28.9	0.23	1015	510	6.25	1.1

Table 4.6: Values in month of February for PVC Tanks

Sites	pH	Temp (^{0}C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7.08	28.4	0.22	970	510	6.21	<1.1
SNS (PVC)	7.08	28.3	0.12	985	550	6.20	<1.1
SEECS	7.06	28.8	0.20	990	480	6.22	<1.1
ZAINAB MESS	7.08	28.9	0.12	989	495	6.24	<1.1
RUMI HOSTEL	7.08	27.6	0.31	1022	550	6.23	<1.1
FATIMA MESS	7.07	29.1	0.23	990	480	6.24	<1.1
IGIS	7.05	28.7	0.14	940	490	6.22	<1.1
NBS	7.09	28.6	0.20	989	490	6.25	<1.1
IQRA APT.	7.08	29.2	0.19	992	510	6.24	<1.1
NUST VILLAS	7.07	29.1	0.18	990	470	6.23	<1.1
ATTAR MESS	7.08	28.6	0.25	990	490	6.24	<1.1
MAIN OFC	7.08	29.2	0.2	980	490	6.26	<1.1
AYESHA MESS	7.08	28.8	0.22	995	480	6.21	<1.1
GHAZALI	7.08	28.4	0.20	980	495	6.27	<1.1
MI ROOM	7.06	28.8	0.22	1005	500	6.20	<1.1
BHITTAI MESS	7.07	28.5	0.22	990	505	6.22	<1.1
BARRACK	7.06	28.6	0.19	995	495	6.25	<1.1
CIE BUILD	7.06	28.2	0.19	980	495	6.24	<1.1
PRINTING	7.06	28.6	0.18	1002	500	6.23	<1.1
RIMMS	7.06	28.8	0.15	920	470	6.24	<1.1
SCME	7.06	29.3	0.30	897	470	6.22	<1.1
GYM	7	28.8	0.26	995	480	6.25	<1.1
MOSQUE	6.99	27.6	0.25	1022	510	6.24	<1.1
CIPS	7.07	28.9	0.21	970	490	6.23	<1.1
CAT-III	7.08	29.2	0.19	1039	540	6.24	<1.1
HBL	7.06	28.1	0.18	1005	490	6.26	<1.1
H.Q BUILD	7.06	28.9	0.20	985	490	6.21	<1.1
S3H	7.10	29.2	0.21	990	500	6.26	<1.1
C-1	7.06	29.2	0.29	890	480	6.21	<1.1
C-2	7.03	27.9	0.21	910	450	6.27	<1.1
ASAB	7.06	29.2	0.26	980	490	6.20	<1.1
NIT	7.05	28.2	0.20	980	505	6.22	<1.1
EXAM CELL	7.06	27.7	0.19	970	495	6.24	<1.1
CAT-IV	7.08	29.2	0.21	1025	520	6.23	<1.1
RCMS	7.06	29.3	0.25	985	480	6.24	<1.1
PMO OFC	7.07	28.4	0.15	1020	500	6.22	<1.1
CAT-V	7.04	28.9	0.23	1015	510	6.25	<1.1

Table 4.7: Values in month of February for RCC Tanks

Sites	pH	Temp (^{0}C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7.05	21.2	0.31	850	425	6.51	1.1
SNS (PVC)	7.1	21.2	0.30	870	435	6.6	1.1
SEECS	7.0	21.4	0.41	880	440	6.53	1.1
ZAINAB MESS	7.09	21.5	0.42	880	440	6.56	1.1
RUMI HOSTEL	7.08	21.0	0.44	870	435	6.6	<1.1
FATIMA MESS	7.07	21.1	0.46	876	437	6.59	1.1
IGIS	7.04	21.6	0.44	850	425	6.6	1.1
NBS	7.1	21.1	0.42	890	445	6.6	<1.1
IQRA APT.	7.04	21.4	0.36	850	425	6.55	1.1
NUST VILLAS	7.05	21.2	0.11	870	435	6.6	1.1
ATTAT HOSTEL	7.05	21.4	0.42	890	445	6.6	<1.1
MAIN OFC.	7.03	21.1	0.43	880	440	6.5	1.1
AYESHA MESS	7.05	21.1	0.45	887	445	6.6	1.1
GHAZALI	7.02	21.2	0.33	888	445	6.6	1.1
MI ROOM	7.0	21.3	0.45	890	440	6.52	1.1
BHITTAI MESS	7	21.3	0.36	870	435	6.6	1.1
BARRACK	7.01	21.4	0.2	898	450	6.6	1.1
CIE BUILD	7.05	21.4	0.21	898	450	6.53	1.1
PRINTING	7.03	21.1	0.24	879	440	6.6	<1.1
RIMMS	7.03	21.4	0.24	870	435	6.6	1.1
SCME	7.02	21.2	0.32	890	445	6.55	1.1
GYM	7.03	21.4	0.32	897	446	6.6	1.1
MOSQUE	7.04	21.4	0.32	895	443	6.57	1.1
CIPS	7.01	21.5	0.36	870	435	6.6	<1.1
CAT-III	7.03	21.6	0.21	869	430	6.53	1.1
HBL	7.03	21.7	0.25	874	435	6.6	1.1
H.Q BUILD	7.02	21.6	0.31	860	430	6.56	<1.1
S3H	7.04	21.5	0.4	890	445	6.6	1.1
C-1	7.05	21.5	0.43	870	437	6.5	1.1
C-2	7.06	21.4	0.35	899	445	6.6	1.1
ASAB	7.01	21.3	0.32	900	440	6.5	1.1
NIT	7.01	21.8	0.36	890	480	6.5	1.1
EXAM BRANCH	7.05	21.4	0.32	870	435	6.6	1.1
CAT-IV	7.04	21.8	0.4	880	440	6.51	1.1
RCMS	7.03	21.4	0.5	890	445	6.6	<1.1
PMO OFC	7.02	21.8	0.3	899	456	6.52	1.1
CAT-V	7.01	21.8	0.36	890	480	6.5	<1.1

Table 4.8: Values in month of March for PVC Tanks

Sites	pH	Temp (^0C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7.08	28.4	0.31	970	510	6.21	<1.1
SNS (PVC)	7.08	28.3	0.21	985	550	6.20	<1.1
SEECS	7.06	28.8	0.23	990	480	6.22	<1.1
ZAINAB MESS	7.08	28.9	0.21	989	495	6.24	<1.1
RUMI HOSTEL	7.08	27.6	0.19	1022	550	6.23	<1.1
FATIMA MESS	7.07	29.1	0.35	990	480	6.24	<1.1
IGIS	7.05	28.7	0.18	940	490	6.22	<1.1
NBS	7.09	28.6	0.24	989	490	6.25	<1.1
IQRA APT.	7.08	29.2	0.21	992	510	6.24	<1.1
NUST VILLAS	7.07	29.1	0.21	990	470	6.23	<1.1
ATTAR HOSTEL	7.08	28.6	0.30	990	490	6.24	<1.1
MAIN OFC	7.08	29.2	0.23	980	490	6.26	<1.1
AYESHA MESS	7.08	28.8	0.25	995	480	6.21	<1.1
GHAZALI	7.08	28.4	0.32	980	495	6.27	<1.1
MI ROOM	7.06	28.8	0.35	1005	500	6.20	<1.1
BHITTAI MESS	7.07	28.5	0.25	990	505	6.22	<1.1
BARRACK	7.06	28.6	0.23	995	495	6.25	<1.1
CIE BUILD	7.06	28.2	0.21	980	495	6.24	<1.1
PRINTING	7.06	28.6	0.24	1002	500	6.23	<1.1
RIMMS	7.06	28.8	0.19	920	470	6.24	<1.1
SCME	7.06	29.3	0.37	897	470	6.22	<1.1
GYM	7	28.8	0.28	995	480	6.25	<1.1
MOSQUE	6.99	27.6	0.28	1022	510	6.24	<1.1
CIPS	7.07	28.9	0.33	970	490	6.23	<1.1
CAT-III	7.08	29.2	0.21	1039	540	6.24	<1.1
HBL	7.06	28.1	0.20	1005	490	6.26	<1.1
H.Q BUILD	7.06	28.9	0.25	985	490	6.21	<1.1
S3H	7.10	29.2	0.23	990	500	6.26	<1.1
C-1	7.06	29.2	0.36	890	480	6.21	<1.1
C-2	7.03	27.9	0.23	910	450	6.27	<1.1
ASAB	7.06	29.2	0.39	980	490	6.20	<1.1
NIT	7.05	28.2	0.21	980	505	6.22	<1.1
EXAM BRANCH	7.06	27.7	0.21	970	495	6.24	<1.1
CAT-IV	7.08	29.2	0.22	1025	520	6.23	<1.1
RCMS	7.06	29.3	0.37	985	480	6.24	<1.1
PMO OFC	7.07	28.4	0.22	1020	500	6.22	<1.1
CAT-V	7.04	28.9	0.36	1015	510	6.25	<1.1

Table 4.9: Values in month of March for RCC Tanks

Sites	pH	Temp (^{0}C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7.05	28.7	0.23	980	515	6.26	<1.1
SNS(RCC)	7.06	29.5	0.29	967	540	6.21	1.1
SEECS (U/G)	7.07	28.5	0.34	980	480	6.22	1.1
ZAINAB MESS	7.06	29.1	0.29	994	498	6.26	1.1
RUMI HOSTEL	7.01	27.9	0.28	995	555	6.21	1.1
FATIMA MESS	7.06	29.2	0.30	957	490	6.27	1.1
IGIS	7.07	28.6	0.27	995	500	6.20	1.1
NBS	7.03	28.7	0.29	1002	485	6.23	1.1
IQRA APT.	7.05	29.2	0.21	1015	513	6.24	1.1
NUST VILLAS	7.06	29.2	0.19	980	480	6.22	<1.1
ATTAT HOSTEL	7	28.5	0.35	997	495	6.25	1.1
MAIN OFC.	6.99	29.3	0.19	993	485	6.24	1.1
AYESHA MESS	7.07	28.7	0.25	987	470	6.23	<1.1
GHAZALI	7.08	28.5	0.21	956	465	6.24	1.1
MI ROOM	7.05	28.9	0.22	991	505	6.26	<1.1
BHITTAI MESS	7.06	28.7	0.33	987	495	6.21	1.1
GATE 1	7.07	28.9	0.35	992	503	6.22	1.1
BARRACK	7.07	28.4	0.26	982	485	6.24	1.1
CIE BUILD	7.03	28.8	0.33	1006	505	6.22	<1.1
PRINTING	7.01	28.9	0.34	977	485	6.25	1.1
RIMMS	7.05	29.3	0.26	933	480	6.24	1.1
SCME	7.1	28.1	0.24	1005	490	6.24	1.1
GYM	6.99	27.4	0.22	1017	515	6.23	<1.1
MOSQUE	7	28.7	0.25	1001	495	6.24	<1.1
CIPS	7.07	29.6	0.18	1025	535	6.26	<1.1
CAT-III	7.07	28.4	0.36	985	495	6.21	1.1
HBL	7.02	28.3	0.27	993	505	6.27	1.1
H.Q BUILD	7.07	29.1	0.29	1007	510	6.20	<1.1
S3H	7.06	28.3	0.32	897	494	6.22	<1.1
C-1	7.04	28.8	0.22	979	467	6.25	<1.1
C-2	7.06	28.9	0.21	982	499	6.24	<1.1
ASAB	7.07	28.8	0.24	1021	512	6.24	1.1
NIT (U/G)	7.1	27.7	0.25	997	507	6.21	1.1
EXAM BRANCH	7.06	28.8	0.24	983	517	6.20	<1.1
CAT-IV	7.09	28.7	0.34	984	495	6.22	1.1
RCMS	7.06	29.1	0.22	985	505	6	<1.1
PMO OFC	7.07	29.2	0.23	1027	517	6.24	1.1
CAT-V	7.21	28.8	0.19	1031	514	6.23	<1.1

Table 4.10: Values in month of April for PVC Tanks

Sites	pH	Temp (^{0}C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7.01	29.7	0.21	778	497	6	< 1.1
SNS (PVC)	7	29.8	0.15	780	490	6.1	<1.1
SEECS	7.04	29.9	0.25	770	460	5.96	< 1.1
ZAINAB MESS	6.81	29.9	0.31	745	489	5.95	<1.1
RUMI HOSTEL	6.83	29.6	0.27	720	464	5.98	<1.1
FATIMA MESS	6.9	29.8	0.3	740	490	6	<1.1
IGIS	7.03	29.9	0.24	760	455	6	<1.1
NBS	7.01	29.8	0.27	740	492	5.97	<1.1
IQRA APT.	7.02	29.9	0.26	735	489	6.1	<1.1
NUST VILLAS	7.04	29.8	0.26	945	489	5.96	<1.1
ATTAR HOSTEL	7.02	29.7	0.19	759	443	5.9	<1.1
MAIN OFC.	7	29.9	0.25	745	495	5.95	<1.1
AYESHA MESS	7.01	29.6	0.24	746	494	5.95	<1.1
GHAZALI	6.89	29.8	0.23	758	473	5.98	<1.1
MI ROOM	7.04	29.5	0.19	969	497	6	<1.1
BHITTAI MESS	6.92	29.8	0.25	761	475	6	<1.1
BARRACK	7.02	29.8	0.22	776	490	6.1	<1.1
CIE BUILD	6.86	29.7	0.28	736	475	5.96	<1.1
PRINTING	7.01	29.9	0.23	775	485	5.9	<1.1
RIMMS	7.03	29.9	0.25	769	458	5.95	<1.1
SCME	7.07	29.6	0.29	760	478	5.94	<1.1
GYM	7	29.8	0.24	738	490	5.98	<1.1
MOSQUE	6.84	29.9	0.22	725	472	5.95	<1.1
CIPS	7.02	29.8	0.23	748	496	5.98	<1.1
CAT-III	7.05	29.9	0.21	970	502	5.99	<1.1
HBL	6.84	29.8	0.23	726	471	6	<1.1
H.Q BUILD	7.02	29.7	0.3	739	491	5.98	<1.1
S3H	7.01	29.9	0.29	743	492	6.0	<1.1
C-1	7.06	29.6	0.26	757	476	5.94	<1.1
C-2	7.04	29.8	0.29	768	458	5.97	<1.1
ASAB	7.07	29.9	0.27	758	461	5.9	<1.1
NIT	6.85	29.9	0.31	735	478	6	<1.1
EXAM BRANCH	6.86	29.8	0.29	736	478	6.0	<1.1
CAT-IV	7.05	29.6	0.21	968	498	5.95	<1.1
RCMS	7.03	29.5	0.27	766	455	5.91	<1.1
PMO OFC	7.01	29.8	0.24	777	496	5.94	<1.1
CAT-V	7.05	29.7	0.22	969	498	5.96	<1.1

Table 4.11: Values in month of April for RCC Tanks

Sites	pH	Temp (^0C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7	29.9	0.27	881	516	5.91	1.1
SNS(RCC)	6.96	30	0.26	883	517	5.91	<1.1
SEECS (U/G)	7.04	29.8	0.28	760	484	5.92	<1.1
ZAINAB MESS	6.81	29.9	0.25	854	503	6.0	<1.1
RUMI HOSTEL	7.09	29.7	0.22	741	472	5.9	1.1
FATIMA MESS	6.81	29.8	0.25	856	505	5.93	<1.1
IGIS	7.03	29.9	0.27	764	486	5.96	<1.1
NBS	6.82	30	0.24	855	506	5.94	<1.1
IQRA APT.	6.80	29.8	0.25	849	504	5.95	<1.1
NUST VILLAS	7.04	29.7	0.25	881	516	5.94	1.1
ATTAR HOSTEL	7.01	29.9	0.28	878	515	5.91	<1.1
MAIN OFC.	6.82	29.9	0.27	849	504	5.91	1.1
AYESHA MESS	6.80	29.6	0.26	854	503	5.92	1.1
GHAZALI MESS	7.01	29.8	0.27	875	513	5.9	1.1
MI ROOM	7.04	29.9	0.22	873	512	5.92	1.1
BHITTAI MESS	9	29.8	0.26	883	517	6.0	1.1
GATE 1	7.02	29.9	0.24	853	505	5.9	1.1
BARRACK	7	29.8	0.26	881	516	5.93	1.1
CIE BUILD	7.06	29.7	0.23	745	475	5.96	1.1
PRINTING	7.01	29.9	0.26	862	512	5.94	1.1
RIMMS	7.04	29.6	0.27	765	485	5.95	1.1
SCME	6.96	29.8	0.24	704	498	5.92	<1.1
GYM	6.82	29.9	0.24	857	504	6.0	<1.1
MOSQUE	7.07	29.9	0.24	748	473	5.9	1.1
CIPS	6.83	30.1	0.25	862	505	5.93	1.1
CAT-III	7.06	29.8	0.21	985	519	5.96	1.1
HBL	7.08	29.7	0.24	841	504	5.94	1.1
H.Q BUILD	6.81	29.9	0.25	861	503	5.95	1.1
S3H	6.82	29.9	0.24	847	504	5.94	<1.1
C-1	7.06	29.6	0.3	842	502	5.91	1.1
C-2	7.03	29.8	0.23	802	490	5.91	<1.1
ASAB	6.96	29.9	0.28	847	502	5.92	<1.1
NIT (U/G)	7.07	29.9	0.24	753	475	5.92	1.1
EXAM BRANCH	7.08	29.8	0.24	751	474	6.0	1.1
CAT-IV	7.05	29.7	0.20	864	517	5.9	1.1
RCMS	7.04	29.9	0.27	772	489	5.92	1.1
PMO OFC	7	29.6	0.25	880	515	6.0	1.1
CAT-V	7.05	29.8	0.25	885	518	5.9	1.1

Table 4.12: Values in month of May for PVC Tanks

Sites	pH	Temp (^0C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7.01	29.7	0.21	778	497	6	< 1.1
SNS (PVC)	7	29.8	0.15	780	490	6.1	<1.1
SEECS	7.04	29.9	0.25	770	460	5.96	< 1.1
ZAINAB MESS	6.81	29.9	0.31	745	489	5.95	<1.1
RUMI HOSTEL	6.83	29.6	0.27	720	464	5.98	<1.1
FATIMA MESS	6.9	29.8	0.3	740	490	6	<1.1
IGIS	7.03	29.9	0.24	760	455	6	<1.1
NBS	7.01	29.8	0.27	740	492	5.97	<1.1
IQRA APT.	7.02	29.9	0.26	735	489	6.1	<1.1
NUST VILLAS	7.04	29.8	0.26	945	489	5.96	<1.1
ATTAR HOSTEL	7.02	29.7	0.19	759	443	5.9	<1.1
MAIN OFC.	7	29.9	0.25	745	495	5.95	<1.1
AYESHA MESS	7.01	29.6	0.24	746	494	5.95	<1.1
GHAZALI MESS	6.89	29.8	0.23	758	473	5.98	<1.1
MI ROOM	7.04	29.5	0.19	969	497	6	<1.1
BHITTAI MESS	6.92	29.8	0.25	761	475	6	<1.1
BARRACK	7.02	29.8	0.22	776	490	6.1	<1.1
CIE BUILD	6.86	29.7	0.28	736	475	5.96	<1.1
PRINTING	7.01	29.9	0.23	775	485	5.9	<1.1
RIMMS	7.03	29.9	0.25	769	458	5.95	<1.1
SCME	7.07	29.6	0.29	760	478	5.94	<1.1
GYM	7	29.8	0.24	738	490	5.98	<1.1
MOSQUE	6.84	29.9	0.22	725	472	5.95	<1.1
CIPS	7.02	29.8	0.23	748	496	5.98	<1.1
CAT-III	7.05	29.9	0.21	970	502	5.99	<1.1
HBL	6.84	29.8	0.23	726	471	6	<1.1
H.Q BUILD	7.02	29.7	0.3	739	491	5.98	<1.1
S3H	7.01	29.9	0.29	743	492	6.0	<1.1
C-1	7.06	29.6	0.26	757	476	5.94	<1.1
C-2	7.04	29.8	0.29	768	458	5.97	<1.1
ASAB	7.07	29.9	0.27	758	461	5.9	<1.1
NIT	6.85	29.9	0.31	735	478	6	<1.1
EXAM BRANCH	6.86	29.8	0.29	736	478	6.0	<1.1
CAT-IV	7.05	29.6	0.21	968	498	5.95	<1.1
RCMS	7.03	29.5	0.27	766	455	5.91	<1.1
PMO OFC	7.01	29.8	0.24	777	496	5.94	<1.1
CAT-V	7.05	29.7	0.22	969	498	5.96	<1.1

Table 4.13: Values in month of May for RCC Tanks

Sites	pH	Temp (^0C)	Residual.Cl_2 (mg/L)	EC (µS/cm)	TDS (mg/L)	DO (mg/L)	MPN
SMME	7	29.9	0.27	881	516	5.91	1.1
SNS(RCC)	6.96	30	0.26	883	517	5.91	<1.1
SEECS (U/G)	7.04	29.8	0.28	760	484	5.92	<1.1
ZAINAB MESS	6.81	29.9	0.25	854	503	6.0	<1.1
RUMI HOSTEL	7.09	29.7	0.22	741	472	5.9	1.1
FATIMA MESS	6.81	29.8	0.25	856	505	5.93	<1.1
IGIS	7.03	29.9	0.27	764	486	5.96	1.1
NBS	6.82	30	0.24	855	506	5.94	1.1
IQRA APT.	6.80	29.8	0.25	849	504	5.95	1.1
NUST VILLAS	7.04	29.7	0.25	881	516	5.94	1.1
ATTAR HOSTEL	7.01	29.9	0.28	878	515	5.91	<1.1
MAIN OFC.	6.82	29.9	0.27	849	504	5.91	1.1
AYESHA MESS	6.80	29.6	0.26	854	503	5.92	1.1
GHAZALI MESS	7.01	29.8	0.27	875	513	5.9	1.1
MI ROOM	7.04	29.9	0.22	873	512	5.92	1.1
BHITTAI MESS	9	29.8	0.26	883	517	6.0	1.1
GATE 1	7.02	29.9	0.24	853	505	5.9	<1.1
BARRACK	7	29.8	0.26	881	516	5.93	1.1
CIE BUILD	7.06	29.7	0.23	745	475	5.96	1.1
PRINTING	7.01	29.9	0.26	862	512	5.94	<1.1
RIMMS	7.04	29.6	0.27	765	485	5.95	1.1
SCME	6.96	29.8	0.24	704	498	5.92	<1.1
GYM	6.82	29.9	0.24	857	504	6.0	1.1
MOSQUE	7.07	29.9	0.24	748	473	5.9	1.1
CIPS	6.83	30.1	0.25	862	505	5.93	1.1
CAT-III	7.06	29.8	0.21	985	519	5.96	1.1
HBL	7.08	29.7	0.24	841	504	5.94	1.1
H.Q BUILD	6.81	29.9	0.25	861	503	5.95	1.1
S3H	6.82	29.9	0.24	847	504	5.94	1.1
C-1	7.06	29.6	0.3	842	502	5.91	1.1
C-2	7.03	29.8	0.23	802	490	5.91	<1.1
ASAB	6.96	29.9	0.28	847	502	5.92	1.1
NIT (U/G)	7.07	29.9	0.24	753	475	5.92	<1.1
EXAM BRANCH	7.08	29.8	0.24	751	474	6.0	<1.1
CAT-IV	7.05	29.7	0.20	864	517	5.9	1.1
RCMS	7.04	29.9	0.27	772	489	5.92	1.1
PMO OFC	7	29.6	0.25	880	515	6.0	1.1
CAT-V	7.05	29.8	0.25	885	518	5.9	<1.1

Table 4.14: Values through calibrated Sensors in month of March for PVC Tanks

Sites	pH	Temp (^{0}C)	EC (μS/cm)
SMME	7.08	28.4	970
SNS (PVC)	7.08	28.3	985
SEECS	7.06	28.8	990
ZAINAB MESS	7.08	28.9	989
RUMI HOSTEL	7.08	27.6	1022
FATIMA MESS	7.07	29.1	990
IGIS	7.05	28.7	940
NBS	7.09	28.6	989
IQRA APT.	7.08	29.2	992
NUST VILLAS	7.07	29.1	990
ATTAR HOSTEL	7.08	28.6	990
MAIN OFC	7.08	29.2	980
AYESHA MESS	7.08	28.8	995
GHAZALI	7.08	28.4	980
MI ROOM	7.06	28.8	1005
BHITTAI MESS	7.07	28.5	990
BARRACK	7.06	28.6	995
CIE BUILD	7.06	28.2	980
PRINTING	7.06	28.6	1002
RIMMS	7.06	28.8	920
SCME	7.06	29.3	897
GYM	7	28.8	995
MOSQUE	6.99	27.6	1022
CIPS	7.07	28.9	970
CAT-III	7.08	29.2	1039
HBL	7.06	28.1	1005
H.Q BUILD	7.06	28.9	985
S3H	7.10	29.2	990
C-1	7.06	29.2	890
C-2	7.03	27.9	910
ASAB	7.06	29.2	980
NIT	7.05	28.2	980
EXAM BRANCH	7.06	27.7	970
CAT-IV	7.08	29.2	1025
RCMS	7.06	29.3	985
PMO OFC	7.07	28.4	1020
CAT-V	7.04	28.9	1015

Table 4.15: Values through calibrated Sensors in month of March for RCC Tanks

Sites	pH	Temp (^{0}C)	EC (µS/cm)
SMME	7.05	28.7	980
SNS(RCC)	7.06	29.5	967
SEECS (U/G)	7.07	28.5	980
ZAINAB MESS	7.06	29.1	994
RUMI HOSTEL	7.01	27.9	995
FATIMA MESS	7.06	29.2	957
IGIS	7.07	28.6	995
NBS	7.03	28.7	1002
IQRA APT.	7.05	29.2	1015
NUST VILLAS	7.06	29.2	980
ATTAR HOSTEL	7	28.5	997
MAIN OFC.	6.99	29.3	993
AYESHA MESS	7.07	28.7	987
GHAZALI	7.08	28.5	956
MI ROOM	7.05	28.9	991
BHITTAI MESS	7.06	28.7	987
GATE 1	7.07	28.9	992
BARRACK	7.07	28.4	982
CIE BUILD	7.03	28.8	1006
PRINTING	7.01	28.9	977
RIMMS	7.05	29.3	933
SCME	7.1	28.1	1005
GYM	6.99	27.4	1017
MOSQUE	7	28.7	1001
CIPS	7.07	29.6	1025
CAT-III	7.07	28.4	985
HBL	7.02	28.3	993
H.Q BUILD	7.07	29.1	1007
S3H	7.06	28.3	897
C-1	7.04	28.8	979
C-2	7.06	28.9	982
ASAB	7.07	28.8	1021
NIT (U/G)	7.1	27.7	997
EXAM BRANCH	7.06	28.8	983
CAT-IV	7.09	28.7	984
RCMS	7.06	29.1	985
PMO OFC	7.07	29.2	1027
CAT-V	7.21	28.8	1031

Table 4.16: Values through calibrated Sensors in month of April for PVC Tanks

Sites	pH	Temp (^{0}C)	EC (µS/cm)
SMME	7.01	29.7	778
SNS (PVC)	7	29.8	780
SEECS	7.04	29.9	770
ZAINAB MESS	6.81	29.9	745
RUMI HOSTEL	6.83	29.6	720
FATIMA MESS	6.9	29.8	740
IGIS	7.03	29.9	760
NBS	7.01	29.8	740
IQRA APT.	7.02	29.9	735
NUST VILLAS	7.04	29.8	945
ATTAR HOSTEL	7.02	29.7	759
MAIN OFC.	7	29.9	745
AYESHA MESS	7.01	29.6	746
GHAZALI	6.89	29.8	758
MI ROOM	7.04	29.5	969
BHITTAI MESS	6.92	29.8	761
BARRACK	7.02	29.8	776
CIE BUILD	6.86	29.7	736
PRINTING	7.01	29.9	775
RIMMS	7.03	29.9	769
SCME	7.07	29.6	760
GYM	7	29.8	738
MOSQUE	6.84	29.9	725
CIPS	7.02	29.8	748
CAT-III	7.05	29.9	970
HBL	6.84	29.8	726
H.Q BUILD	7.02	29.7	739
S3H	7.01	29.9	743
C-1	7.06	29.6	757
C-2	7.04	29.8	768
ASAB	7.07	29.9	758
NIT	6.85	29.9	735
EXAM BRANCH	6.86	29.8	736
CAT-IV	7.05	29.6	968
RCMS	7.03	29.5	766
PMO OFC	7.01	29.8	777
CAT-V	7.05	29.7	969

Table 4.17: Values through calibrated Sensors in month of April for RCC Tanks

Sites	pH	Temp (^{0}C)	EC (µS/cm)
SMME	7	29.9	881
SNS(RCC)	6.96	30	883
SEECS (U/G)	7.04	29.8	760
ZAINAB MESS	6.81	29.9	854
RUMI HOSTEL	7.09	29.7	741
FATIMA MESS	6.81	29.8	856
IGIS	7.03	29.9	764
NBS	6.82	30	855
IQRA APT.	6.80	29.8	849
NUST VILLAS	7.04	29.7	881
ATTAR HOSTEL	7.01	29.9	878
MAIN OFC.	6.82	29.9	849
AYESHA MESS	6.80	29.6	854
GHAZALI MESS	7.01	29.8	875
MI ROOM	7.04	29.9	873
BHITTAI MESS	9	29.8	883
GATE 1	7.02	29.9	853
BARRACK	7	29.8	881
CIE BUILD	7.06	29.7	745
PRINTING	7.01	29.9	862
RIMMS	7.04	29.6	765
SCME	6.96	29.8	704
GYM	6.82	29.9	857
MOSQUE	7.07	29.9	748
CIPS	6.83	30.1	862
CAT-III	7.06	29.8	985
HBL	7.08	29.7	841
H.Q BUILD	6.81	29.9	861
S3H	6.82	29.9	847
C-1	7.06	29.6	842
C-2	7.03	29.8	802
ASAB	6.96	29.9	847
NIT (U/G)	7.07	29.9	753
EXAM BRANCH	7.08	29.8	751
CAT-IV	7.05	29.7	864
RCMS	7.04	29.9	772
PMO OFC	7	29.6	880
CAT-V	7.05	29.8	885

Table 4.18: Values through calibrated Sensors in month of May for PVC Tanks

Sites	pH	Temp (^0C)	EC (µS/cm)
SMME	7.01	29.7	778
SNS (PVC)	7	29.8	780
SEECS	7.04	29.9	770
ZAINAB MESS	6.81	29.9	745
RUMI HOSTEL	6.83	29.6	720
FATIMA MESS	6.9	29.8	740
IGIS	7.03	29.9	760
NBS	7.01	29.8	740
IQRA APT.	7.02	29.9	735
NUST VILLAS	7.04	29.8	945
ATTAR HOSTEL	7.02	29.7	759
MAIN OFC.	7	29.9	745
AYESHA MESS	7.01	29.6	746
GHAZALI MESS	6.89	29.8	758
MI ROOM	7.04	29.5	969
BHITTAI MESS	6.92	29.8	761
BARRACK	7.02	29.8	776
CIE BUILD	6.86	29.7	736
PRINTING	7.01	29.9	775
RIMMS	7.03	29.9	769
SCME	7.07	29.6	760
GYM	7	29.8	738
MOSQUE	6.84	29.9	725
CIPS	7.02	29.8	748
CAT-III	7.05	29.9	970
HBL	6.84	29.8	726
H.Q BUILD	7.02	29.7	739
S3H	7.01	29.9	743
C-1	7.06	29.6	757
C-2	7.04	29.8	768
ASAB	7.07	29.9	758
NIT	6.85	29.9	735
EXAM BRANCH	6.86	29.8	736
CAT-IV	7.05	29.6	968
RCMS	7.03	29.5	766
PMO OFC	7.01	29.8	777
CAT-V	7.05	29.7	969

Table 4.19: Values through calibrated Sensors month of May for RCC Tanks

Sites	pH	Temp (^0C)	EC (μS/cm)
SMME	7	29.9	881
SNS(RCC)	6.96	30	883
SEECS (U/G)	7.04	29.8	760
ZAINAB MESS	6.81	29.9	854
RUMI HOSTEL	7.09	29.7	741
FATIMA MESS	6.81	29.8	856
IGIS	7.03	29.9	764
NBS	6.82	30	855
IQRA APT.	6.80	29.8	849
NUST VILLAS	7.04	29.7	881
ATTAR HOSTEL	7.01	29.9	878
MAIN OFC.	6.82	29.9	849
AYESHA MESS	6.80	29.6	854
GHAZALI MESS	7.01	29.8	875
MI ROOM	7.04	29.9	873
BHITTAI MESS	9	29.8	883
GATE 1	7.02	29.9	853
BARRACK	7	29.8	881
CIE BUILD	7.06	29.7	745
PRINTING	7.01	29.9	862
RIMMS	7.04	29.6	765
SCME	6.96	29.8	704
GYM	6.82	29.9	857
MOSQUE	7.07	29.9	748
CIPS	6.83	30.1	862
CAT-III	7.06	29.8	985
HBL	7.08	29.7	841
H.Q BUILD	6.81	29.9	861
S3H	6.82	29.9	847
C-1	7.06	29.6	842
C-2	7.03	29.8	802
ASAB	6.96	29.9	847
NIT (U/G)	7.07	29.9	753
EXAM BRANCH	7.08	29.8	751
CAT-IV	7.05	29.7	864
RCMS	7.04	29.9	772
PMO OFC	7	29.6	880
CAT-V	7.05	29.8	885

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Experimental and statistical analysis of drinking water treatment facilities at NUST shows that the physicochemical parameters like pH, temperature, conductivity, turbidity and TDS are within the permissible limits of the WHO and Pakistan National Drinking Water Quality Standards whereas the microbiological analysis revealed that microbial count in the samples is significantly high as compared to the samples collected from RCC tanks.

1. Physicochemical parameters in RCC tanks showed higher values as compared to PVC tanks. However, the values were within the range proposed by WHO and PSDWQ.
2. RCC tanks depicts higher number of microorganisms (MPN index/100ml) as compared to PVC tanks as the disinfection of biofilm on PVC Tanks is generally effective at 1 mg/l of free chlorine or monochloramine but disinfection of organisms on RCC Tanks remains ineffective even at free chlorine residuals as high as 5 mg/l for several weeks..
3. Storage capacity in RCC tanks was higher as compared to PVC tanks, depicting storage of water in RCC tanks for longer periods results in higher values in comparison to PVC tanks having lower storage capacity.

This study shows that the water from RCC Tanks is not fit for drinking due to high coliform count and also the monitoring of water quality is essential to ensure the availability of safe drinking water to the people.

It can also be concluded that factors contributing to deterioration of microbial quality may be affiliated to:

1. Quality of source water.

2. Treatment processes.
3. Distribution network characterization or disinfectant stability during water distribution.
4. Storage period.

Locations in distribution network out of mainstream of water are the most opportune sites for sediments to accumulate, tuberculations to expand, and microbial colonies to get established. Corroded pipe surfaces (RCC Tanks) are not only a habitat for bacterial proliferation, but also a source of substrate encapsulation of chlorine disinfectant residuals. Importance of this aspect is obvious from the study stating that in drinking water systems, coliform bacteria form colonies in corrosion tubercles on iron pipes; this has been reported by a number of investigators. This can also be the reason of high coliform count obtained from various samples

5.2 RECOMMENDATIONS

1. Water quality degradation can be prevented in both types of water storage tanks by scheduling regular inspections of storage reservoirs for slime development on structural surfaces in contact with the water, and for the accumulation of sediments that serve as 42 protective sites for microorganisms. These bacterial growths and sedimentary deposits should be removed to reduce ill locations where taste and odor problems and bacterial count originating..
2. There must be proper cleaning of both underground and overhead tanks.As well as rigorous check on installed tanks.
3. Corrosion control through the manipulation of physicochemical properties of water (i.e., pH and alkalinity) or application of phosphate and silicate-based corrosion inhibitors should be thought of as not only protecting the tank materials, but also as a necessary component of a microbial control plan.
4. The prevailed decentralized drinking water treatment system of NUST is hard to maintain and will incur high cost. So, considering current drinking water quality it is recommended that RO system should be installed which can replace conventional three

stage water treatment units, including UV disinfection. RO drinking water system installed in Environmental Microbiology Teaching Lab, IESE, was regularly monitored for physicochemical and microbial parameters. The water samples were analyzed as per standard methods. The average values of all the physical and chemical parameters are within the WHO limits. Microbial analysis also reveals that there is no presence of coliform and fecal coliform counts. The water is free of contamination and safe for drinking purpose.

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ANNEXURE-I

Under Ground Tank (SMME)

Under Ground Tank (NIT)

Over Head Tank (Gate 1)