Improving Harvested Rain Water Quality of NUST Lakes By Three Stage Portable Water Filter

By

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Master of Science
In
Environmental Science

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"Improving Harvested Rain Water Quality of NUST Lakes By Three Stage Portable Water Filter"

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Has been found satisfactory for the requirement of the Master of Science degree in Environmental Science.

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DEDICATED….!!!

"To My Mother
She Is Woman of
Strength
My Strength"

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All the praises are for only **ALLAH** Who knows the secrets of heart. **He** is the master of this universe. Single leaf can't move without **His** will; **His** will is essential in all the proceedings. It would not have been possible for me to reach my aim without his help. Countless salutations are upon the **"Holy Prophet Muhammad (Sallallah-o-Alaih-Wassalam)",** the city of knowledge who has guided his "Umma" to seek knowledge from cradle to grave.

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MEHWISH HAQ NAWAZ

CONTENTS

LIST OF ABBREVATIONS

mg/L	Milligram per Liter
µS/cm	Micro siemens Per centimeter
MGD	Million gallon per day
EPA	Environmental Protection Agency
EC	Electrical Conductivity
DO	Dissolved Oxygen
TDS	Total Dissolved Solids
TP	Total Phosphates
COD	Chemical Oxygen Demand
EMB	Eosin Methylene Blue
IESE	Institute of Environmental Sciences and Engineering
CFU	Colony Forming Unit
T Hard	Total Hardness
T Alk	Total Alkalinity
TN	Total Nitrates
NDSWQ	National Drinking Standard Water Quality
Temp	Temperature
APHA	American Public Health Association
EDTA	Ethylene diamine tetre acetic acid
<	Less than
>	Greater than

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ABSTRACT

Rainwater Harvesting Systems are considered best, especially in arid and semi-arid regions. They have the potential to supply low-cost decentralized water to urban and rural population. Untreated harvested rainwater consumption has association with significant aesthetic and public health risk. This health risk is linked with the contamination of harvested rainwater through addition of raw sewerage and surface runoff from the nearby area. NUST authorities have constructed lakes for collecting rain water, which gets polluted while passing through various terrains and drains before entering into lakes. In order to monitor the quality of three lakes, a study was designed to assess the pollution status of three lakes. Based on quality, water was treated using indigenously designed (Pakoswiss) water filter employing physico-chemical methods for improving its quality. Water quality was identified in terms of its biological, and physico-chemical parameters: odor, color, turbidity, pH, temperature, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), total hardness, total chlorides, total alkalinity, total phosphorus, total nitrates, total bacterial count and total coliform. Results showed that t bacterial count, t coliform, turbidity, hardness and color of water relatively high when compared with national standard for drinking water quality. This indicates presence of considerable evidence of water pollution load. The effectiveness of Pakoswiss treatment by physico-chemical methods (Coagulation, Filtration, and Chlorination) was extremely found to be significant. It was found that water quality improved and was under the permissible limits of National standards drinking water quality.

Chapter 1

INTRODUCTION

Water is considered important for life sustenance on this planet. Reliable and continuous access to safe drinking water is essential for health, livelihood, and development (Grey and Sadoff, 2007). In order to ensure water security, there must be access to safe and sufficient drinking water at an affordable cost to meet basic needs, which include sanitation and hygiene. The United Nations has estimated that 1.2 billion people do not drink safe water and at least 746 million people still do not have access to safe drinking water (World Bank, 2014).

The most common fresh water sources of supply for human consumption and irrigation are surface and ground water. Most of the fresh water is locked in glaciers, snow caps, and ice (Gleick and Palaniappan, 2010). The ecosystem is experiencing increasing pressure due to anthropogenic activities, such as urbanization, agriculture, industry, infrastructure development. Therefore, pressure being built to extract from ground water sources to meet this demand.

Climate change and population growth have also strongly impacted the ecosystem (Sukereman et al., 2013). Since the last century, the use of water has increased more than two times relative to population growth. By 2025, water withdrawal is predicted to increase by 50% in developing countries and 18% in developed countries.

As such, it is predicted that almost 800 million people might not have access to treated water and face absolute water scarcity (GWP, 2010). It is further predicted that seven billion people from 60 countries will face water crisis in the year 2050 (WWDR, 2003) and feeding a population of nine billion people in 2050 would require 50% more water than the amount currently used (World Bank, 2014).

In Pakistan, the availability of safe drinking water is increasingly becoming short. Both water sources surface and ground are being polluted in Pakistan, highly dominated by microorganisms (Azizullah *et al.*, 2011). About 44 % Pakistan's population is lacking the safe water resources reported by Pakistan Council of Research in Water Resources (PCRWR). The water availability situation in Pakistan is also dire. The ground water sources, including confined aquifers, are getting contaminated due to unregulated and inappropriate practices in bore drilling. The ground water is fast depleting due to negligence in the development of recharge sources, such as large or small dams and traditional village water body reservoirs. The surface and groundwater use has reached the upper limits in most parts of the country.

Different developmental activities of society have been disturbed due to the unavailability of needed water (Hashim *et al.*,2013). Thus, it is in need to search or develop sustainable water resource management so that our society grow for the betterment of mankind. According to national water quality monitoring program (NWQMP), all the selected water resources (364) from major 23 cities of Pakistan, had representation of bacteriological contamination (40-100%). So, for future guidelines for water quality were developed in 2008. According to this bacterium must not be detectable in any 100 ml sample, color ≤ 15 TCU, odor non objectionable, turbidity ‹ 5NTU, total hardness ‹ 500 mg/l, TDS ‹ 1000, pH 6.5 – 8.5, chloride ‹ 250 mg/l, nitrate ≤ 50.

1.1 RAIN WATER HARVESTING

Rainwater harvesting (RWH) is proposed to save the water without wasting it. Different harvesting structures (Percolation Ponds, Subsurface Dykes, Farm Ponds, Check Dams, Bunds etc) are used worldwide (Rao *et al.*, 2005). These are the best systems, which are helpful in the hour of need to address the water scarcity (Morales-Pinzon *et al.*,2015).

1.2 RAIN WATER HARVESTING AND PUBLIC HEALTH

In principle, the collection of rainwater is considered safe from contamination before it touches the ground as compared to the surface water in lakes and rivers, and groundwater from shallow wells. However, numerous current studies propose that rainwater can be contaminated, and consumption of untreated rain water can become a source of serious public health (Ahmed *et al.,* 2014).

And untreated rainwater is linked with many serious health problems like bacterial diarrheas, bacterial pneumonia, tissue helminths, and protozoal diarrheas (Lye, 2014). Therefore, number of research findings support that rainwater should be used after treatment (Gwenzi *et al.*, 2015).

1.3 WATER TREATMENT

Water treatments are being used for the recovery of water. Which make it fit in its chemical composition, taste and odor as well (Ray, 1993). Basically, water treatments are applied to kill the pathogens present in water. These treatments may have different stages e.g. coagulation, flocculation, sedimentation, filtration and disinfection (WHO ,2006). However, surface water is majorly polluted with particles (i.e., turbidity), pathogenic microorganisms, and natural organic matter (NOM), which can be treated by an efficient treatment technology (R.D. Letterman, 1999). Filters are used for suspended particles removal. Coagulation based treatment method are also very efficient and commonly used worldwide WHO (2006). A process which removes the risk from water is termed as disinfection. And for this purpose, chlorine in the most popular chemical agent (Silas *et al.*, 2013). Chlorination is done for the destruction of microorganisms. However, it also helps to remove some other chemicals WHO (2006). According to WHO chlorine, chloramines, ozone, and ClO_2 are mostly used as disinfectant (WHO, 2004).

1.4 PRESENT STUDY

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Being an important factor of life, water is needed all over the world for the best survival (Dassanayake *et al.*, 2015). Similar situation is present in National University of Sciences and Technology Islamabad where rain harvesting in lakes is in practice but need to address the public risks associated with the consumption of polluted lake water (NOM) by treatment processes prior to supply the water. In the present study water was collected from NUST lakes, and pollution load was assessed on the basis of physico - chemical and micro biological parameters. Three stage portable water filter was used to improve the lake water by coagulation, filtration and disinfection. Since 20th century the most popular water treatment systems adopted worldwide is a combination of coagulation, sedimentation and filtration and disinfection.

1.5 RESEARCH OBJECTIVES

- To assess physico - chemical and biological pollution load of NUST lakes.
- To assess the effectiveness of coagulation, filtration and chlorination to improve its water quality.
- To compare the water quality improvements before and after rainy season.

Chapter 2

Literature Review

2.1. RAIN WATER HARVESTING

2.1.1. Historical Development

Rain water harvesting is the best option used all over the world since 4500 B. C. developing countries adopt this practice simply due to its easy distribution and low cost (Verma and Tiwari, 1995). RWH is a common and old practice in which rain water is collected and stored in order to be used for domestic and small scale agricultural uses. Nevertheless, RWH is in practice in modern − urban environments as part of the solution to the growing challenges associated to the supply of good quality water to the world population which is getting concentrated in cities (Buhaug & Urdal, 2013).

2.1.2. Characteristics

Technically capturing of water before its overflow to the ground is termed as water harvesting. In the dry periods water, can be used for irrigation and drinking purposes as well from rain water harvesting structure, which are the source of increase in ground water recharge and water table (Oweis *et al.*,2001).

RWH systems comprise of three common features (Boers and Benasher, 1982):

i. RWH are locally adopted systems.
ii. RWH is specific, like in arid and semi-arid regions.
iii. RWH is a relatively small-setup, which generally starts from home.

2.1.3. Contamination of Harvested Rain Water

In principle, the collection of rainwater before it hits the ground is safer than surface water in lakes and rivers, and groundwater from shallow wells. However, several recent studies suggest that rainwater can be contaminated, thereby posing public health risk if consumed without treatment. For example, consumption of untreated rainwater has been linked to bacterial diarrheas, bacterial pneumonia, botulism, tissue helminths, and protozoal diarrheas (Lye, 2014).

2.1.4. Advantages and Uses of Rain Water Harvesting

RWH is a source of water without any cost, best option when no other source in available, helps in limited water resources, good option when ground water is unsafe, affordable if tap charges are high, it reduces flood conditions by storing water, which ultimately control the spread of non-point source pollution, it provides soft water (safe Water), it can be used for irrigation practices, it can be safe drinking source for human beings after proper treatment, this is a sources which reduces the pressure from other water sources, it is also used in industries for Cooling agent (Ali and Khan, 2010).

2.2. WATER AND GLOBAL DISEASE BURDEN

Surprisingly world is facing 80 percent health problems due to unsafe water (Beikler *et al.*, 2011). WHO reports 0.842 million deaths due to unsafe water and inadequate sanitation and hygiene, out of which 58 percent due to diarrhea. About 0.361 million of these deaths occur in children aged under 5 years (WHO, 2014). However, it’s a big challenge in health, because a large number of 663 million people have not safe water sources, and about 159 million of these are compelled to use untreated water which ultimately linked with health risks (Onda, LoBuglio & Bartram, 2012).

2.2.1. Situation in Pakistan

Estimates regarding diseases due to water are worse. Approximately more than three million Pakistanis are being caught by the water related diseases WASP (2004). Yearly 0.23 million children's deaths occur due to water related diseases in Pakistan (The Nation, 2008). There is a large number of patients suffering from water borne diseases, UNICEF reports that great number of water borne disease patients fill the hospital and approximately 20- 40 percent hospital beds a are just for these patients. Estimates spoke about a big number is found in the hospitals of Pakistan, yearly one hundred million cases of diarrheal diseases on record (Pakistan Economy Survey, 2010-2011).

2.3. DRINKING WATER QUALITY

WHO defines consumption of safe drinking water having standards of Table 2.1 is essential for the healthy life, it does not have any health risks for the life time.

Table 2.1:Water quality parameters associated with their units and WHO and Pak-EPA Standards. Sources: (WHO, 2008; Pak-EPA, 2008)

Parameters	**WHO Guidelines**	**Pak Guidelines**
E. Coli/ Coliform bacteria	Not detectable in 100 ml water sample	Not detectable in 100 ml water sample
Color TCU	15	5
Odor	Unobjectionable	Unobjectionable
Turbidity NTU	5	5
T- Hardness mgL^{-1}	< 500	-
pH	6.5-8.5	6.5-8.5
DO mgL^{-1}	-	-
TDS mgL^{-1}	< 1000	< 1000

T- Chloride mgL^{-1}	< 250	< 250
T- Nitrate mgL^{-1}	50	50
T- Phosphorus mgL^{-1}	-	-
T- Alkalinity mgL^{-1}	1000	1000
EC μs/cm	-	-
Temperature °C	25 °C	-

2.4. HARVESTED RAIN WATER TREATMENT

HRW is the best source for the provision of water but public health risk associated with its consumption is the most significant issue (Ahmed *et al*. 2012a). As Ahmed *et al*.(2008) reports presence of potential bacterial pathogens in harvested rain water. Therefore, treatment of water is highly dependent on the technology used and type of raw water (Hussain *et al.*, 2013).

2.4.1. Water Treatment Systems

It was 2000 BC when water was boiled as treatment. Then first fabric filter was made by Greek Scientist Hippocrates around 500 BC. In 1627Sir Robert Bacon used sand filtration for filtering sea water. In 1700 wool, sponge and charcoal was used for the purification of domestic water. In 1854 British scientist John Snow discovered that pathogens can be treated with chlorine. In 1900 water guidelines were established by most of the governments. And currently in 2000, water can be treated by a number of methods depending upon the conditions.

2.4.2. Types and kinds of water treatment: Pre-treatment

In order to provide safe water for domestic purpose, several types of water filtration are being used worldwide (Table 2.2).

Table 2.2: Different Water Treatment Methods

Physical	Filtration, sedimentation, distillation, pasteurization and electro-magnetic variation
Chemical	Flocculation, coagulation, chlorination, ozone, chlorine dioxide, hydrogen peroxide
Biological	Slow sand filter, activated sludge

2.4.3. Roughing filtration

Turbidity can be removed by roughing filters before the treatment (Wegelin, 1996). Where natural purification system is involved without any chemical. Quartz sands, gravel, insoluble and resistant materials are usually used as media (Graham, 1988).

2.4.3.1. Mechanism of roughing filters

Roughing filtration/Coarse gravel filtration has been the main focus over the last two decades; due to its effectiveness, simplicity, reliability, and adaptability. Filters have been reported as potential treatment option for physical, biological and chemical improvement of drinking water quality, wastewater and leachate worldwide. Augustine (2013) found vertical roughing filters as an effective treatment option for leachate. Nikwonta *et al.* (2010) reported roughing filters as good treatment options for suspended solids. Performance of roughing filters of some researchers is given in table 2.3.

Table 2.3: Performance of roughing filters

Reference	**Parameters**	**Mean % removed**
Pacini (2005)	Iron & Manganese	85 and 95
Dome (2000)	Algae & Turbidity	95 and 90
Mahvi (2004)	Turbidity	90
Ochieng and Otieno (2004)	Turbidity & Algae	90 and 95
Dastanaie (2007)	Turbidity, TSS and Coli forms	63.4, 89 and 94
Jayalath (1994)	Color and turbidity	50 and 60
Nkwonta, O. (2010)	TSS and Turbidity	95 and 95
Mukhopadhay (2008)	Turbidity	75
Rabindra (2009)	Turbidity, Coliforms	90, 90
Nzabuherahea (2012)	TDS, TSS, COD and BOD^5	72.07, 80.01, 81.22 and 78.37,

2.4.3.2. Experience of roughing filter/gravel filters in developing countries:

Roughing filters have been proved efficient in developing countries (Table,2.4).

Table 2.4: Removing Efficiencies of Filters in Developing Countries

Husnain and Khan ,2014	**Pakistan**	Khokhar Zar Dam water was tested by three-stage up-flow roughing filter (UFRF). Results showed considerable reduction in turbidity level during dry period and rainfall seasons.
Dastanaie 2007	**Iran**	Application of vertical flow gravel filter on Zayandehroud River water The overall function of the filter by removing 63, 20, 15, 64, 89, 94 percent turbidity, color, iron, manganese, TSS and coliform removal respectively.
APSU, 2006	**Bangladesh**	Performance of two stage pre-filtration units (sand) was found very effective, 83% turbidity and 34% color removal was achieved.
Tamar and	**Northern Ghana**	Gravel filters removed 76 and 84% of the influent turbidity according to the settling test and pilot HRF data respectively.

Losleben 2004		
Patil *et al.* 2012	**India**	Tested roughing filters for improvement of drinking water and wastewater. Based on the treatability performance of roughing filters these were recommended as suitable option for dinking and wastewater treatment in India.
Jayalath 2004	**Sri Lanka**	Considerable reduction in Synedra population (80 – 87% in terms of cell count) as well as color and turbidity (50 – 60%) was achieved by application of HRF.

2.4.4. Coagulation and Flocculation Processes in Water Treatment

Coagulation–flocculation crucial steps of water treatment, as play important role in water purification. In which alum or polyaluminum chloride (PACl) are introduced in a raw water as a coagulant, which helps in the formation of flocs, can be removed after settling (Trinh & Kang, 2011).

2.4.4.1. Commonly used Coagulants in Water Treatment

There are number of chemicals having characteristics to be used as coagulant. These are: Aluminum sulfate (common name alum), Ferric chloride, Polyaluminum chloride (PACl), Lime and Polyelectrolytes (consist of synthetic or natural polymers).

2.4.4.2. Aluminium Sulphate (Alum) $Al_2(SO_4)_3$

Most popular coagulant for water purification is Aluminium Sulphate which is commonly termed as alum. It is in use since 1800s (AWWA, 1999). Here hydrolysis process is involved for the breakdown of particles. Colloidal particles have negative charges which can be neutralized by the Al^{3+} efficiently (Jarvis *et al.,* 2012).

2.4.4.3. Ferric Chloride $FeCl_3$

Another popular coagulant is Ferric chloride. Since 1880s it is being used in filtration plants, because it has the ability to remove water turbidity efficiently. Again, hydrolysis is involved as in the case of alum (Zhao *et al.,* 2012). In comparison of coagulants, there is formation of color when ferric coagulant in use and alumic coagulants give efficient results by removing natural organic matter (Yao *et al.,* 2015).

2.4.4.4. Disinfection

A process to reduce water pathogens up to the safe health standards is called disinfection. This controls the transmission of disease. So, for the control or destruction of pathogens highly reactive chemicals are involved like chlorine. There are number of methods for the disinfection but chlorination is used worldwide. Because of having the ability to combine with the dissolved chemicals, pathogens, plant materials, taste, odors and colors. It is also reported that chlorine handling is not so difficult, it can be monitored and controlled as a drinking water disinfection easily (WHO ,2006).

2.5. MULTISTAGE FILTRATION

A number of studies on multi-stage filtration process (combination of treatment steps staring from gravel pre-filters, slow sand filters and ending with terminal disinfection) proved the effectiveness of the multiple barrier concepts for pathogen removal and production of water fit for human consumption. In MSF system Figure 2.1. processed water is safe, having low risk after complete treatment (Galvis *et al.,* 1992).

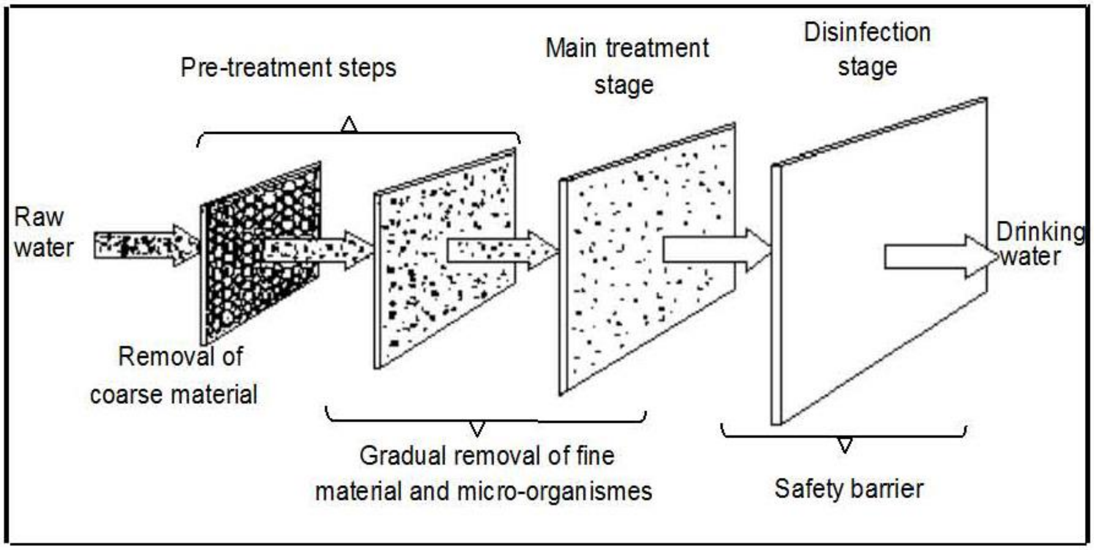

Figure 2.1: Multi stage concept (Galvis et al., 1998)

The removal efficiency of contaminants is not the same at all stages, therefore to overcome the limitation of each stage for different types of contaminants integrated treatment should be applied for effective treatment (Lloyd *et al.,* 1991). In MSF process, heaviest and larger materials are removed in initial stages and in latter stages smaller particles (colloidal/microbes), are removed. The last stage in MSF is known as disinfection (Terminal Disinfection). In order to get effective terminal disinfection adequate treatment at different stages in MSF is necessary to get safe water.

Asami *et al.* (2016) treated water in Bangkok by using different setups of coagulation-sedimentation (CS) and rapid sand filtration (RSF). Significant results were found when compared the concentration before and after treatment in wet and dry season. Removal efficiency by CS and RSF was totally dependent on raw water quality.

	Wet Season		Dry Season	
	CS	RSF	CS	RSF
Totalcoliform	26%	53%	35%	43%
Turbidity	94%	95%	97%	97%
pH	10%	8%	8%	6%
Temperature	3%	3.6%	4%	2%
EC	3.6%	1.5%	0%	6%

Vuppaladadiyam *et al.* (2013) conducted a comparative study to treat the water from Palar River Basin by coagulation process. This optimization was done by using moringaoleifera seed, alum and ferric chloride as coagulants. Alum and ferric chloride gave significant results with dose of 45mg/L and 25mg/L respectively. Chemical disinfection with chlorine is a very popular means of disinfection. Oluka *et al.* (2013) managed coliform contamination by chlorination in urban water supply system in by-products. So, negative correlation was found between coliforms and chlorine by products. Levy *et al.* (2015) reported after a study that chlorination is the best option for the disinfection of water with in certain conditions.

Mineral pot filter was used for the treatment of water in coastal areas of Bangladesh by Karim *et al.* (2016). The MPFs reduced Total Coliform (TC), Fecal Coliform (FC) and *E. Coli* concentrations significantly ($p < 0.05$) in all monitoring cycles. The average reductions of *E. Coli* were 83.65%, 84.34%, 97.18% and 77.85% in four monitoring cycles and TC and FC showed significant variation ($p < 0.05$) in filtered water in all monitoring cycles. The turbidity of all filtered water samples was well below 5 NTU. The average removal of turbidity by the filters was found to be 78, 78, 73 and 53 percent, respectively in four cycles. The MPFs reduced turbidity significantly ($p < 0.05$) in all monitoring cycles and the mean turbidity of the filtered water was less than 1.0 NTU.

Chapter 3

MATERIALS AND METHODS

3.1. GENERAL

Series of experiments were conducted during this study (Fig 3.4). These included treatments of water by three stage portable water filter, with different coagulants (Alum and Ferric Chloride). The coagulated/flocculated and settled water was tested for physico chemical and microbiological water parameters. Methodology designed to achieve research objectives was based upon following phases (Fig, 3.1).

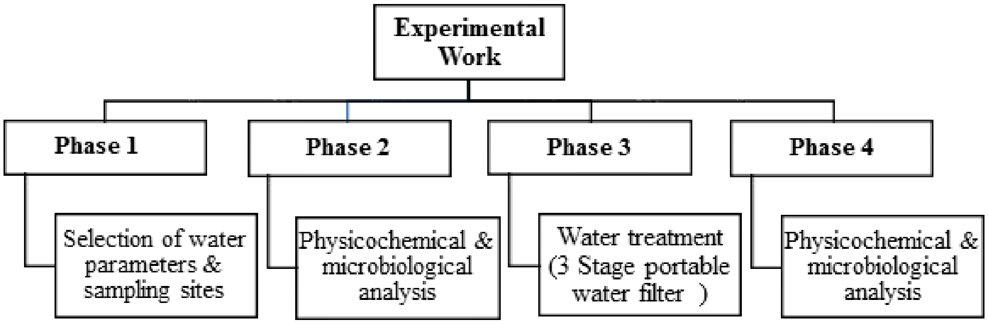

Figure 3.1: Methodology phases

3.2. SELECTION OF WATER PARAMETERS AND SAMPLING SITES

Physic -o- chemical and microbiological parameters (odour, colour, turbidity, EC, TDS, pH, temperature, Dissolved Oxygen, T. Hardness, T. Chlorides, T. Alkalinity, T. Phosphorus, T. Nitrates, bacterial count and T. Coliform) were selected in order to assess the pollution of NUST lakes. Preliminary surveys were made to get clear picture of NUST lakes and to select the sampling sites as well.

Table 3.1: Weather during sampling in terms of rainfall, temperature and humidity

	Oct-15			**Nov-15**			**Dec-15**			**Jan-16**			**Feb-16**			**Mar-16**			**Apr-16**			**May-16**			**Jun-16**			**Jul-16**		
	Rain fall	Temp.	Humidity	Rain fall	Temp.	Humidity	Rain fall	Temp.	Humidity	Rain fall	Temp.	Humidity	Rain fall	Temp.	Humidity	Rain fall	Temp.	Humidity	Rain fall	Temp.	Humidity	Rain fall	Temp.	Humidity	Rain fall	Temp.	Humidity	Rain fall	Temp.	Humidity
1st week	0	27	56	2.4	18	74	0	16	55	0	13	67	0	13	62	0.8	19	55	0.05	22	62	0.01	29	40	0.7	33	44	8.3	31	70
2nd week	1.4	26	61	0.24	17	65	3.7	13	63	51	12	74	9.5	12	67	19	17	75	0.7	23	54	0.6	30	46	0.8	33	48	3.5	30	67
3rd week	2	23	65	0	18	56	0	12	57	0	10	82	2.8	15	55	8.5	17	71	0.8	25	52	0	32	34	4.4	32	56	13	29	71
4th week	18	24	66	0	16	57	0	11	56	0.6	11	77	0	19	56	0.2	21	58	0.05	24	39	2.3	31	47	0.5	33	57	16	29	74
Mean	5.8	25	62	0.64	17	62	0.89	13	58	12.9	11	75	3.1	15	60	6.9	19	64	0.4	24	51	0.8	30	42	1.6	33	51	10	30	71
Sampling	0.1	19.5	43	0	17.5	54	0	11.5	59	0	12	76	0	16	55	0	17	73	2	25.5	51	0.1	27.5	50	0	33.5	63	23,0.1	27,29	80,67

Rain fall in mm, Temperature in °C and Humidity in %.

3.2.1. Description of Study Area

Lakes of New campus of National University of Sciences and Technology, Pakistan were taken as the study site (Fig, 3.2). It was established in 1991 while its new campus was recognized in 2008 in H-12 sector, Islamabad. These lakes 1, 2 and 3 were constructed in 2011, they have area 1.5, 2 and 2.25 acre with height 25,16 – 20 and 25 feet respectively. And they have storage volume 0.17, 0.16 and 0.74 GL respectively. Islamabad is categorized into five seasons with humid subtropical climate: Winter period is (November–February), Spring is from (March and April), Summer starts (May and June), Rainy Monsoon period (July and August) and autumn in the end (September and October). In June average temperature, may exceeds 38 °C (100.4 °F), so it is the hottest month. July receives heavy rains and known as wettest month. And in winter by having low temperature January is coolest month (Climate Records: Islamabad). Diverse nature soil makes up the parent material of potohar plateau in the form of loess, alluvium, colluviums and mixed by nature (Khan *et al.*, 2001). Soil is classified into silt loam, silt clay loam, and clay loam where rain is received (Kazmi and Rasool 2009).

3.3. SAMPLING

3.3.1. Sample Collection, Transportation and Storage

Composite water samples were collected from lake 1, 2 and 3 before and after rain (Fig,3.3) in autoclaved glass bottles for physico chemical and microbiological analysis and plastic gallons were used to collect the water for treatment from lake1, 2 and 3 respectively. These gallons were rinsed two or three times with lake water before sample collection. Samples were transported to IESE for analysis and treatment without any dely. All the sampling and preservation methods carried out for the quality analysis

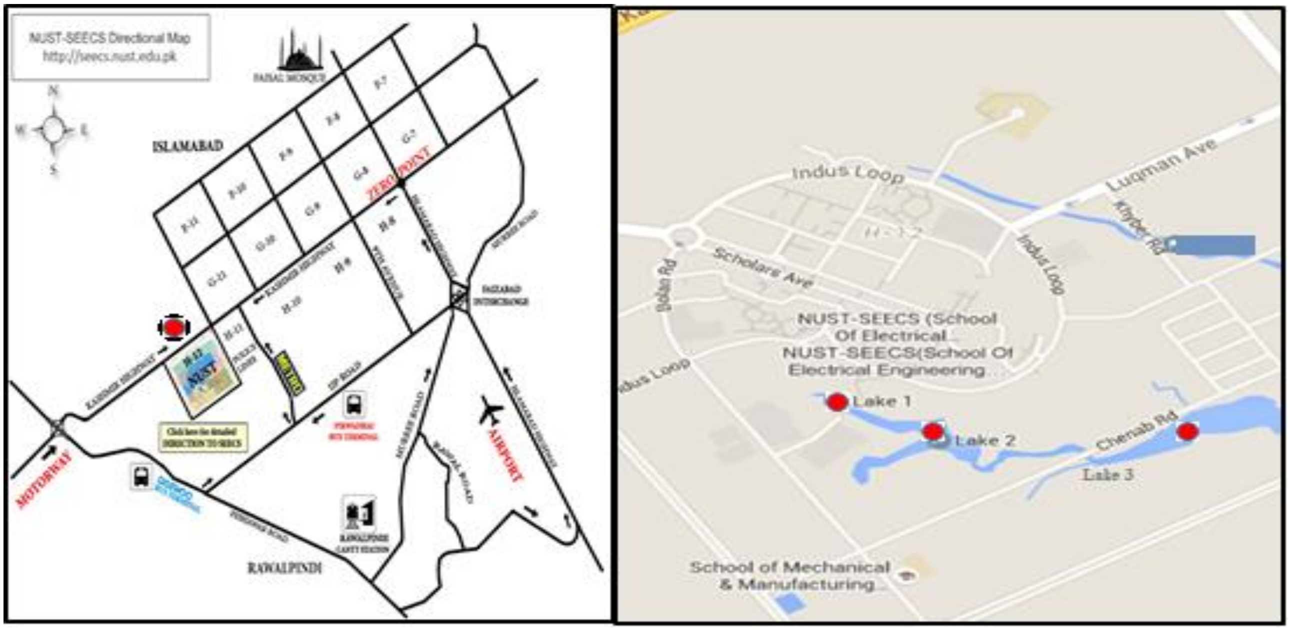

Figure 3.2: Red circles represent location of NUST and lakes

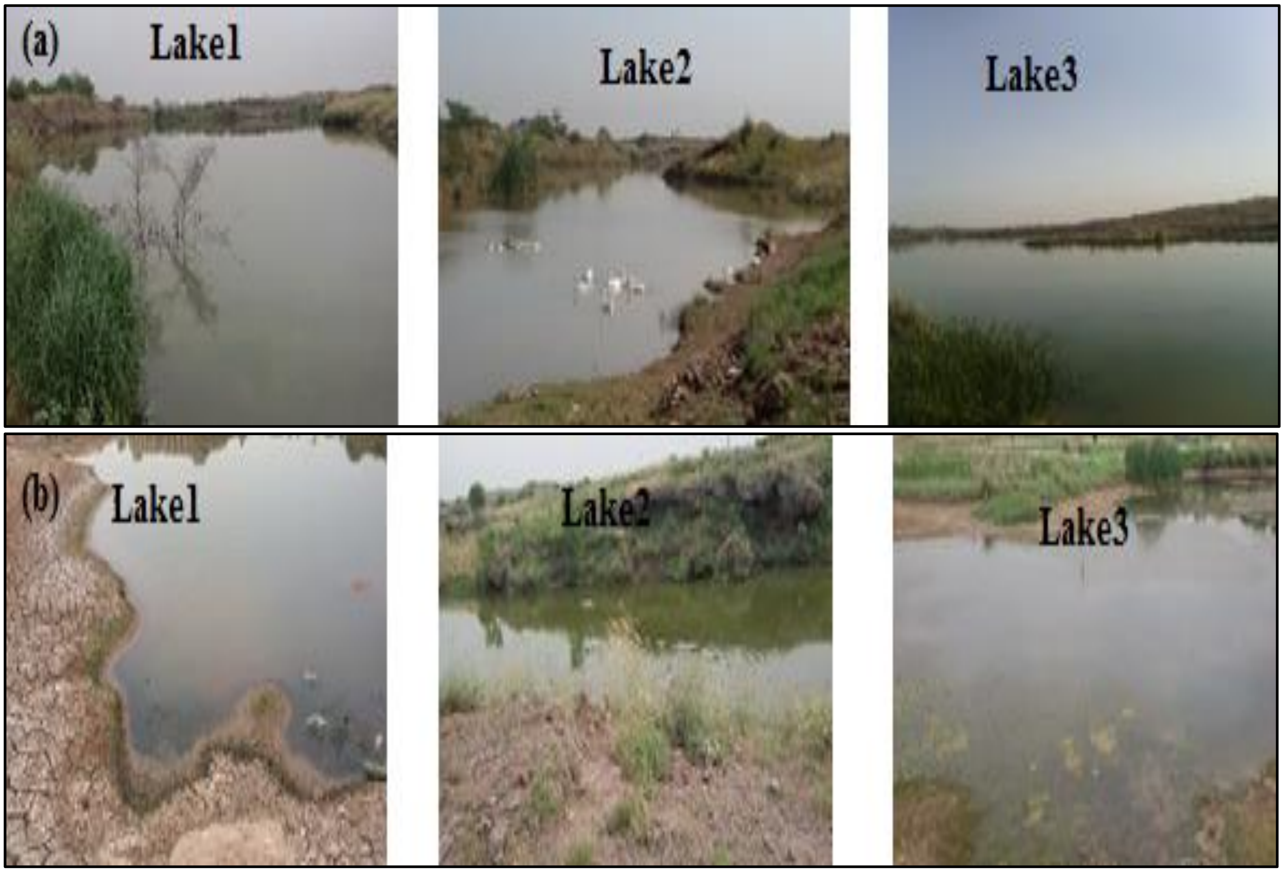

Figure 3.3: (a) Lakes in wet, (b) Lakes in dry season

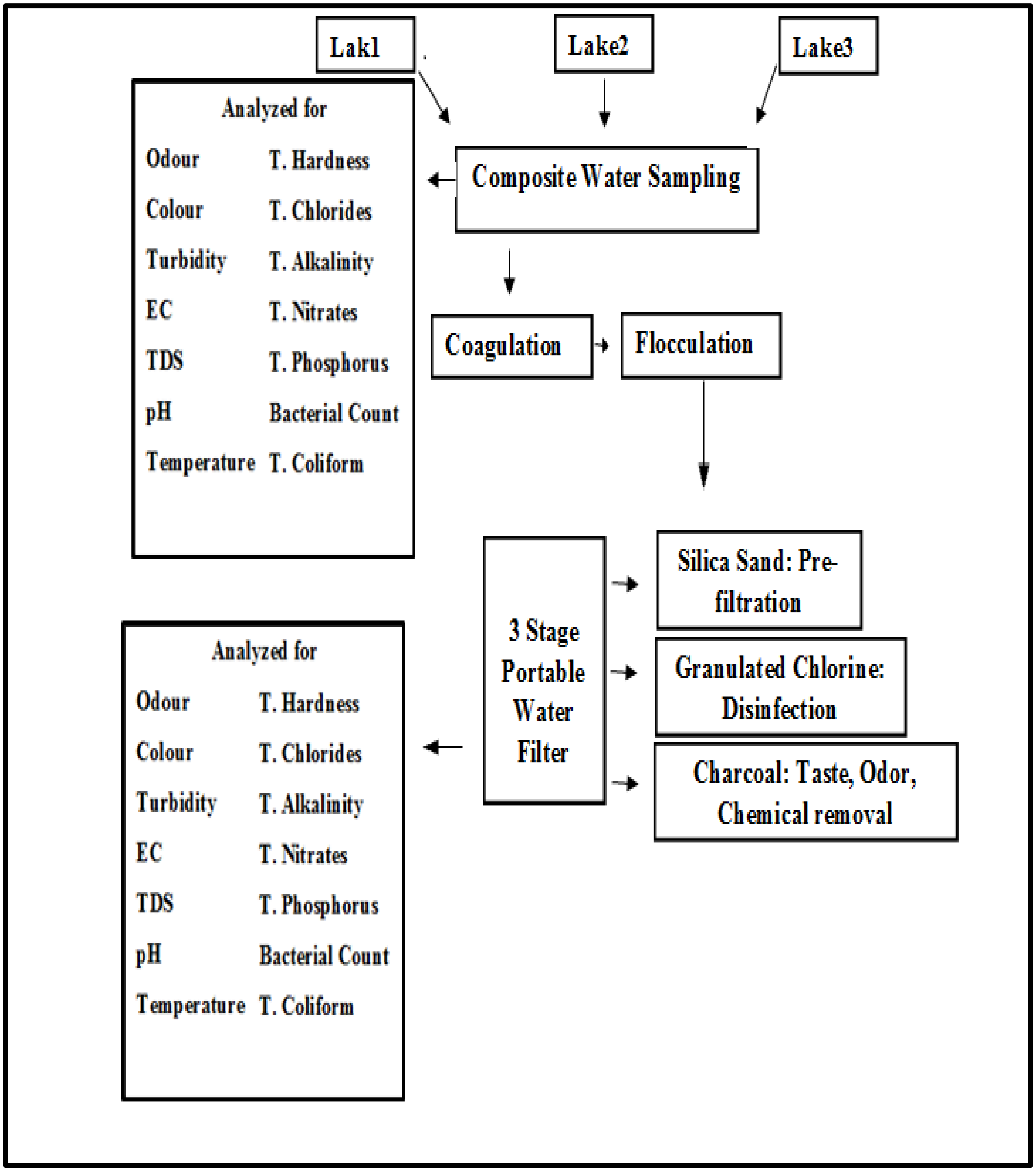

Figure 3.4: Flow Diagram of Study

in water samples were according to Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Sampling was done on monthly basis (before and after rain) and results were observed. Triplicate water samples were taken and monitored for result validation. Weather conditions during sampling are given in table 3.1

3.4. WATER QUALITY ANALYSIS

3.4.1 Physicochemical Analysis

3.4.1.1 On Site Analysis

3.4.1.1.1. Odor

Water was smelled to find if it is acceptable or not.

3.4.1.1.2. Temperature

Temperature was measured on site by using mercury filled Celsius thermometer.

3.4.1.2. Laboratory Analysis

3.4.1.2.1. pH

The pH of all water samples in this study was measured using pH meter (Hach). The meter was calibrated using suitable buffer whose pH was known. The pH of water in the sample bottles was measured by dipping the pH glass electrode. Equilibrium between electrode and sample was established by stirring the sample to ensure homogeneity. Using the same temperature was also recorded in degree centigrade. The pH meter used in this study is shown in (Fig, 3.6).

3.4.1.2.2. Dissolved Oxygen

Dissolved oxygen of water samples was measured by using DO meter (Hach). The meter was calibrated before taking the readings. Then by immersing the DO glass electrode into sample bottles, readings were taken in mg/L (Fig, 3.6).

3.4.1.2.3. Color

Color of the water samples was measured with Spectrophotometer DR 2010, in co. pt. units. It worked by using spectrophotometric single – wavelength method at wavelength between 450 and 465 nm. A blank sample of distilled water was prepared to zeroize the equipment prior putting the actual sample in the spectrophotometer. The water sample to measure the color was placed in the equipment and color was recorded as co. pt. units. The spectrophotometer used in this study is shown in the Fig (Fig, 3.6).

3.4.1.2.4. Turbidity

In this study the turbidity measurements were performed using Nephelometric method. Hach 2100 N model turbidimeter was used throughout the work. This method is based on a comparison of the intensity of light scattered under the defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The turbidimeter used in this study is shown in (Fig, 3.6).

3.4.1.2.5. Electrical Conductivity (EC)

Electrical conductivity of water samples was measured by EC meter (Hach) (Fig,3.6).

3.4.1.2.6. Total Dissolved Solids (TDS)

Total dissolved solids of the water samples were measured by gravimetric method (Fig,3.6). China dish was pre-weighed and 50 ml water sample was filtered and poured in a china dish. Water sample was evaporated in water bath then china dish was dried in oven at 180 °C. After drying china dish was weighed.

So mg TDS/L (A-B) ×1000 / sample volume

Where A = weight of dried residue + dish mg, B = weight of dish mg

Given formula was used to calculate total dissolved solids from water samples.

3.4.1.2.7. Total Hardness

Hardness was measured as magnesium ions consumed in complex formation by using EDTA-titrimetric method. Eriochrome Black T was used as indicator in 50 ml of buffered sample. Blue color showed end point of the reaction. 50ml water sample with 1ml buffer solution was taken in a beaker and few drops of EBT were added, then it was titrated against the EDTA titrant. End point was purple to blue color.

Calculations

T – Hardness mg/L $A \times B \times 1000 / \text{sample volume ml}$

A = titrant, B = 1

Given formula was used to measure hardness from water samples.

3.4.1.2.8. Total Chlorides

Chlorides were analyzed by argentometric method in which samples were titrated against 0.05 N $AgNO_3$. 100ml water sample was taken in a flask and 1ml indicator was added and titrated against 0.05 N $AgNO_3$ titrant. Pinkish yellow color was end point.

Calculations $(A - B) \times N \times 35450 / \text{ml sample}$

A = ml titrant used for sample,

B = ml titrant used for blank,

N = normality of $AgNO_3$

3.4.1.2.9. Total Alkalinity

Alkalinity was measured by titration; water samples were titrated against 0.02 N H_2SO_4. 50ml of water sample was taken in titration flask and 1 drop of phenolphthalein indicator was added. It was titrated against 0.02 N H_2SO_4 by swirling the flask until the solution changes from pink to colorless. Volume of acid used was noted. Then 2 drops of methyl orange indicator were added in the same titration flask and continued the titration until end point reached (yellow to pink).

Calculations (Total Alkalinity mg/L total volume of acid ×N of acid×50,000 / volume of sample)

3.4.1.2.10. Total Nitrates

Absorbance of each standard and the actual sample at 220nm and 275nm against the blank was measured on a spectrophotometer. Standard curve was constructed by plotting absorbance due to NO^-_3 against NO^-_3 N concentration of the standard. Using correct sample absorbance (A_{220} - $2 \times A_{275}$), sample concentration was directly obtained from standard curve.

3.4.1.2.11. Total Phosphorus

Absorbance of each actual water sample and standard was measured at 470nm on spectrophotometer.

3.4.2. MICROBIOLOGICAL ANALYSIS

3.4.2.1. Spread Plate Count

3.4.2.1.1. Preparation of Agar Plates

For the enumeration of heterotrophic plate counts (HPC), 20 g nutrient agar was mixed in 1 L distilled water and autoclaved at 121°C and 15 psi for 15 minutes. Molten agar was then poured in autoclaved petri plates and incubated at 37°C for 48 hours to check sterility.

3.4.2.1.2. Dilution Preparation

For preparation of dilution, test tubes were filled with 9 ml of distilled water. These were then autoclaved and preserved at 4ºC for further use.

3.4.2.1.3. HPC Count

Heterotrophic plate counts from water samples were analyzed using spread plate count technique as per standard procedures (APHA, 2012). 0.5 mL of the sample was spread plated onto sterile nutrient agar plates. The plates were incubated at 37°C for 24 hours and counted with Colony Counter (Fig, 3.6).

3.4.2.2. Membrane Filter Technique

3.4.2.2.1. Preparation of Media

Eosin methylene blue (EMB) agar was used as it is selective agar for coliforms. It was prepared as 2.8 gram per 100 ml of water in volumetric flask erlenmeyer flask. After media preparation flask was sealed tight with aluminum foil and was autoclaved. Molten and liquefied agar was poured in pre-autoclaved petri plates. After pouring plates were incubated for 24 hours at 37ºC for sterility test.

3.4.2.2.2. Dilution Preparation

For preparation of dilution erlenmeyer flask were filled with 90ml of distilled water each and sealed with aluminum foil. Flasks were then autoclaved and preserved at 4ºC for further use.

3.4.2.2.3. Membrane filtration

Before analysis section surface was disinfected with ethanol. After sample bottles were uncapped 10ml disposable pipette was used to transfer sample in the first flask. 10 ml from 1st flask was then transferred in the next one and so on. After transfer of sample till the 5th flask, filter assembly was assembled and was fitted with membrane filter with a pore size that retained coliforms selectively. Sample from each flask was allowed to pass through membrane filter. For each flask, different filter was used and each filter was then placed in prepared EMB agar plates. Plates were incubated at 37ºC for 24 hours. Plates were removed from incubator and colonies from each plate were counted in colony counter.

3.4.3. WATER TREATMENT

Treatment was done by three stage portable water filter provided by Chief Executive at Pakoswiss Technology Mr Saad Khan here: coagulation was done by alum and ferric chloride. After flocculation water was poured into three stage portable water filter (Fig, 3.4). It was specifically designed for treating turbid and microbial contaminated water, which is based on modern filtration technologies of large filter plants. It keeps water cool and fresh without using energy. It improves the filtration process and significantly prolongs the life of replaceable filter cartridges. It is the only portable filter with chlorine dosing mechanism and has provision for coagulating very turbid waters. This filter is powered by gravity flow. Beside the use of designed filter, water was treated by different setups treatment scheme is given in (Fig, 3.5).

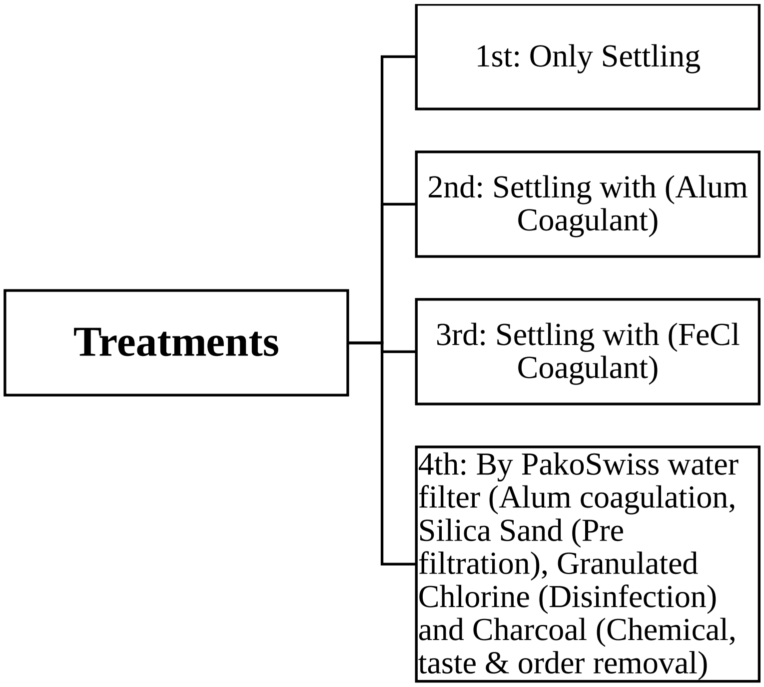

Figure 3.5: Water Treatment Scheme

3.4.4. THREE STAGE PORTABLE WATER FILTER

3.4.4.1. Upper Part

Sample water was poured into three stage portable water filter, upper part of the filter was made of plastic pipe (Fig, 3.6) which had silica sand for pre-filter, granulated chlorine as disinfection charcoal for the removal of chemicals, taste and odor.

3.4.4.2. Centre Part

Centre part of the filter was made of mud pitcher (Fig, 3.6) in which stored water and also provide cooling.

3.4.4.3. Lower part

Lower part of the filter had tap, from which water was taken out.

3.4.4.4. Coagulant used in treatment

The most common coagulants used in study were

- Aluminum sulfate (also referred to as alum),
- Ferric chloride

3.4.4.5. Disinfectant

Liquid chlorine Aqua Clean Drops (ACD) and active chlorine was used for disinfection. 3 – 4 drops were added into 1 liter of water, and 30 minutes were given to disinfection process.

3.4.5. PREPARATION OF CHLORINE

3.4.5.1. Preparation of Brine Solution

2 liters of water was taken in a plastic bottle, large amount of salt (400g / liter) was added into it. Then it was mixed for 30 minutes.

3.4.5.2. Production of active chlorine

40ml of saturated brine was taken in a half liter plastic bottle, it was topped up with water until it reached 0.5 L and Mini – WATA was immersed in the salt solution. Mini – WATA was plugged in the power supply (110 or 220 V) for 3 hours to produce 0.5 L of concentrated chlorine (6g/L or 6000pm). WATA test reagent was used to check the concentration of chlorine.

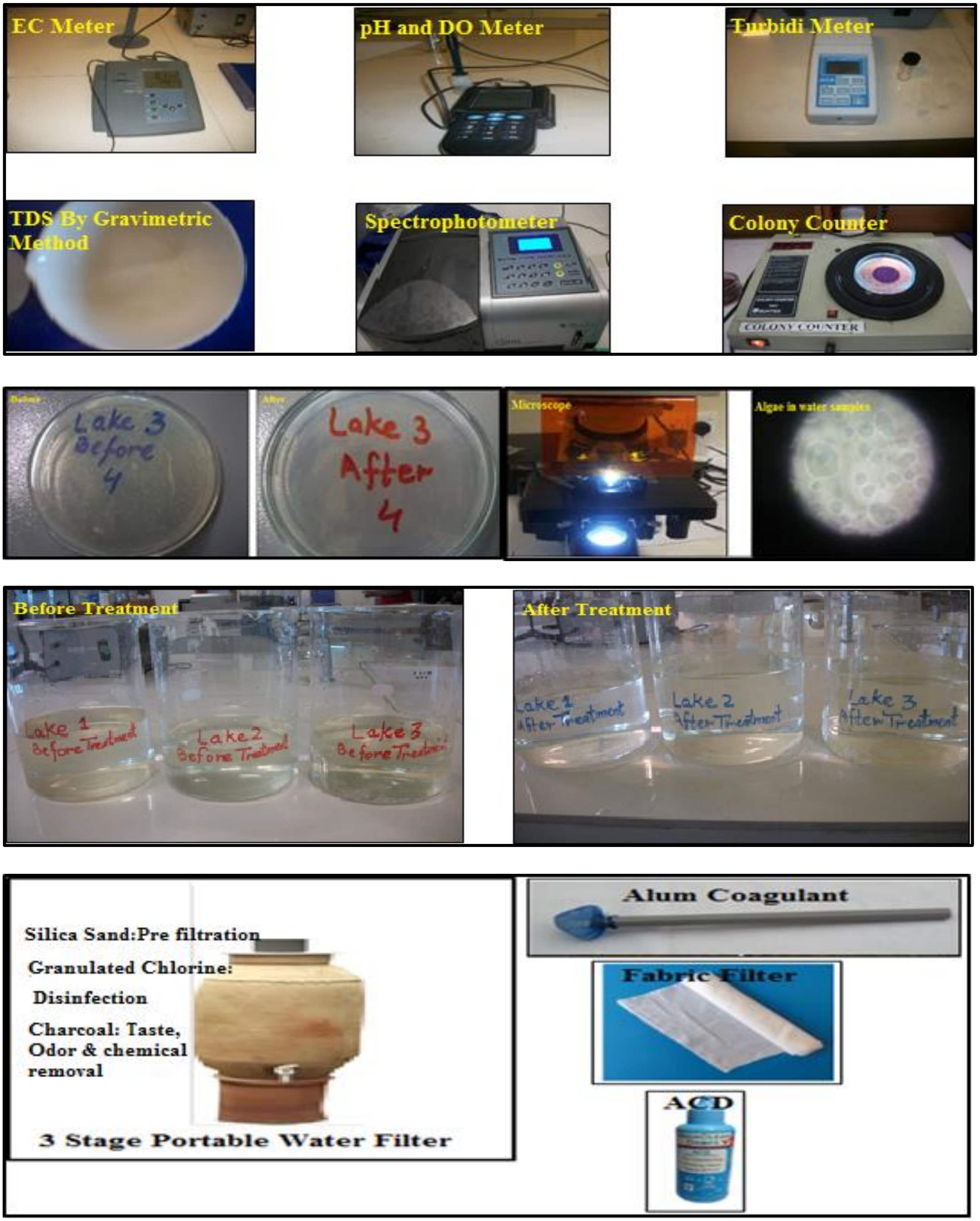

Figure 3.6: Pictorial

Chapter 4

RESULTS AND DISCUSSION

Physicochemical biological parameters of water samples collected from NUST lakes were compared with World Health Organization and Pakistan Standards for Drinking Water Quality. These lakes 1, 2 and 3 were constructed in 2011, they have an area 1.5, 2 and 2.25 acre with height 25,16 – 20 and 25 feet respectively. And they have storage volume 0.17, 0.16 and 0.74 GL respectively as previously shown in chapter 3, Fig (3.3). Physicochemical and biological parameters e.g. odor, color, turbidity, EC, TDS, pH, Temp, DO, T Hard, T Chlorides, T Alkalinity, T Phosphorus, T Nitrates, T Bacterial Count and T Coliform were analyzed and results as presented below.

4.1.0 Temperature

It was recorded that lakes temperature ranged from 15-33.6 °C. Temperature data showed that temperature was low in winter and lowest temperature was found in the month of January and highest in the month of July. In summers lake temperature exceeded the permissible limits. Temperature above 25 °C may enhance the growth of microorganisms and may increase problems related to taste, odor and color. Figure 4.1 shows average temperature values obtained from lake water which were about 23 °C ± 0.14 in all three lakes. Water temperature is an important parameter because it is a critical factor in determining the growth of the microorganisms (Ramteke *et al.,* 1992). Bacterial growth rates, decay of disinfection residual is affected by water temperature (Kelin *et al.,* 2005).

4.1.1. pH

It is said that pH should range from 6.5 to 8.5. Although pH usually has no direct impact on water consumers. In water analysis pH ranged from 7.2-8.7. It was found that pH was lower in winter as minimum value was recorded in the month of October and January and higher in summers where maximum value was recorded in the month of July. Average pH recorded from lake 1, 2 and 3 was 7.84 ± 0.03 (Fig. 4.2). Most of the time pH was within the permissible limits of WHO and NSDWQ, 2008. Only in the month of May and July it exceeded the limits.

4.1.2. Dissolved Oxygen

It ranged from 7.2-10.7 mg/L. A relation between DO and temperature was found, when low temperature in lakes DO was more and less DO was recorded in higher temperature. Dissolved oxygen was minimum in July and in the month of February maximum DO was recorded. Average DO was 8.77 mg/ L ± 0.01 in lake1, 2 and 3 (Fig. 4.3). DO is effected by temperature level in a water body and found to be critical for the survival of aquatic organisms for aerobic respiration.

4.1.3. Electrical Conductivity

EC of lake water ranged from 220-1233 µS cm^{-1}(Fig. 4.4). Most of the time decreasing trend of EC value was found from L1 › L2 › L3 in different months. Lowest value of EC was recorded in month of January and highest in the month of May. It was found that EC is low every time when measured in after precipitation and high in dry conditions. So, it was also linked with the temperature. Average measured EC was 552 ± 83 µS cm^{-1} in lake 1, 2 and 3.

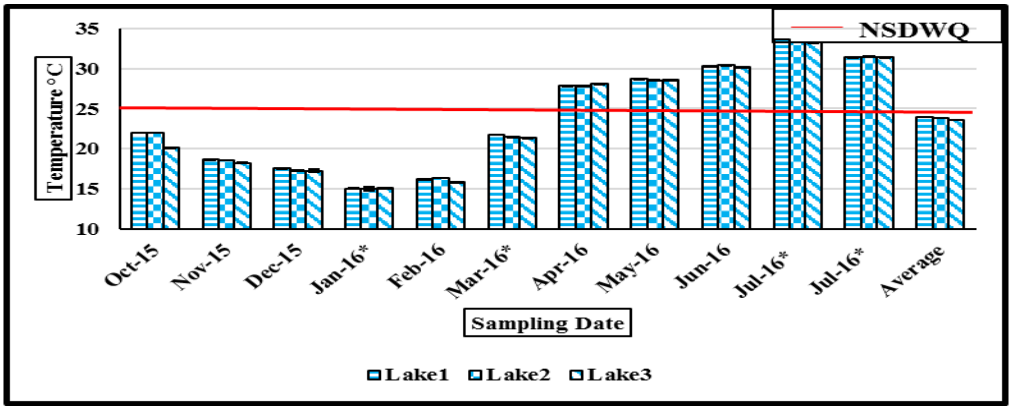

*Figure 4.1: Seasonal variation (mean values observed) of temperature recorded in NUST lakes * showing water sample after rain*

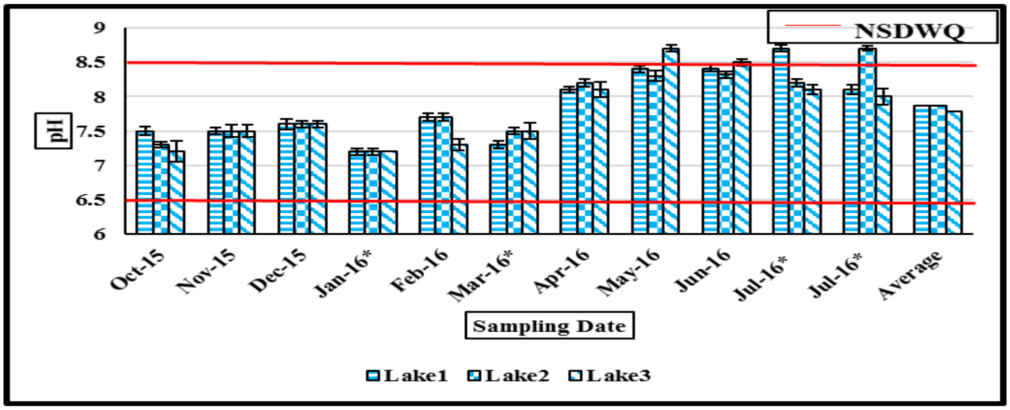

*Figure 4.2: Seasonal variation (mean values observed) of pH recorded in NUST lakes * showing water sample after rain*

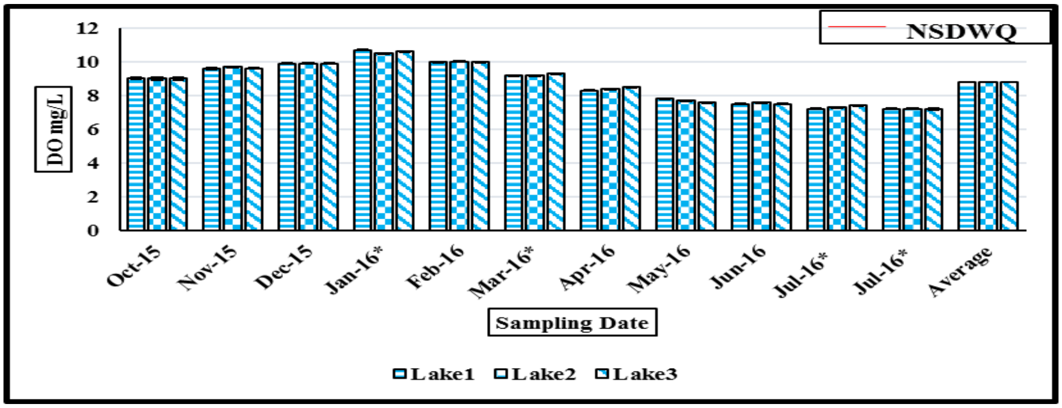

*Figure 4.3: Seasonal variation (mean values observed) of DO recorded in NUST lakes * showing water sample after rain*

4.1.4. Total Dissolved Solids

There is a relationship between TDS and conductivity. As the dissolved salts (usually salts of sodium, calcium and magnesium, bicarbonate, chloride, and sulphate) increases in water, electrical conductivity increases (Kelin *et al.*, 2005). The electrical conductivity is higher for water that has more dissolved ionic species. TDS of lake water ranged from 116-655 mg/L (Fig. 4.5). Most of the time decreasing trend of TDS was found from L1 › L2 › L3 in different months. Lowest value of TDS was recorded in month of March and highest in the month of June. After rain TDS were less as compared to previous reading, it was due to the dilution. Average TDS measured were 285 ± 45 mg/L in Lake1, 2 and 3. Water containing TDS value below 1000 mg/L is usually acceptable to consumers, although acceptability may vary according to circumstances (WHO, 2004).

4.1.5. Turbidity

Turbidity of lake water ranged from 7.5-210 NTU. Most of the time lake 2 had more turbidity as compared to other lakes. It was due to the other waste water sources coming in the lake. But it was also found that value of turbidity increases every time after precipitation. And it was due to the turbulence of water and soil erosion. In all the months' turbidity recorded was higher than the permissible limits. Average measured turbidity was 30 ± 7 NTU in lakes (Fig. 4.6).

4.1.6. Color

Lake water color ranged from 21-351 TCU. Mostly this color was due to the algae present in lakes. It was found that color was low after the precipitation. Recorded color of lakes in all the

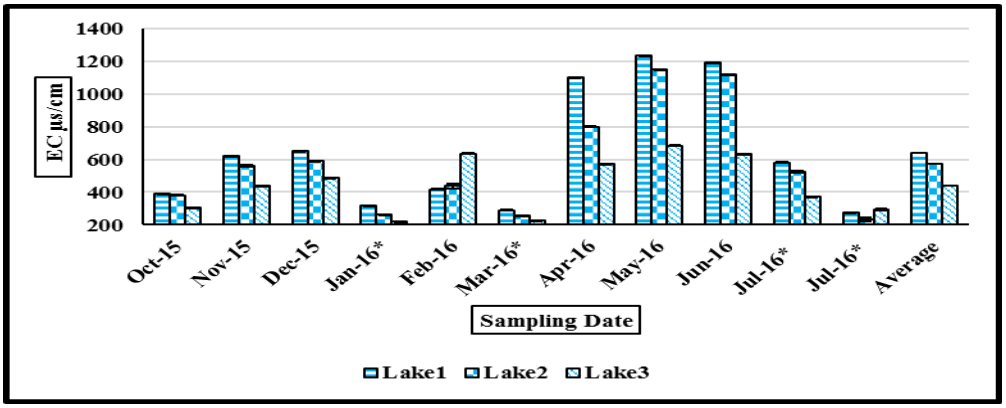

*Figure 4.4: Seasonal variation (mean values observed) of EC recorded in NUST lakes * showing water sample after rain*

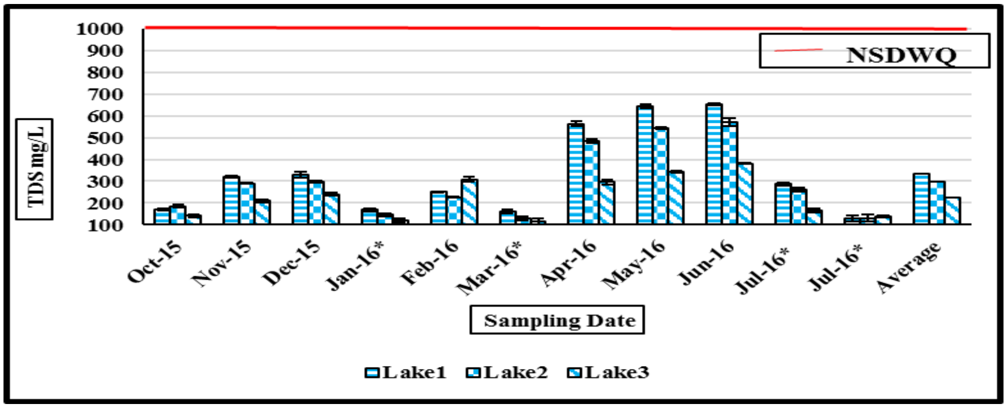

Figure: 4.5: *Seasonal variation (mean values observed) of TDS recorded in NUST lakes * showing water sample after rain*

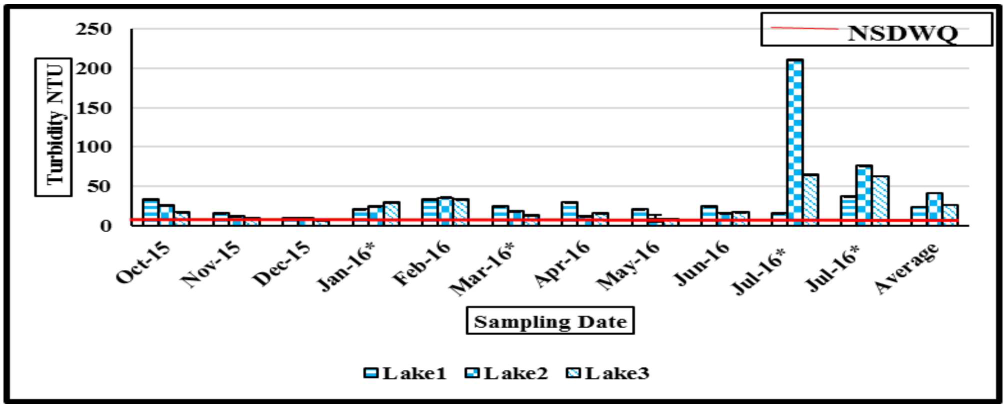

*Figure 4.6: Seasonal variation (mean values observed) of turbidity recorded in NUST lakes * showing water sample after rain*

months was higher than the permissible limits. Analysis showed that average color was 100 ± 19 TCU in lakes (Fig. 4.7).

4.1.7. Total Hardness

Hardness of lake water ranged from 109-337 mg/L. Here again same decreasing trend in lakes was found most of the time in different months. Minimum hardness was measured in the month of March and maximum in the month of May. In dry season hardness was high as calculated in month of April, May and June. It was due to the lake water, which evaporated in dry season. After precipitation, due to dilution hardness decreased all the time. Average hardness calculated from lakes was 188 ± 18 mg/ L (Fig. 4.8).

4.1.8. Total Chlorides

Chlorides ranged from 6.6-129 mg/L. Similar decreasing trend was found as for other parameters. After rain samples Cl were lower it was due to the dilution, as lowest value was found in the month of July and highest Cl value was found in the month of June. Average chlorides measured from lakes were 63 ± 8 mg/L in lakes (Fig. 4.9).

4.1.9. Total Alkalinity

It was recorded that alkalinity of lake water ranged from 52-345 mg/L. In wet season alkalinity was low because lakes were having more water due to precipitation. Lowest alkalinity was recorded in month of January. And higher alkalinity was found in the month of June in dry season when lakes water level was low. Average alkalinity was 152 ± 23 mg/ L (Fig. 4.10).

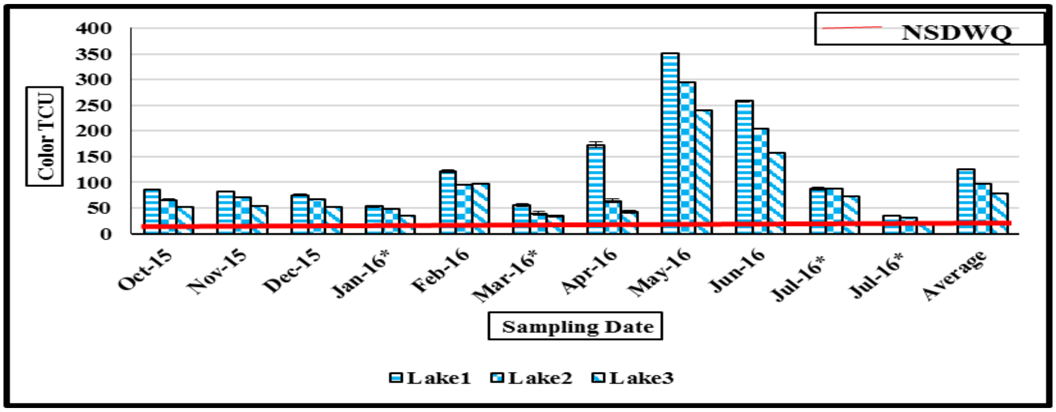

***Figure 4.7: Seasonal variation (mean values observed) of color recorded in NUST lakes** * showing water sample after rain*

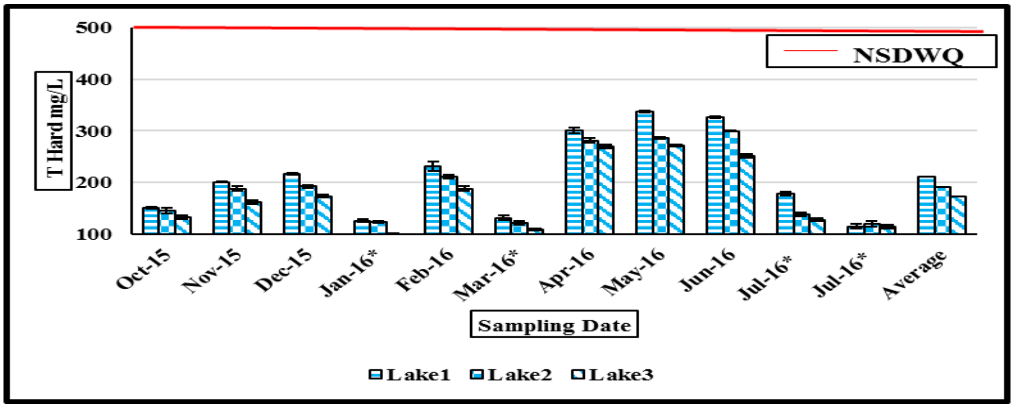

***Figure 4.8: Seasonal variation (mean values observed) of T Hard recorded in NUST lakes** * showing water sample after rain*

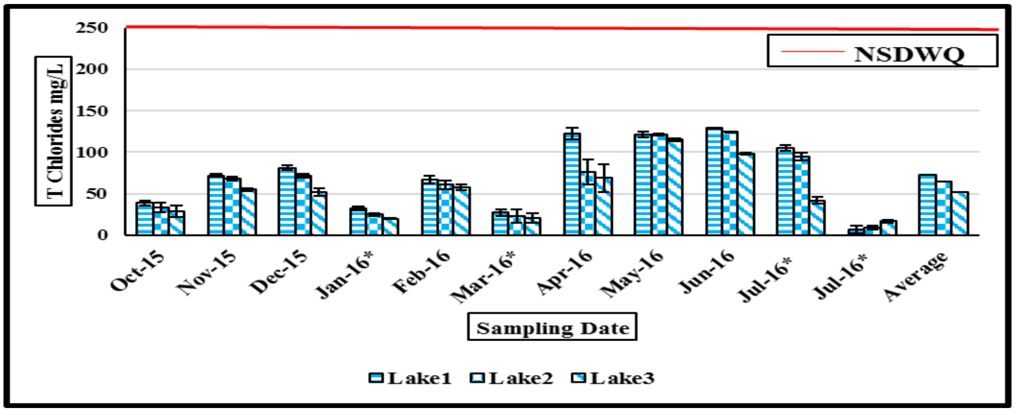

Figure 4.9: ***Seasonal variation (mean values observed) of T Chlorides recorded in NUST lakes** * showing water sample after rain*

4.1.10. Total Phosphorus

Phosphorus ranged from 1.32-16.84 mg/L. Its value was low in the month of January and high value of phosphorus was found in month of July. Average phosphorus of lakes was 5.05 ± 0.51 mg/L. (Fig.4.11).

4.1.11. Total Nitrates

Nitrates of lake water ranged from 3.29-29.02 mg/L. Mostly lake 1 had low nitrates it was due to the water coming from source and precipitation. But in lake 2 and 3 already present water had nitrates so having more nitrates. In month of January value of nitrate was minimum and in the month of March it was recorded maximum. Total nitrates were found within WHO limit of 50 mg/L. Average nitrates of lake measured were 15.39 ± 2.3 mg/L (Fig. 4.12).

4.1.12. Total Bacterial Count

Water was polluted with microorganisms and water analysis showed range of bacterial count 0.5×10^5-3×10^5 / ml. It was found that bacterial count was less in winter as compared to summer. Lowest bacterial count was found in month of March and highest in month of July. After rain sample, bacterial count was low due to dilution and fresh water. Average bacterial count was 147924 ± 13501/ ml. (Fig. 4.13).

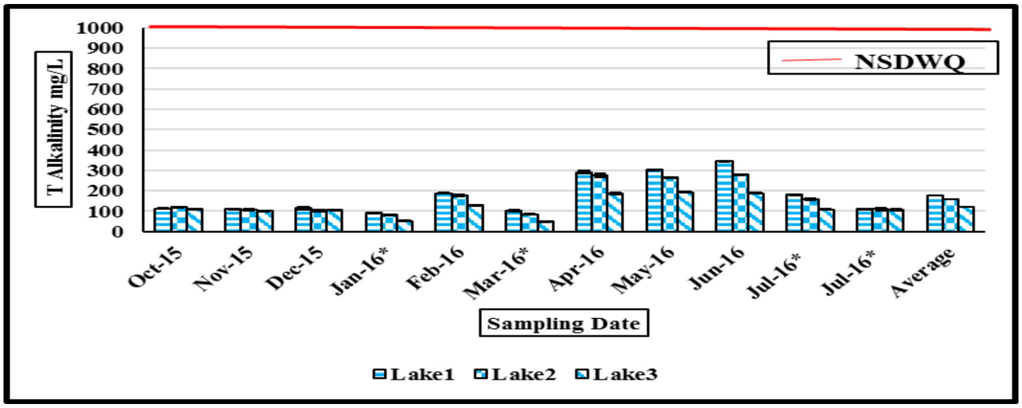

Figure 4.10: Seasonal variation (mean values observed) of T Alkalinity recorded in NUST lakes ** showing water sample after rain*

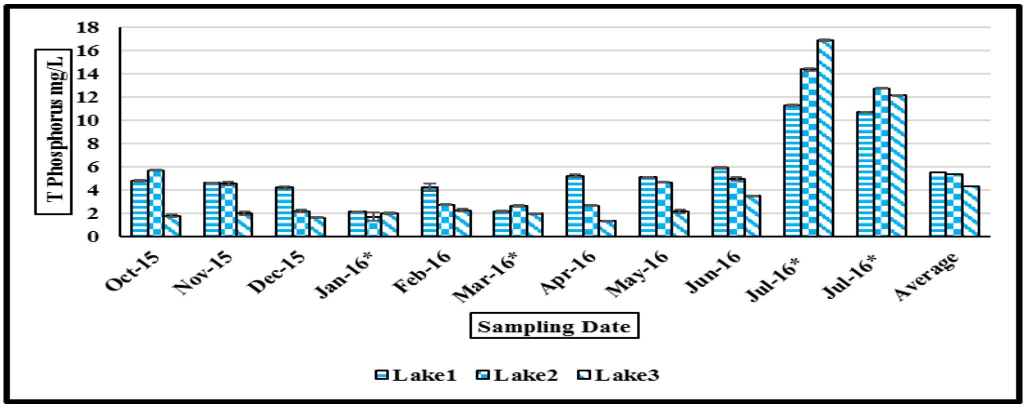

Figure 4.11: *Seasonal variation (mean values observed) of T Phosphorus recorded in NUST lakes* ** showing water sample after rain*

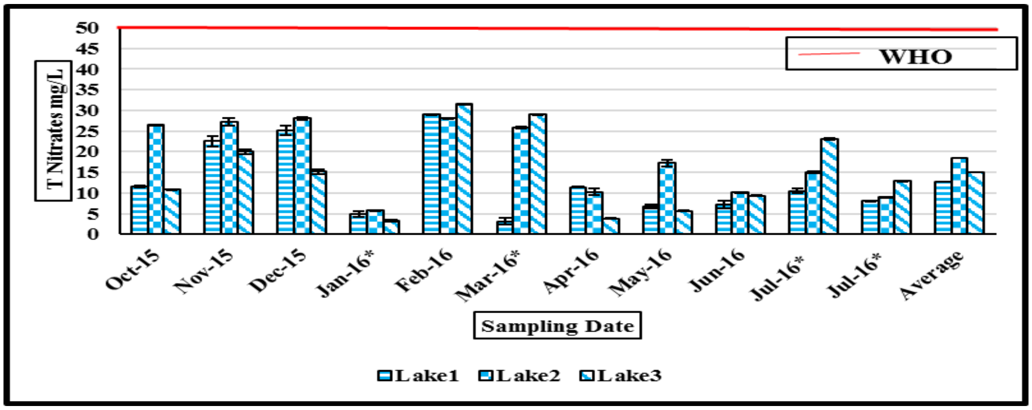

Figure: 4.12: Seasonal variation (mean values observed) of T Nitrates recorded in NUST lakes ** showing water sample after rain*

4.1.13. Total Coliform

Identification of coliforms from water samples represent the biological contamination of drinking water (Le Chevallier *et al.*, 1991). So, makes unnecessary to analyze all water pathogens. Escherichia coli are found in all mammal feces, directly linked with the public health problems associated with water (Edberg *et al*., 2000). In lake1, 2 and 3 average 2.46, 2.19 and 1.77 × 10^4 T. Coliform/100 ml was found. Similar results were found as bacterial count. T. Coliforms were higher in summer as compared to winter. T Coliform ranged from 5900-29800/100 ml. Minimum no of coliform was found July maximum no of coliform found in month of May. Average no of coliform was recorded as 20915 ± 2789 (Fig. 4.14).

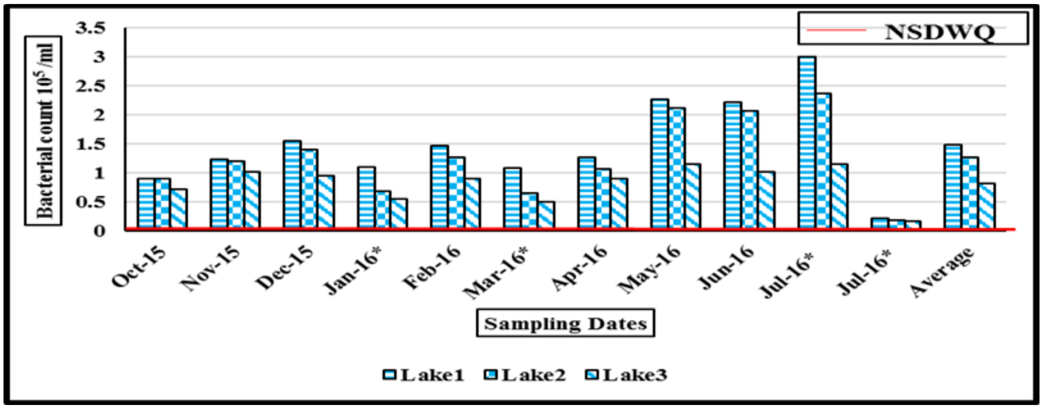

Figure 4.13: ***Seasonal variation (mean values observed) of T Bacterial Count recorded in NUST lakes*** **** showing water sample after rain***

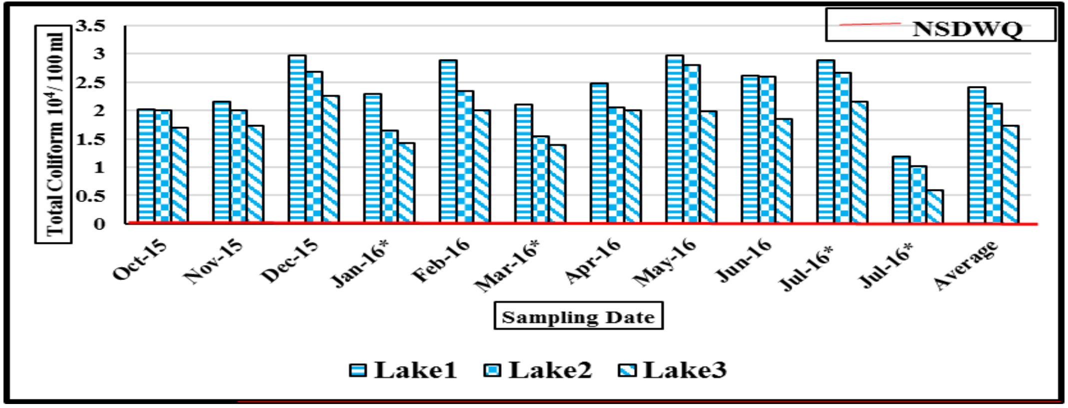

Figure 4.14: ***Seasonal variation (mean values observed) of T Coliform recorded in NUST lakes*** **** showing water sample after rain***

4.2 PAKO SWISS TREATMENT

PakoSwiss treatment was done by portable water filter, which had Silica sand for pre-filtration, granulated chlorine for disinfection and carbon (charcoal) for the removal of chemicals, taste and odor. Treatment proved effective for the rain water harvested in NUST lakes.

4.2.1. Temperature

Every time after treatment odor was removed. And a slight difference of temperature 4-8 percent decrease was found for wet and dry condition water samples by PakoSwiss treatment. Similar results 3.5-4 percent were found with the use of different setups: only settling, settling with alum and settling with Fecl. So, it means this decrease in temperature was due to mud pitcher not by any chemical (Fig. 4.15).

4.2.2. Dissolved Oxygen

DO is one of the most important quality parameter as it effects living organisms in water bodies. It was found that DO was same even after PakoSwiss treatment. And similarly, no significant results were found when different treatment setups were used (Fig. 4.16). Normally, DO levels fewer than 3 mg/L are stressful and harmful to many aquatic organisms whereas DO level of 7.0 mg/l or more are preferred to sustain aquatic ecosystem. In general, DO is measured in mg/l (Enrique Sánchez. et al 2007).

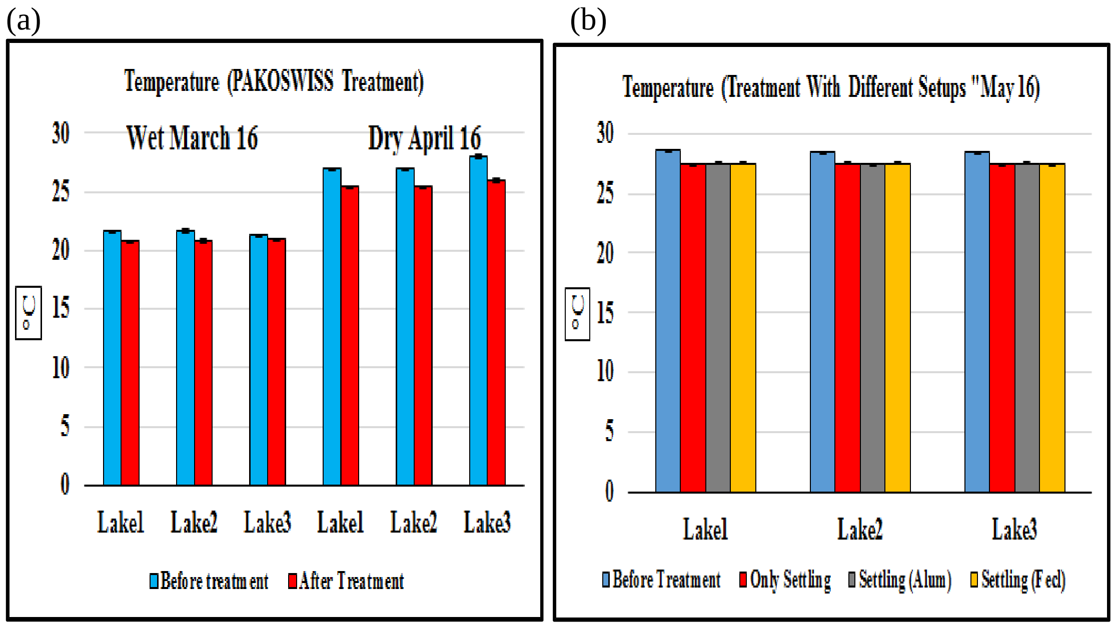

Figure 4.15: (a) PakoSwiss treatment for water temperature (b) Treatment with different setups

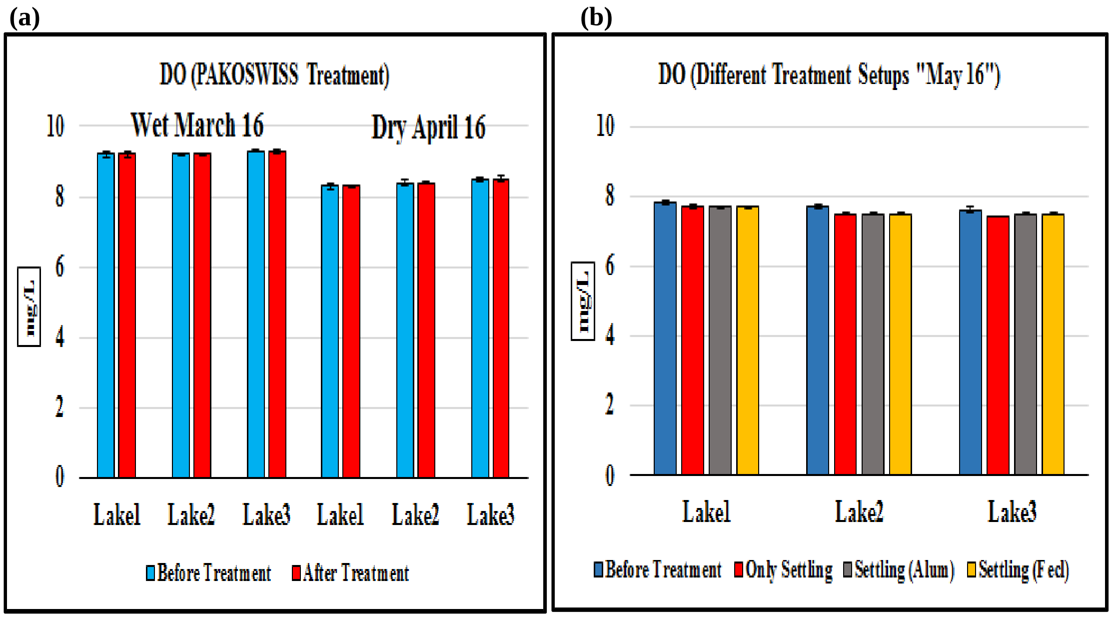

Figure 4.16: (a) PakoSwiss treatment for water DO (b) Treatment with different setups

4.2.3. pH

The pH is a measure of the acid-base equilibrium and, in most natural waters, is controlled by the carbon dioxide and bicarbonate carbonate equilibrium system. It is hard to ascertain any direct relationship between human health and the pH of DWs even though pH has a close association with other water quality aspects, e.g., taste, odor and appearance (WHO, 2007). Again, chemical did not play any major role in the water pH change. A minor decrease of 4-9 percent was found from both types of samples by a PakoSwiss treatment. And similar results were found with a different treatment setup. With alum and Fecl settling 6.8-9.9 and 5.6-9.9 percent decrease was found respectively (Fig. 4.17).

4.2.4. Electrical Conductivity

Electrical conductivity is a measure of the ions present in water, as the conductivity increases with the number of ions, while it does not tell us what specific ions are present (Rahman *et al.*, 2016). In a dry period, lakes EC concentration exceeds the permissible limits, here a PakoSwiss treatment efficiently removed EC 20-30 percent from both dry and wet water samples. With different treatment setups alum and Fecl settling efficiently removed 27- 37 and 26- 30 percent respectively. In this case both chemicals were efficient for the treatment as compared to only settling in pitchers (Fig. 4.18).

4.2.5. Total Dissolved Solids

TDS in natural waters consists predominantly of carbonates, bicarbonates, chloride, sulfate, Ca, Mg, Na and K, while dissolved metals and dissolved organic matter represent a small percentage (Ritter, 2010). However, no recent data on health effects associated with the ingestion of TDS in DWs appear to exist (Rahman et al., 2016).19-37 percent TDS removal was achieved by PakoSwiss treatment in water samples. 29-34 and 26- 28 percent removal was found by alum and Fecl settling respectively (Fig 4.19).

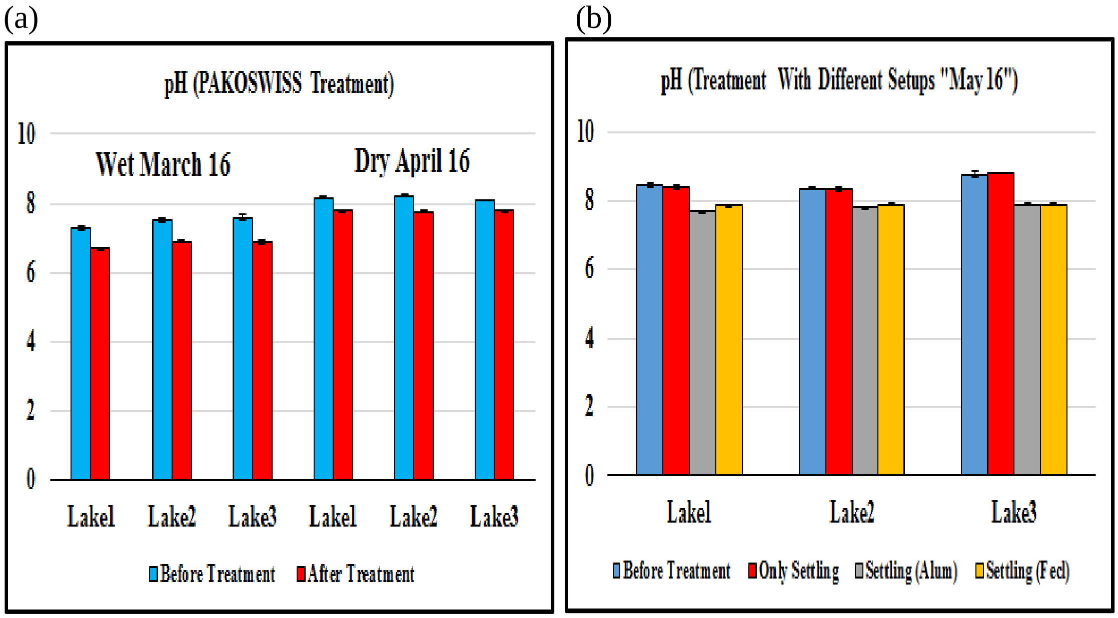

Figure 4.17: (a) PakoSwiss treatment for water pH (b)Treatment with different setups

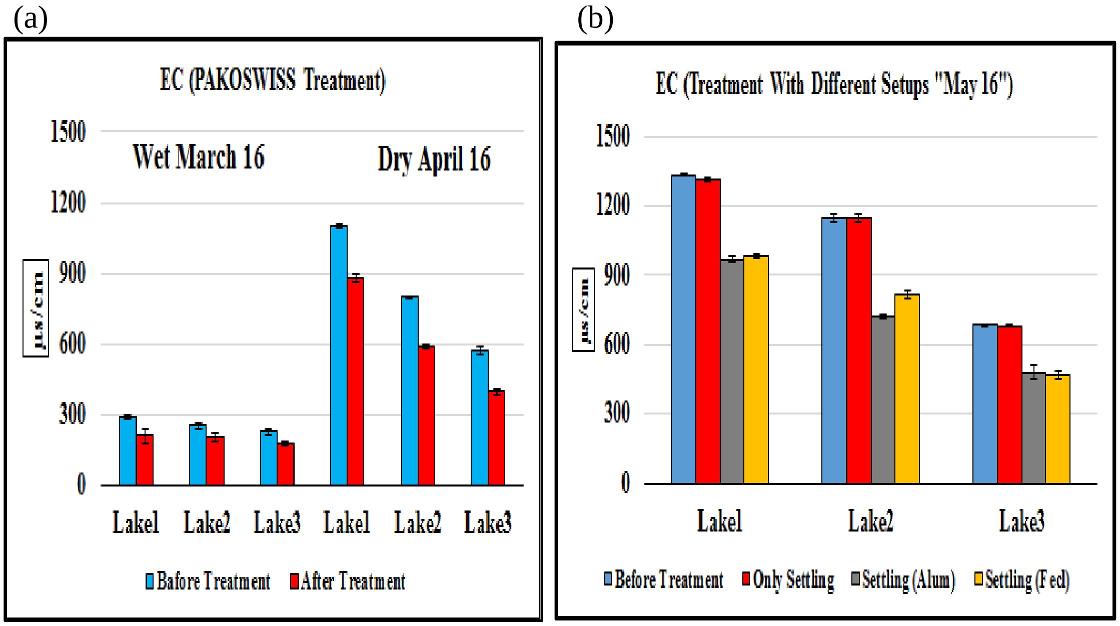

Figure 4.18: (a) PakoSwiss treatment for water EC (b) Different treatment setups

4.2.6. Turbidity

NUST lakes were having higher turbidity in both dry and wet season, which exceeds every time after rain. PakoSwiss treatment proved very efficient for the removal of turbidity 92-94 percent. Turbidity couldn’t be treated by only settling in pitchers, because it removed 66-67 percent turbidity. For turbidity treatment alum was more efficient by removing 91-94 percent as compared to Fecl which gave 82-87 removal results (Fig. 4.20). Similarly, Katukiza et al., (2014) achieved 85 percent removal of organic matter and 50-70 percent phosphorus removal from grey water by sand and crushed lava.

4.2.7. Color

Efficient results were found for the removal of water color. It was found that 94-97 percent removal achieved by PakoSwiss treatment. But color removal 49-56 percent was not efficient when only mud pitchers settling was used. And 98-99 and 97-98 percent removal was achieved by alum and Fecl settling respectively (Fig. 4.21).

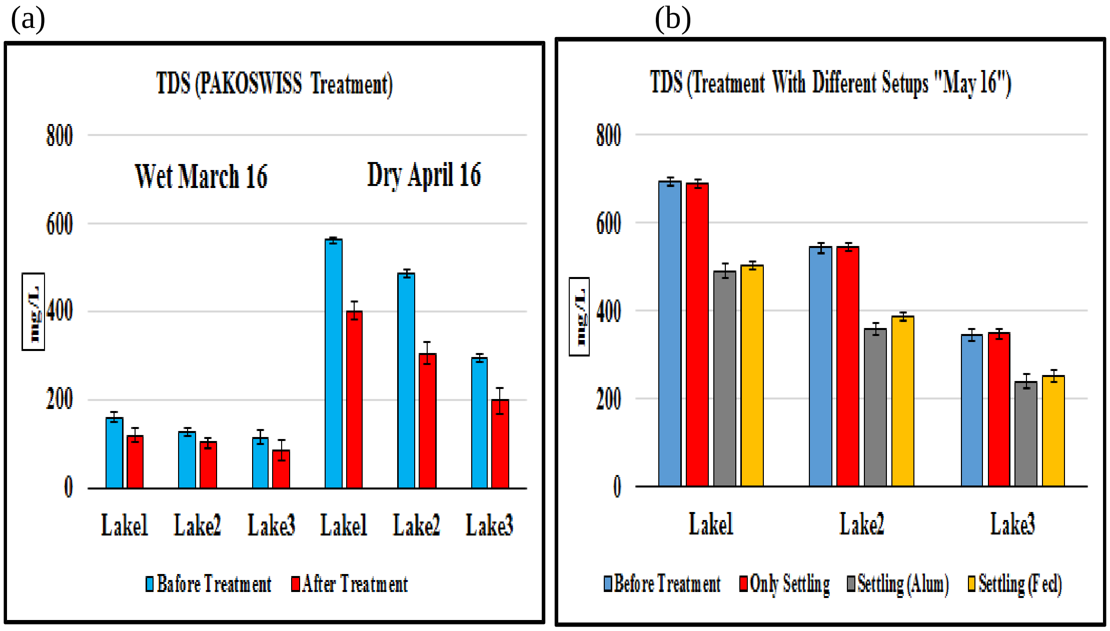

Figure 4.19: (a) PakoSwiss Treatment for water TDS (b) Different treatment setups

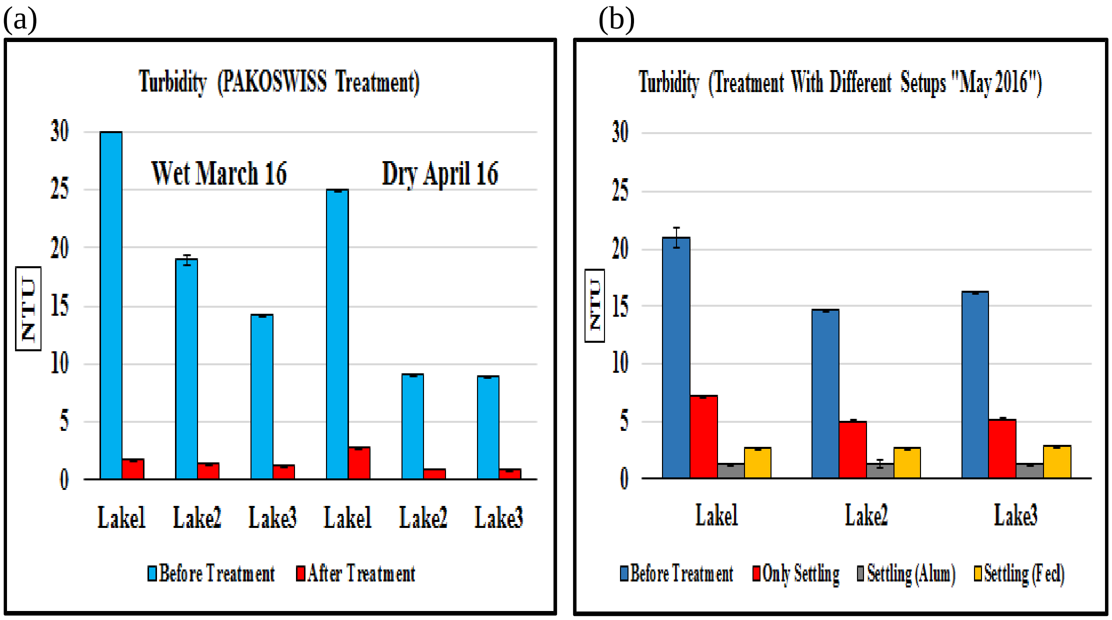

Figure 4.20: (a)PakoSwiss treatment for water turbidity (b)Different treatment setups

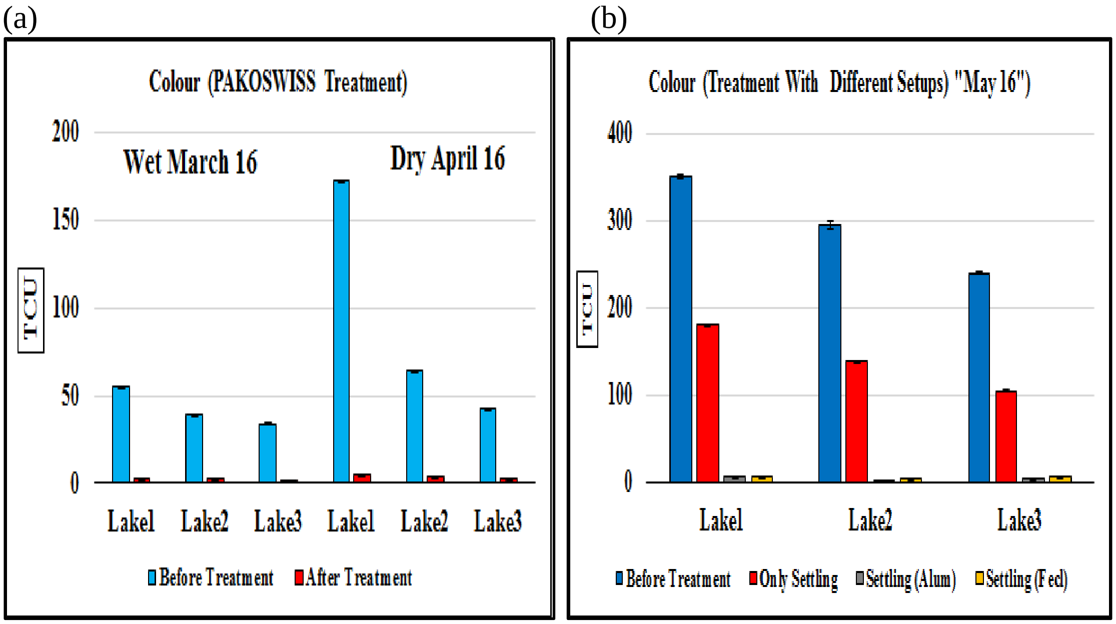

Figure 4.21: (a) PakoSwiss treatment for water color (b) Different treatment setups

4.2.8. Total Chlorides

In a PakoSwiss treatment 22-34 percent chlorides were removed from both wet and dry water samples. Alum and Fecl settling contributed to remove Cl 26-28 and 16-23 percent respectively. Alum's settling results were better than Fecl settling (Fig. 4.22).

4.2.9. Total Hardness

The principal sources of T Hard in natural water are dissolved polyvalent metallic ions from sedimentary rocks, seepage, and runoff from soils. The predominant species of the cations are Ca and Mg, although other cations, e.g. Ba, Fe, Mg, Sr, and Zn, also contribute (WHO, 2003b). There is not enough convincing evidence to correlate between TH in DWs and adverse health effects in humans (WHO, 2004b). In a PakoSwiss treatment 29-43 percent hardness removal was found. Same removal results 41-46 and 36-43 percent were found for only alum and Fecl settling respectively (Fig 4.23).

4.2.10. Total Alkalinity

The TA of waters, which is a measurement of its buffering capacity or ability to react with strong acids at a designated pH, is taken primarily as an indication of the concentration of carbonate, bicarbonate, and hydroxide contents (Clesceri et al., 1998). By PakoSwiss treatment alkalinity removal was 22-32 percent in both types of samples.

Alum removed 49-50 percent and 40-55 percent removal was achieved by Fecl settling (Fig.4.24).

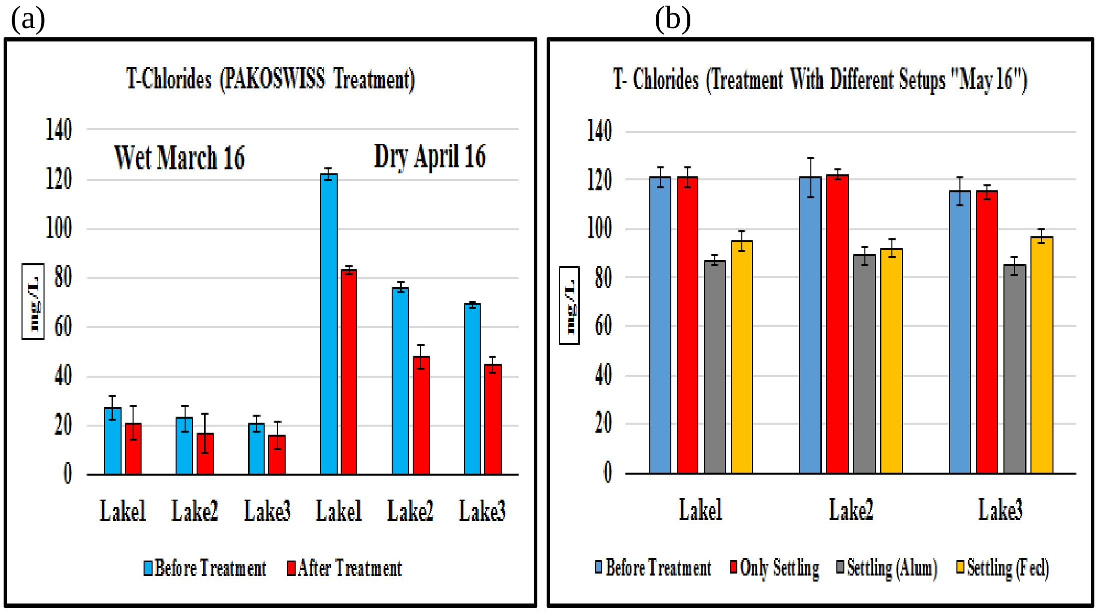

Figure 4.22: (a)PakoSwiss Treatment for water T - Chloride(b) Different treatment setups

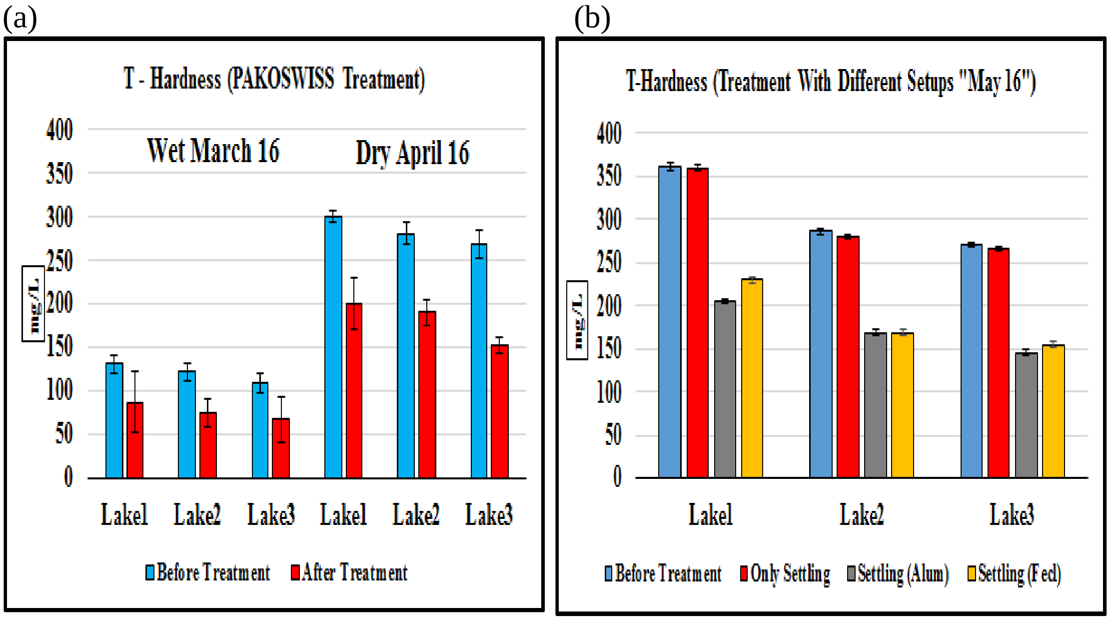

Figure 4.23: (a) PakoSwiss Treatment for water T - Hardness(b) Different treatment setups

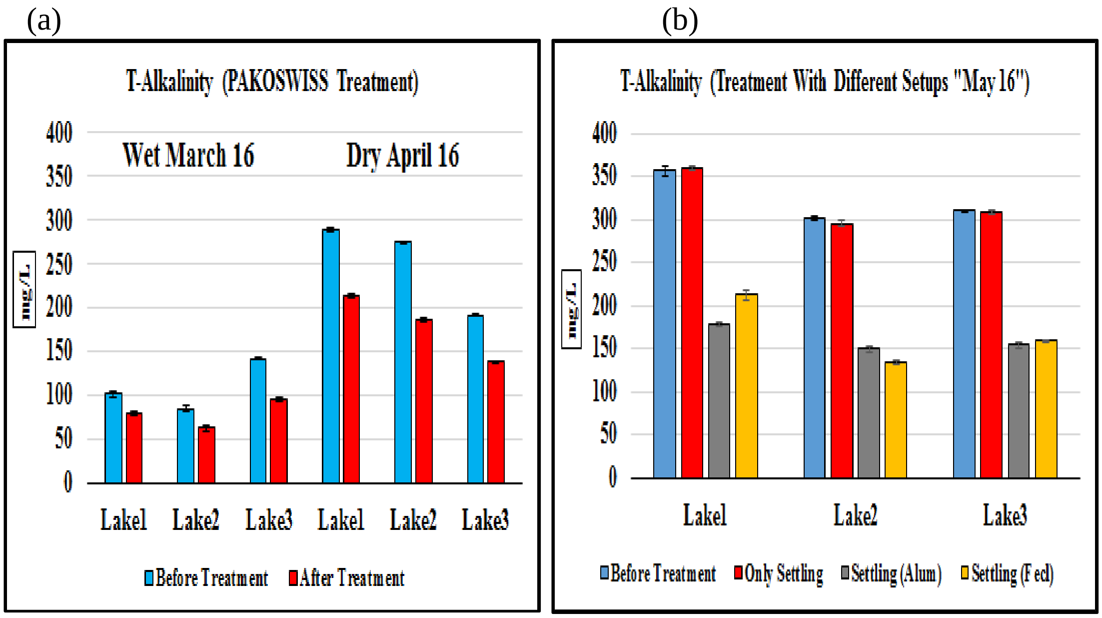

Figure 4.24: (a) PakoSwiss treatment for water T -Alkalinity (b) Different treatment setups

4.2.11. Total Phosphorus

It was found that PakoSwiss treatment improved the water quality by removing 42- 64 percent phosphorus. 49- 68 and 44-61percent removal was found by alum and Fecl settling respectively. Alum was more efficient as compared to Fecl (Fig. 4.25).

4.2.12. Total Nitrates

In PakoSwiss treatment nitrates removal was 67-97 percent from both types of samples. 38-66 percent removal was achieved when alum settling used. And by using Fecl settling 31- 66 percent removal was achieved (Fig. 4.26).

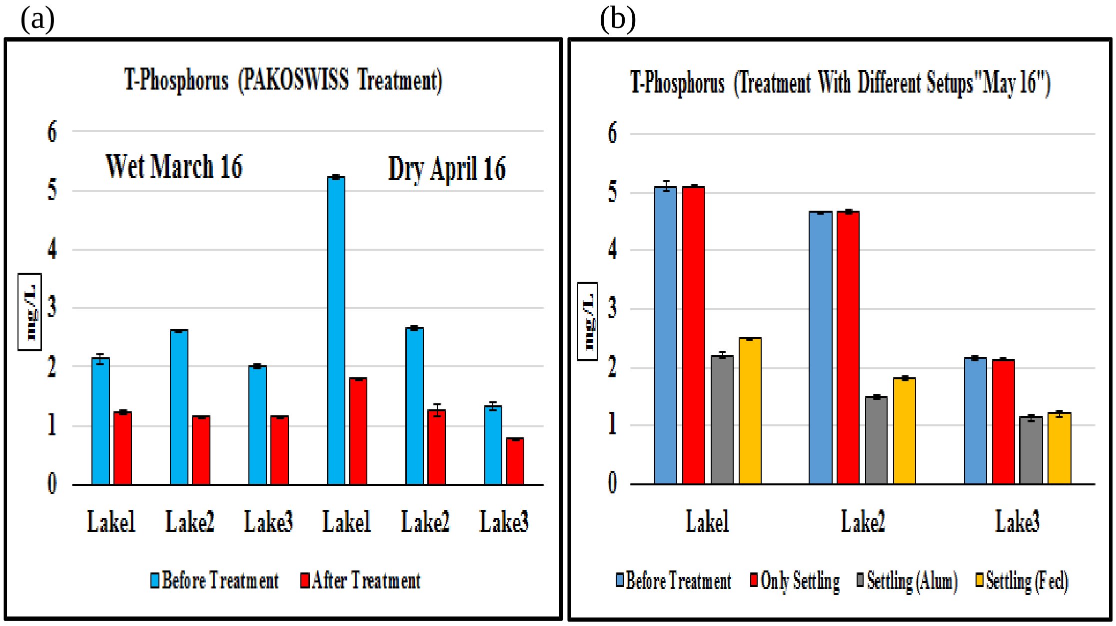

Figure 4.25: (a) PakoSwiss treatment for water T-Phosphorus (b)Different treatment setups

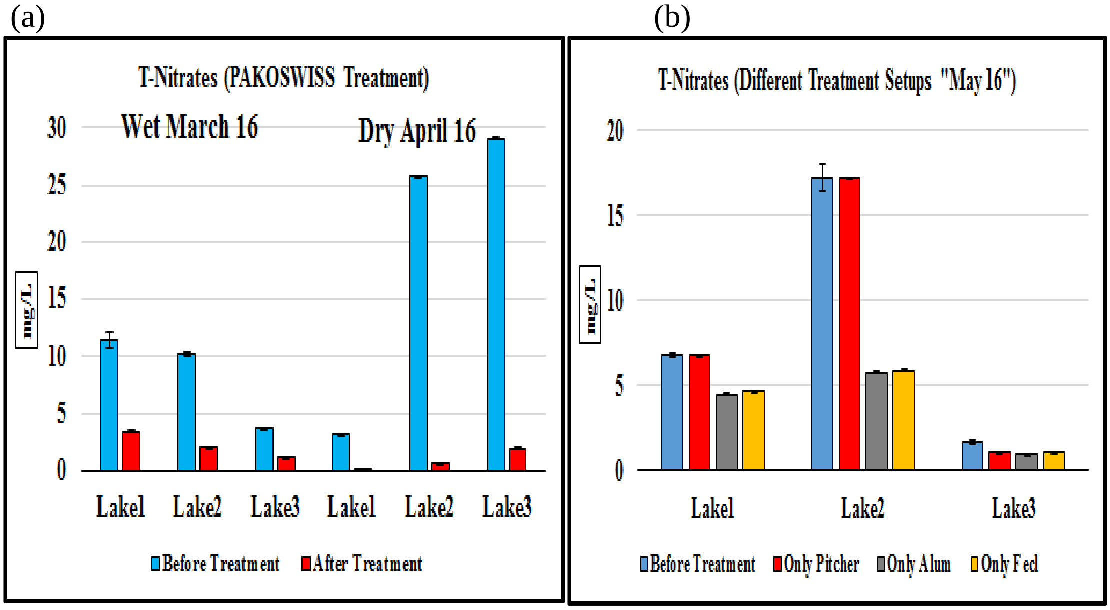

Figure 4.26: (a) PakoSwiss treatment for water T- Nitrates (b)Different treatment setups

4.2.13. Total Bacterial Count

PakoSwiss treatment was very effective for the removal of bacteria present in lake water. This removal was 100 percent. But in a different treatment setups none of the method identified as reliable option for the microbial treatment of water (Fig. 4.27).

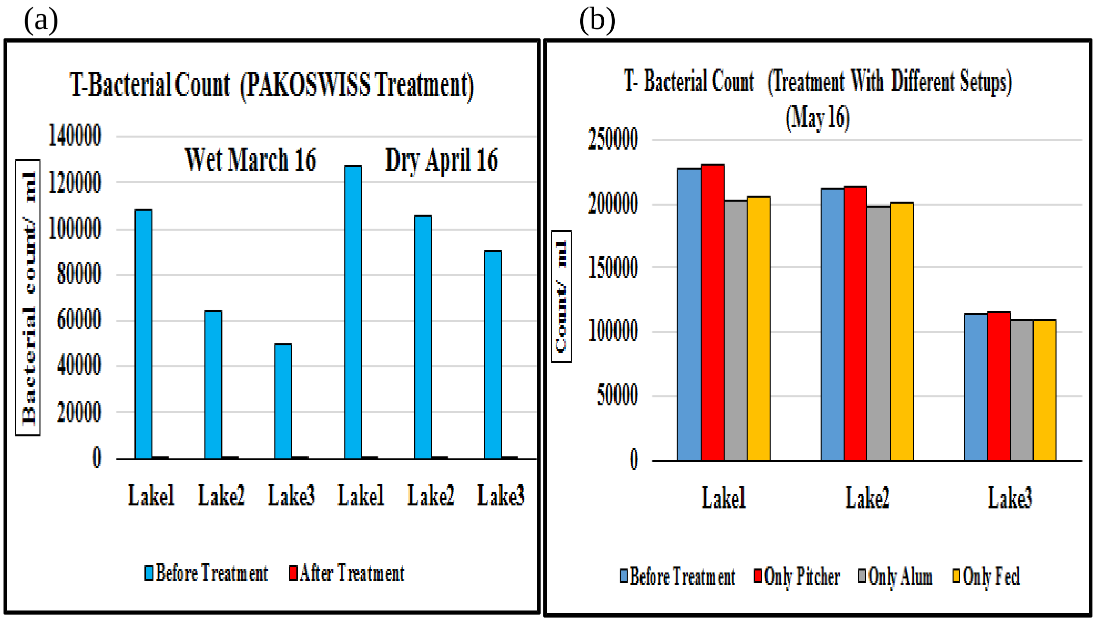

Figure 4.27: (a) PakoSwiss treatment for water T. Bacterial Count (b)Different treatment setups

4.2.14. Total Coliform

Again, this PakoSwiss treatment proved very much effective 100 percent removal of coliforms and no significant results were found when different treatment setups were used. (Fig. 4.28).

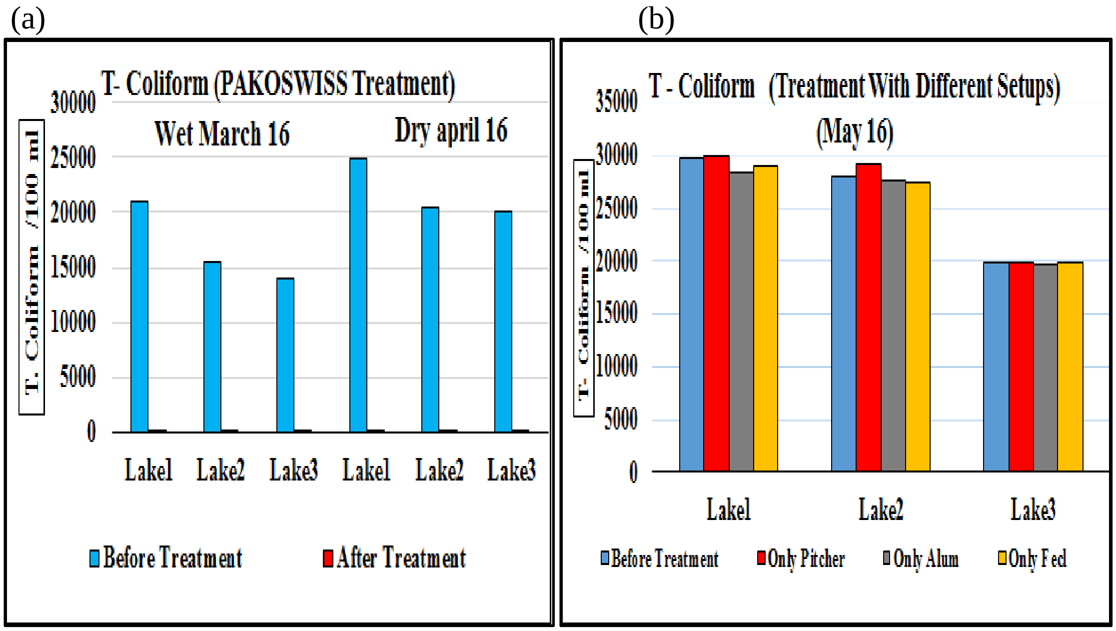

Figure 4.28: (a) PakoSwiss treatment for water T -Coliform (b) Different treatment setups

4.3. Comparison of Treated Lake Water and Tube well

After complete treatment water was suitable for dinking. And when this treated water was compared with the NUST tube well water which is already the source of drinking water, it was found that temperature was totally different and it was due to the seasonal variation. Water sample was taken in different months of the year (Fig. 4.29a). It is clear from the comparison that turbidity of lake water after treatment was higher as compared to the tube well water but this level of turbidity was also in permissible level (Fig. 4.29b). Comparison of pH tells that pH was higher in treated lake water as compared to the tube well water. But again, this level of pH was in a permissible limit (Fig. 4.30a). In comparison of DO it was found that DO was higher in tube well water as compared to treated lake water (Fig.4.30b).

It was found that tube well water was very clean, no color was found in it. And the level of color found in treated lake water was in a permissible limit (Fig. 4.31a). It was found that EC of treated lake water was lower than found in tube well water. EC of treated lake water was with permissible level (Fig. 4.31b).

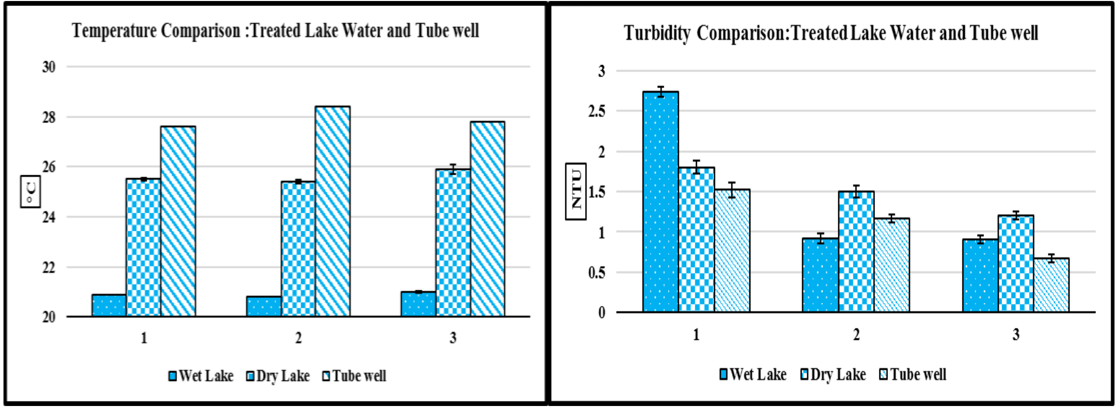
(a) (b)

Figure 4.29: Comparison of water (temperature, turbidity) value observed in treated lake and tube well

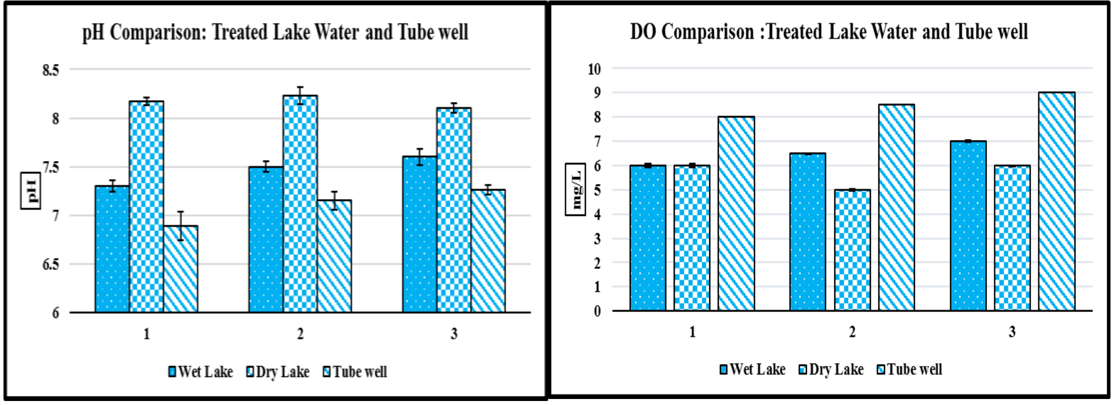
(a) (b)

Figure 4.30: Comparison of water (pH, DO) value observed in treated lake and tube well

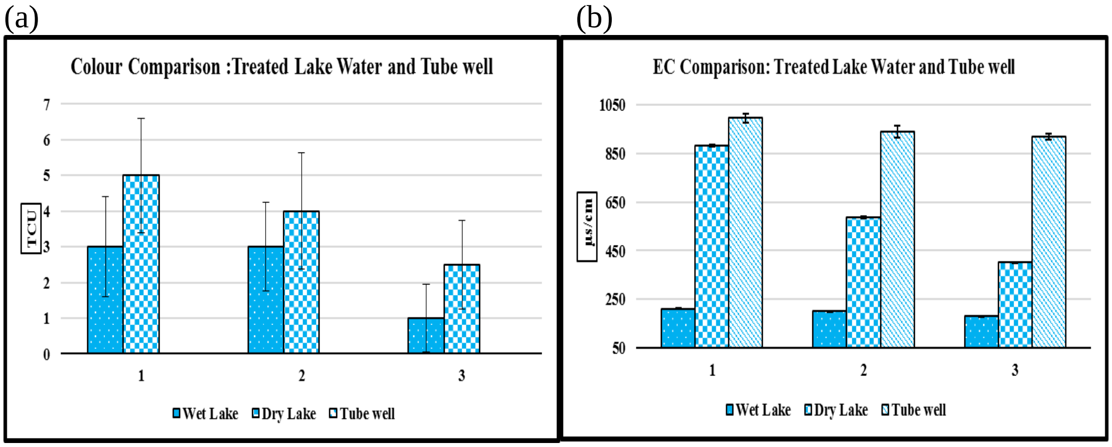

Figure 4.31: Comparison of water (color, EC) value observed in treated lake and tube well

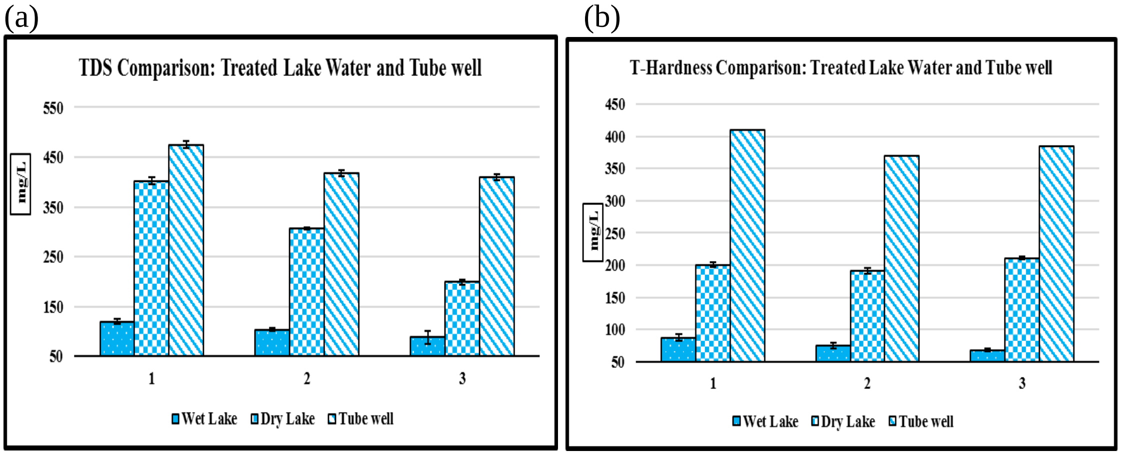

Figure 4.32: Comparison of water (TDS, T Hard) value observed in treated lake and tube well

In comparing hardness of treated lakes water and tube well, it was found that hardness was very low in lakes as compared to the tube well water (Fig. 4.32b). Similar comparison was found for the TDS where treated lake water’s TDS was lower than that in the tube well water (Fig. 4.32a). Comparison told that chloride concentration was in permissible limit in treated lake water. And when compared with tube well water it was found that tube well’s chloride concentration was lower as compared to the treated lake water of dry season (Fig. 4.33a). It was found that phosphorus of treated lake water was higher than the tube well water but this higher concentration was also in a permissible limit (Fig. 4.33b).

Total Alkalinity was also in permissible level when compared of treated lake water with tube well water (Fig. 4.34a). Nitrates analysis showed that in treated lake water these were in permissible level, but concentration of nitrates was lower when compared with the tube well water (Fig. 4.34b).

It was found that tube well water was safe for drinking. And treated lake water was also found safe, having no bacterial count which showed that disinfection process used during treatment was efficient. (Fig. 4.35a). Similar results of comparison were found for T – Coliform between treated lake and tube well water. It was found that tube well having no indicator of water biological pollution was safe for drinking purpose as compared to the treated lake water. Here the treatment efficiently cleaned the harvested lake water. (Fig. 4.35b).

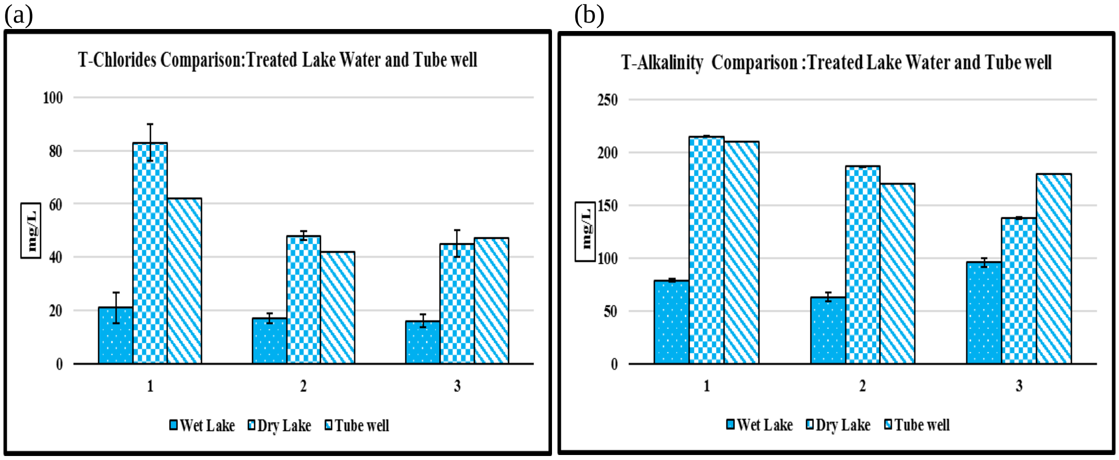

Figure 4.33: Comparison of water (T Ch, T Alk) value observed in treated lake and tube well

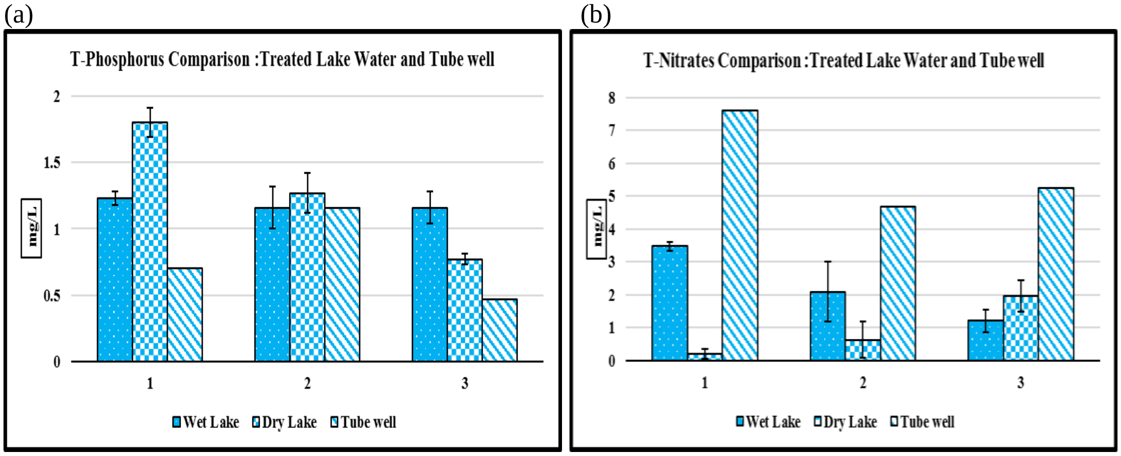

Figure 4.34: Comparison of water (T P, T N) value observed in treated lake and tube well

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

Following conclusions were drown from the current study

1. NUST lakes which store and harvest rain water were found to have pH, turbidity and color not within the permissible limits of standards.
2. All the three lakes were polluted with microorganisms (Total Bacterial Count and Total Coliform)
3. Alum showed comparatively good results than ferric chloride by improving water quality more efficiently.
4. After Pako Swiss treatment lake water was comparable with the NUST tube well water.

5.1.1. Recommendation

1. Three stage portable water filter was found most efficient for the improvement of NUST lakes water quality.
2. This treatment method can be successfully applied in any remote, dry (Thar, Thal and Balochistan) and arid site to treat rain harvested water.
3. This is the best option in flooded condition to provide drinking water.
4. This lake water can also be used for irrigation purpose without treatment.

REFRENCES

Ahmed, W., Brandes, H., Gyawali, P., Sidhu, J.P., Toze, S., 2014. Opportunistic pathogens in roof-captured rainwater samples, determined using quantitative PCR. Water Res. 15 (53), 361–369.

Ahmed, W., Huygens, F., Goonetilleke, A., & Gardner, T. (2008). Real-time PCR detection of pathogenic microorganisms in roof-harvested rainwater in Southeast Queensland, Australia. Applied and environmental microbiology, 74(17), 5490-5496.

Ahmed, W., Sidhu, J.P.S., Toze, S., 2012a. An attempt to identify the likely sources of Escherichia coli harbouring toxin genes in rainwater tanks. Environ. Sci.Technol. 46, 5193–5197.

American Water Works Association, (1999) "Water Quality and Treatment, A Handbook of Community Water Supplies", 5th Edition, McGraw-Hall: New York.

APHA. 2005. Standard Methods for the Examination of Water and Wastewater. 21st ed., American public Health Association, Washington D. C.

APSU., (2006). "Optimising multi-stage filtration units for use in Bangladesh", Arsenic Policy Support Unit, Dhaka, Bangladesh. as indicators of water quality in India. *Journal of Applied Bacteriology,* 72(4), 352-356.

Asami, T., Katayama, H., Torrey, J. R., Visvanathan, C., & Furumai, H. (2016). Evaluation of virus removal efficiency of coagulation-sedimentation and rapid sand filtration processes in a drinking water treatment plant in Bangkok, Thailand. Water research, 101, 84-94.

Augustine C.A, Nordin A, M. (2013) "operational performance of vertical up flow roughing filter for pre-treatment of leachate using limestone filter media. Journal of urban and environmental engineering, 7(1) 117-125.

Azizullah, A., M. N. K. Khattak, P. Richter and D. P. Hader. (2011). Water pollution in Pakistan and its impact on public health – A review. Environ. Int., 37,479-497.

Beikler, T. & Flemmig, T. F. (2011). Oral biofilm-associated diseases: trends and implications for quality of life, systemic health and expenditures. Periodontology, 55(1), 87-103.

Boers, T. M., & Ben-Asher, J. (1982). A review of rainwater harvesting. Agricultural water management, 5(2), 145-158.

Buhaug, H., & Urdal, H. (2013). An urbanization bomb? Population growth and social disorder in cities. Global Environmental Change, 23(1), 1-10.

Dassanayake, K.B., G.Y. Jayasinghe, A. Surapaneni and C. Hetherington. (2015). A review on alum sludge reuse with special reference to agricultural applications and future challenges. Waste Management., 38 ,321–335.

Dastanaie, A. J., Bidhendi, G. N., Nasrabadi, T., Habibi, R., & Hoveidi, H. (2007). Use of horizontal flow roughing filtration in drinking water treatment. *International Journal of Environmental Science & Technology*, *4*(3), 379-382.

Edberg, S., Rice, E. W., Karlin, R. J. & Allen, M. J. (2000). *Escherichia coli*: the best biological filtered drinking water supplies. *Applied and Environmental Microbiology*, 57(9), 2617-2621.

Galvis, Gerardo, Jan teun Visscher, and Barry Lloyd. (1992) 'Multi-Stage Surface Water Treatment for Community Water Supply in Colombia'. Waterlines 10.3 (1992): 26-29.

Gleick, P. H. (2000). A look at twenty-first century water resources development. *Water International*, *25*(1), 127-138.

Gleick, P.H., Palaniappan, M., (2010). Peak water limits to freshwater withdrawal and use. In: Proceedings of the National Academy of Sciences,107(25), 11155-11162. http://dx.doi.org/10.1073/pnas.1004812107.

Global Water Partnership (GWP) (2010). As found online in http://www.gwp.org/en/The-Challenge/The-Urgency-of-Water-Security/

Graham N ED (1988). "Slow sand filtration, recent development in water treatment technology", Wiley and sons Chichester England.

Grey, D., Sadoff, C.W., (2007). Sink or swim? Water security for growth and development. Water Policy, 9(6), 545-571. http://dx.doi.org/10.2166/wp.2007.0

Gwenzi., W., N. Dunjana, C. Pisa, T. Tauro and G. Nyamadzawo. (2015). Water quality and public health risks associated with roof rainwater harvesting systems for potable supply: Review and perspectives. Sustainability of Water Quality and Ecology., 6,107–118.

Hashim, H., Hudzori, A., Yusop, Z., Ho,W.S., 2013. Simulated based programming for optimization of large-scale rainwater harvesting system: Malaysia case study. Resour. Conserv. Recycl. 80, 1-9.

Hussain, S., van Leeuwen, J., Chow, C., Beecham, S., Kamruzzaman, M., Wang, D., & Aryal, R. (2013). Removal of organic contaminants from river and reservoir waters by three different aluminum-based metal salts: Coagulation adsorption and kinetics studies. Chemical engineering journal, 225, 394-405.

IUCN, U. (2009). WWF (1980) World conservation strategy: Living resource conservation for sustainable development. IUCN, Gland, Switzerland.

Jayalath J (1994). Algae removal by roughing filter. 20 th WEDC conference.

Karim, M. R., Rahman, S., Hossain, M. A., Islam, M. A., Mahmud, S. G., & Mahmud, Z. H. (2016). Microbiological effectiveness of mineral pot filters as household water treatment in the coastal areas of Bangladesh. *Microbial Risk Analysis*, *4*, 7-15.

Katukiza, A. Y., Ronteltap, M., Steen, P., Foppen, J. W. A., & Lens, P. N. L. (2014). Quantification of microbial risks to human health caused by waterborne viruses and bacteria in an urban slum. Journal of applied microbiology, 116(2), 447-463.

Kazmi, D. H., & Rasul, G. (2009). Early yield assessment of wheat on meteorological basis for Potohar Region. Pakistan Journal of Meteorology, 6(11), 73-87.

LeChevallier, M. W., Norton, W. D. & Lee, R. G. (1991). *Giardia* and Cryptosporidium spp. In filtered drinking water supplies. *Applied and Environmental Microbiology*, 57(9), 2617-2621.

Levy, K., Anderson, L., Robb, K.A., Cevallos, W., Trueba, G., Eisenberg, J.N.S., 2014. Household effectiveness vs. laboratory efficacy of point-of-use chlorination. Wa- ter Res. 54, 69–77.

Lloyd, B. and Helmer, R. (1991). "Surveillance of drinking water quality in rural areas". Harlow, UK, Longman Scientific and Technical.

Lye, D., 2014., Rooftop Runoff as a Source of Contamination: A Review. USEPA. 2014 Rainwater Resources. http://www.rainwaterresources.com/rooftoprunoff- source-contamination-review.

M. Yao, J. Nan, T. Chen, D. Zhan, Q. Li, Z. Wang, H. Li. (2015). Influence of flocs breakage process on membrane fouling in coagulation/ultrafiltration process-effect of additional coagulant of poly aluminium chloride and polyacrylamide, J.

Mahvi AH (2004). Performance of a DHRF system in treatment of highly turbid water. Iranian J. Environ. Health Sci. Eng. 1(1): 1-4.

Morales-Pinzon, T., Rieradevall, J., Gasol, C.M., Gabarrell, X., 2015. Modelling for economic cost and environmental analysis of rainwater harvesting systems. J. Clean. Prod. 87, 623-626.

Muhammad, A and Zahiruddin K. (2010). Rain water harvesting potentials for Rawalpindi and Islamabad. World Water Day, Pakistan Engineering Congress.

Mukhopadhay B, Majumder M (2008). Verification of filter efficiency of horizontal roughing filter by wegelin design criteria and artificial neural Network. Copernius publication.

Nkwonta, O. (2010). A comparison of horizontal roughing filters and vertical roughing filters in wastewater treatment using gravel as a filter media. International Journal of Physical Sciences, 5(8), 1240-1247.

Nzabuheraheza F.D, Katima J.H.Y, Njau K.N, Kayombo S and Niyigena N.A. (2012), "Wastewater treatment for pollution conrol" Rwanda Journal of Health Sciences (1)

Ochieng., GM and Otieno FAO (2004)." Performance of different filter media against conventional water treatment system", Watersa Vol. 30.

Oluka, S., A. L. Steigen and O. T. Randhir. (2013). Managing coliform contamination and chlorine by-products in urban water supply system in Uganda. Sustainability of Water Quality and Ecology., 1–2, 59–67.

Onda, K., LoBuglio, J., & Bartram, J. (2012). Global access to safe water: accounting for water quality and the resulting impact on MDG progress. International journal of environmental research and public health, 9(3), 880-894.

Oweis, T., Prinz, D., & Hachum, A. (2001). Water harvesting. Indigenous knowledge for the future of the drier environments. International Centre for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. p, 40.

Pacini V (2005). "Removal of iron and manganese using biological roughing up flow filtration technology". Water Res. 399: 4463-4475.

Pakistan Economy Survey, 2010- 2011.

Pakistan Environmental Protection Agency (Pak EPA), (2008), "National Standards for Drinking Water Quality" (NSDWQ).

Patil., V.B; Kulkarni., G.S. and Kore V.S (2012). "Performance of Horizontal Roughing Filters for Wastewater; A Review. International Research Journal of Environment Sciences' 1(2), 53-55.

R.D. Letterman, Water Quality and Treatment: A Handbook of CommunityWater Supplies, 5th ed., McGraw Hill, Inc., New York, 1999.

Rabindra. N.B. Diswajit. M., Pankaj K. R. Mazumdar. Asis (2009) "A study for estimating if bacteriological removal efficiency of HRF in combination of SSF" Journal of the IPHE India Vol.2008/9 (1).

Ramteke, P. W., Bhattacharjee, J. W., Pathak, S. P., & Kalra, N. (1992). Evaluation of *coliforms*
Ray, B. T., "Environmental Engineering, Southern Illinois University", PWS Publishing Company, 1993.

Sánchez, E., Colmenarejo, M. F., Vicente, J., Rubio, A., García, M. G., Travieso, L., & Borja, R. (2007). Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. Ecological Indicators, 7(2), 315-328.

Silas, O., L. Andreas, Steigen, O. Timothy and Randhir. (2013). Managing coliform contamination and chlorine by-products in urban water supply system in Uganda. Sustainability of Water Quality and Ecology., 1–2, 59–67.

Sittivate, D. (2000). How to Estimate and Design the Filter Run Duration of a Horizontal-Flow Roughing. Thammasat Int. J. Sc. Tech, 5(2).

Sukereman, A.S., Suratman, R., Hussin, K., (2013). The issues towards sustainability of water resource management and the current governance practice in managing water crisis in Malaysia. In: Proceedings of the International Conference on Social Science, ICSSR 2013, Penang, pp. 301-319.

Tamar R; Losleben P,(2004). "Study of Horizontal Roughing Filtration in Northern Ghana as Pretreatment for Highly Turbid Dugout Water" B.A. Environmental Science and Engineering, Rice University.

The Nation, 2008, estimate of disease spread in Pakistan.

Tiwari, R. C., Verma, D. N., & Mishra, A. K. (1995). Effect of long-term cropping systems on chemical characteristics of soil profiles. Journal of the Indian Society of Soil Science, 43(2), 278-279.

Trinh, T. K., & Kang, L. S. (2011). Response surface methodological approach to optimize the coagulation–flocculation process in drinking water treatment. Chemical engineering research and design, 89(7), 1126-1135.

Vuppaladadiyam, A. K., Sowmya, V., & Dasgupta, P. (2013). Comparative Study on Coagulation Process for Vellore Municipal Drinking Water Using Various Coagulants. Universal Journal of Environmental Research & Technology, 3(1).

Wegelin, M. (1996), "Roughing filters for surface water pretreatment. *In* Slow sand filtration: an international compilation of recent scientific and operational developments". American Water Works Association, Denver, Co 61–75.

WHO (2007). Guidelines for Drinking-Water Quality. Vol. 1. Recommendations. 2nd ed. Geneva, Switzerland, World Health Organization.

WHO/UNICEF, 2006. Core Questions on Drinking Water and Sanitation for House- hold Surveys. World Health Organization, Geneva.

World Bank (2014). Water: Overview, as can be found online at http://www.worldbank.org/en/topic/water/overview

World Health Organization (WHO), (2008), "Guidelines for Drinking-water Quality" Vol. 1, Third Edition.

World Health Organization. (2004). Guidelines for drinking-water quality (Vol. 1). World Health Organization.

World Health Organization. (2014). 20 Avenue Appia, 1211 Geneva 27, Switzerland.

World Water Development Report (WWDR), (2003). Water for People, Water for Life. United Nations Educational, Scientific and Cultural Organization (UNESCO) and Berghahn Books, Barcelona.

Zhao, Y.X., Y. Wang, B.Y. Gao, H.K. Shon, J.-H. Kim, Q.Y. Yue (2012) "Coagulation performance evaluation of sodium alginate used as coagulant aid with aluminum sulfate, iron chloride and titanium tetrachloride" Desalination 299: 79–88.