DRINKING WATER QUALITY ASSESSMENT OF METRO BUS STATIONS OF ISLAMABAD AND RAWALPINDI

By

ALEENA NAZIR

SAIMA LATEEF

ZOHAIB ASLAM

Department of Earth and Environmental Sciences

Bahria University, Islamabad, Pakistan.

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A thesis submitted to Bahria University, Islamabad in partial fulfilment of the requirement for the degree of B.S in Environmental Sciences.

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ABSTRACT

In this study, the drinking water quality of all Metro Bus Stations of Islamabad and Rawalpindi were analyzed. The main source of drinking water in this area is water from filtration coolers. The main purpose of this study was to determine the quality of drinking water in all Metro bus stations of Islamabad and Rawalpindi. For this, 24 water samples from filtration coolers were collected from all Metro bus stations of twin cities. The study aimed to analyze physicochemical and microbiological parameters. The overall result of the study showed that the concentration of all the physicochemical and microbiological parameters were within the permissible limits except the concentration of salts and few microbiological parameters exceeded the permissible limits given by WHO. Punjab Metrobus Authority (PMA) and Capital Development Authority (CDA) should start focusing on the quality of water as it is directly linked with human health.

ABBREVIATIONS

AHP	Analytic Hierarchy Process
CFU	Colony Forming Units
CDA	Capital Development Authority
DO	Dissolved Oxygen
EC	Electrical Conductivity
EMB	Eosin Methylene Blue
EBT	Eriochrome Black-T
EDTA	Ethylene diamine tetra acetic acid
EPA	Environmental Protection agency
NA	Nutrient Agar
NEQS	National Environmental Quality Standards
Mn	Manganese
MPN	Manufacturer Part Number
ORP	Oxidation Reduction potential
PCRWR	Pakistan Council of Research in Water Resources
SS	Suspended Solids
SS	*Salmonella Shigella*
TDS	Total Dissolved Solids
TA	Total Alkalinity
TC	Total Coliform
TC	Total Chlorides
TDS	Total Dissolved Solids
TH	Total Hardness

WHO	World Health Organization
WFP	World Food Programme
WAPDA	Water and Power Development Authority
WASA	Water and Sanitation Agency

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CHAPTER 1

INTRODUCTION

1.1 Water is Life

Water is the most wonderful substance. We use water for many purposes for washing, cooking, drinking for domestic purposes, and industrial and commercial purposes for washing and drinking. Water is universally present around and within us. Almost 70% of our planet comprise of water. Human body comprise of almost 60% of water. It is the most plentiful substance present in the universe particularly because it consists of hydrogen and oxygen (H_20) that are major 3 extensively found elements of the world. For a very short range of temperature, water exists in liquid form, but in this short-range and the liquidity of water, that is of great interest looking for unearthly life that also has potential planets giving rise to different habitats where human species can migrate to far places for future survival. Safe and clean water is necessary for all purposes in daily life which include different practices like washing, drinking, cooking, and personal cleanliness(Frances and Brack, 2018).

1.2 Water Resources on Earth

Water is the ultimate universal element to be found in the natural environment. Water is present in three states: liquid, solid, and vapours. The surface water is used to forms the oceans, seas, lakes, rivers, and underground waters that exist in the top layers of the Earth's crust and soil cover. Water that is present in solid state exists in ice and snow form in the alpine and polar regions. A particular quantity of water is present in the air in vapor form, water droplets, and ice crystals, and is also found in the biosphere. Large amounts of water are found in the composition of the various minerals present in the Earth’s crust and core. It remains in continuous motion, persistently changing from liquid to solid or gaseous form and vice versa.

Recent research predicts that the Earth's hydrosphere consists of a huge amount of water about 1386 million cubic kilometers. Whereas only 2.5% is freshwater remaining 97.5% of which is saline waters and. A large proportion of this freshwater (68.7%) is in the form of ice caps and snow.

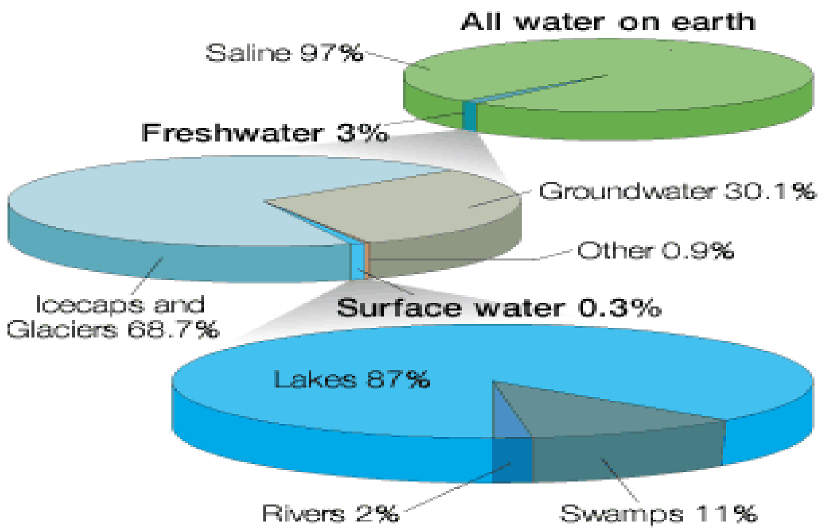

Figure1**Error! No text of specified style in document.**1 Global Distribution of Water (US Geological Survey Department of the Interior)

1.3 Fundamental Characteristics of water

Water is containing a large number of stimulating properties. These characteristics result in providing an ideal forum to encourage life on Earth. It is known as a universal solvent because it can dissolve a large proportion of natural or man-made substances. The state of water depends upon the boiling and freezing temperature of water, so they are classified into three phases; solid, liquid, and gas, that exist on Earth. when the water is in a freezing state it's lighter, so it floats. If water is in form of solid it will sink at bottom of the oceans. Therefore, in such conditions, we would have only a liquid narrow layer on the surface. When Water is in form of ice it floats because of the reason that it becomes lighter, this is the deviating property of water. There would be remarkably less global ocean currents, which would comprise of much of our nutrients. The existence of the life forms would not possible if these characteristics were not possessed by water(Balasubramanian, 2015).

1.4 Surface Water of Pakistan

In Pakistan, the main source of surface water is river, and its all-perennial branches have their origin in mountainous areas. The major source of water supply to these rivers are water runoff generated from seasonal rain in watershed areas, water generated from glacier melting, seepage from the geological formation. Jhelum, Chenab, Ravi, Beas, and Sutlej are the five main rivers that join Indus from eastern side and whereas three minor rivers are that running in Indus are Soan, Harrow, and Soan. Multiple small rivers join Indus from western side, the Kabul river with its tributaries is known as the biggest one i.e., Panjkora, Kumar, Swat, and many small streams other than this, such as Kohat, Khurram, Tank, etc. The catchment area of Indus river in total is 374,700 sq. in miles approximately 55% is 204,299 sq. miles is in Pakistan. Therefore, this data is used to demonstrate the variation of water inflow so we can used to develop strategies to meet irrigation and drinking needs of the country. The major hurdle in development of agricultural sector of Pakistan is seasonal variability. As Indus Basin is not having sufficient water during Rabi season and end of Kharif Season.

1.5 Ground Water of Pakistan

According to WAPDA research, in 1979 the level of water in 42% of Indus Basin was lower than 3 m which is known as waterlogged, while 22% of the area has water less than 2 m. The amount of water in Sindh depicts that 57% of the area has average water less than 3 m which is in result of waterlogging. Indus Basin data shows that water level in 1.5 m through 22% of the year. Whereas study shows that water level in the dams rise below the ground that resulted in waterlogging. Waterlogging in Indus basin is not only connected with Tarbela and Mangla Dams. The Indus Basin is made up of alluvial deposits that flow to Indus and the side streams of it and below by unconstrained aquifer that consists of almost 15 million acres in surface area. Nearly 78% of the area in Punjab and almost 28% of area in Sindh intrinsic with fresh groundwater, which is commonly used as subsidiary irrigation-water and pumped across tube wells. Some of the ground-water is salted and saline tube wells water is normally wasted and if its not possible, it can be discharged to the huge canals for irrigational (Alurralde et al., 1998).

1.6 Water Quality in Pakistan

People in Pakistan are currently having 79% of water supply. This insufficient supply of water and its bad quality causes health risks to the people. Faecal contaminated water is the main reason to waterborne disease. With quick urbanization, the chemical feature of water quality has contributed to increasing concerns as toxic chemicals industrial effluents pose a high hazard to life. Sadly, less attention is being given to drinking water standards. Due to well equipped laboratories shortage, poor management, and lack of a drinking water standards and legal framework creates a lot of problems.

1.7 Ground Water Quality in Pakistan

Commonplace information shows that Punjab water holds are 79% appropriate for utilization while Sindh new groundwater saves are 28% reasonable for utilization. The groundwater nature goes from (saltiness under 1000-mg/l TDS) close to the significant channels to greatly saline farther saltiness above 3000-mg/l TDS. Overall flow of fresh and seawater in nation is notable and planned the impacts of its substitutes for water system and supplies of drinking water. Groundwater Quality Total Area – 2931/Million acres salinity more than 3000-mg/l-TDS. During most recent twenty years, the waste framework in Pakistan shows improvement which is related with. critical increase in speculation yet, waterlogging is acritical issue in Pakistan.

1.8 Surface Water Quality in Pakistan

Based on Total Dissolved Solids (TDS) level water of Indus River and its branches is demonstrated best for its quality which is between 60 to 375 ppm. This is suitable for agroindustry, home-grown and mechanical utilization. Examination of streams shows that absence of preparation of removal of horticulture water which incorporates waste from composts and mechanical waste which incorporate heavy metals are the significant reasons for bad quality water in waterways. A study in 1995 on water quality shows that 3.4 billion litres of contaminated water were blended in streams and waterways. Besides, large city information shows that everyday wastewater level of Karachi and Lahore was 250 to 350 million gallons which are the noteworthy reason for the increase in infections related to utilization of polluted water by individuals.

1.9 Drinking Water Quality in Pakistan

In recent years people in Pakistan have gotten a lot of awareness regarding water quality, as poor water quality plays a very important role in health and environment. With sufficient land and groundwater wealth, Pakistan has been blessed, but unfortunately over the years, industrial development, over population, and rapid growth has slowed down the water resources(Daud et al., 2017). In both urban and rural Pakistan, drinking water quality has not been focused on. Different studies show that the majority of the supplies of potable water are polluted. In sites, the quality of groundwater is falling because of the natural contamination from sub-soils and anthropogenic behaviours(Aziz, 2005). The quality of water is not managed satisfactorily, in terms of drinking water, Pakistan ranks 80 out of 122 nations, and both ground and surface drinking water sources are polluted throughout the country with toxic metals, microbes, and pesticides(Nabeela et al., 2014). Even now-a-days some rural areas in Pakistan have no availability of fresh and clean water for their daily life. The water capitals of the country have been stressed immensely by rapid population growth and continuous industrialization. The extended deficiencies and population growth have further worsened water shortages and contamination. While Pakistan does have both ground and surface water resources, the availability of water per capita has fallen from 5600 m^3 to 1000 m^3 per year(Shahid et al., 2014). Quality of drinking water in Pakistan is reducing day by day due to the waste and pollutants released by the industries. Channeled water also gets contaminated because the network of the pipeline is not planned properly and laid poorly. This leads to the leachate being seeped into the water sources and cause diseases which are ware borne. Accordance with the report published by the Pakistan Council of Research in Water Resources, they monitored 369 drinking water sources out of which 116 water sources (31%), were supplying safe drinking water and 253 (69%) were determined as unsafe(Saiqa Imran, 2018).

1.10 Physical Properties of Drinking Water

Drinking water is also called potable water, which is safe to drink and it is accessed from freshwater bodies. Water is also an odourless liquid and can say tasteless, at standard temperate and pressure. It is a small solvent occupying about 55.5 moles/ litre at liquid stage at room temperature, however, it still possesses strong intermolecular bonds which are hydrogen bonds (H-bonds), between the oxygen and hydrogen atoms. And it is because of the H-bonds the boiling point, vaporization, and surface tension are quite high. However, by replacing the hydrogen atoms, bond can be destabilized which ultimately reduces the vaporization point, boiling point, and surface tension. Due to the immense strength of the unified interactions, specific heat capacity of water is also steep(Reimers et al., 1982)

1.11 Chemical Properties of Drinking Water

1.11.1 Dissolution Properties

As we probably are aware, water is named as all-inclusive dissolvable in light of the fact that it breaks up a considerable lot of the elements. Water particles have a polar course of action of the oxygen and hydrogen molecules one side has a positive electrical charge and the opposite side has a negative charge. That allows the water particle to get pulled into numerous other various sorts of atoms. Water can turn out to be so strongly dragged into an alternate particle, similar to salt that it can upset the appealing powers that hold the sodium and chloride in the salt atom together and, consequently, break up it. It additionally ready to split solutes considering the course of action of the molecules in its design. The particles are in a V-like arrangement. Since the connections between the oxygen and hydrogen are covalent, which implies that the electron is divided among the oxygen and hydrogen particles. A response called hydration happens when salts interact with water. Water breaks up surprizing number of salts which ends up being valuable factor in moving supplements. Water is an amazing dissolvable due to its high logic steady. The solutes which work together with water can either be hydrophobic or hydrophilic. Hydrophilic as the name demonstrate, water adoring the effectively break up in a water though hydrophobic are the solutes which don't blend or disintegrate with water. Substances like salt are hydrophilic and natural substances like oil are hydrophobic. The dissolving capacity of water likewise relies upon the way that whether that other compound s can beat the bonds in the water particles(Reimers et al., 1982).

1.11.2 pH Properties

Water in nature is occasionally unadulterated in the refined water since it contains broke down salts, cradles, supplements, and so forth, with accurate focuses reliant on nearby conditions. pH gauges the causticity and basicity of a substance, even more eagerly it alludes to the measure of free hydrogen and hydroxyl particles in the water. Water is known to be at an unbiased pH of 7, which implies it neither acidic nor fundamental. It is profoundly important that the water stays at an impartial pH on the grounds that just at this state it is protected to burn-through. Water additionally portrays the buffering limit which is the capacity of water to keep the pH steady as the bases or acids are added into it. The boundaries we chose are referenced underneath in the content. To keep the prosperity of any amphibian framework at an ideal level, certain water quality pointers or boundaries should be checked and controlled. The physicochemical boundaries give a top to the bottom point of view on the capacity and design of the water body(Asadullah et al., 2013).

1.12 Water Pollution

The prompt reason for expanding water contamination is the development of wastewater flowing towards rivers and lakes. Extreme reason of an increase in population, economic progress strengthening and extension of agricultural development, and expanded sewerage with no or a low degree of treatment. Among the gatherings generally helpless against water quality weakening in agricultural sectors are ladies as they are using more surface water for domestic purpose, kids due to their play exercises in neighbourhood surface waters, and in light of the fact that they regularly have the assignment of gathering water for the family, low-pay country individuals who devour fish as a significant wellspring of protein, and low-pay fishers and fishery laborers who depend on the freshwater fishery for their business. Although water contamination is not kidding and deteriorating in Latin America, Africa, and Asia, most of streams on these three mainlands are as yet in great condition, and there are incredible chances for shortcutting' further contamination and re-establishing the waterways that are dirtied. A blend of the board and specialized alternatives upheld by great administration will be required for these errands(Khan and Salam, 1997).

Although water pollution is serious and getting worse in Latin America, Africa, and Asia, the majority of rivers on these three continents are still in good condition, and there are great opportunities for shortcutting' further pollution and restoring the rivers that are polluted. A mix of management and technical options supported by good governance will be needed for these tasks(Bush, 2020).

1.13 Global water crisis

Water is a vital piece of life. An aggregate of just 39. water is available as freshwater on earth as a feature of all-out volume of water on earth. For humans utilize the measure of new water open and present is 0,01% as it were. The measure of treated water present is in steady damage in view of the absence of water preservation plans, modern area works, and exercises, quickly developing populace development us, insufficient use or water in ventures and agrarian area. Secured and safe drinking water is a major prerequisite for better wellbeing, and it is an essential right of people. New water is present in even the destinations focuses on around the universes numerous parts, with developing populace rates, climatic. conditions advances and Metropolitan improvement's water will turn out to be more pressure source in the following century(Jackson et al., 2001). An anticipated 1.1 billion individuals have no sources to get the secured and great quality drinking water. Alongside 2.5 billion individuals don't have appropriate administrations for disinfection. Every year an excess of 5 million individuals loses their lives because of the illnesses identified with water. Individuals' death rates are multiple times more than the normal pace of passing's of individuals from wars. Water is utilized in overabundance sums as opposed to in a controlled manner. Then again, regardless of whether the accessibility of water is in huge sum and still, after all that the water. quality and amount are in danger because of the universes developing, urbanization, and populace. Two third of the populace living on the planet should endure the hurtful effects of water shortage before the finish of 2025(Worldwildlife, 2021).

1.14 Literature Review

Clean drinking water is a fundamental human right in any area of the world. Because of a growing population and due to pollution resulting from anthropogenic activities, this fundamental element is at risk. This condition is more adverse in developing countries where no examination and conservation are followed. This study depends upon analysing of drinking water filtration plants in two populated twin cities of Pakistan to examine the drinking water quality condition. To access the drinking water quality, the water sample was taken from Sanitation Agency (WASA) in Rawalpindi and filtration plants installed by Capital Development Authority (CDA) in Islamabad. To analysed physio-chemical parameters metals standard procedures were used and health risks and variable marks were estimated. The analytical outcome of all the filtration plants indicated that alkalinity, electrical conductivity, and arsenic were above the permissible limit followed by World Health Organization. In Rawalpindi 32 out of 53 samples, while in Islamabad 26 out of 32 samples were found below indigent water quality with water quality index greater than 100. Risk index of arsenic was observed. Arsenic was the crucial cause of water contamination in the study area. It also creates the hazard to health conditions especially in children in Rawalpindi and Islamabad. The water quality index was also measured and mostly water samples resulted in adverse condition. Islamabad was observed to have more unsafe drinking water than Rawalpindi Pakistan. Majority of filtration plants were observed to provide poor quality drinking water. Microbiological elements were used to monitor the health hazards occurred due to water pollution. Proper techniques should be use for management and sustainability of drinking water quality maintained. This research provides information about water quality in two populated cities of Pakistan(Sohaila et al., 2020).

The administration of drinking water in complex system is a technological confrontation with both in quantitative and qualitative terms. It is necessary that every part of the framework be supplied without interference with a constant flow of water organizing with all the qualitative parameters of the drinking water quality operation. This is necessary to establish the safety of public health and general hygiene of community. Various microbiological and physicochemical reactions are performed in drinking water dispensation systems and provoke phenomena through which the bacteriological attribute of the disseminate water are altered. Remembered, the study was performed to analyze the dissemination network water supply to the individuals of sector I-9 Islamabad as per Standard Methods. Total and fecal coliforms and quality counts were estimated for microbiological analysis, whereas physicochemical research was held to examine pH, turbidity, temperature, TDS, conductivity, free chlorine, and chloramines. Water diffusion system was demonstrated for a month. Samples was gathered from eight different points. Facts exhibit that the residual chlorine value is low in concentration. This low concentration of residual chlorine generated in high level of microbial pollution. Standard of water supplied to group was inadequate as much of the samples gathered were faecal contaminated. Low budget provision, governance and develop infrastructure are some reasons. Execution of national drinking water strategy and plans should be incorporated to for provide clean drinking water to people. The purpose of this study was to estimate the purity of potable water in flow within I-9 / 4 sector of Islamabad and propose safety measures to lower the rate of occurrence of water-borne diseases(Yasin et al., 2012).

With a purpose to confirm the water best for human consumption the microbial contamination turned into analysed in a potential have a look at which become conducted in collaboration with country wide Institute of fitness, Islamabad. This surveillance painting was carried out for the duration of the months of July to August at the height of summer season. with a purpose to evaluate the goal parameters for assessment of the public fitness issues inside the peri-city areas of each Islamabad and Rawalpindi, a move section of general 108 water samples from different assets become analyzed by means of well-known microbiological techniques. To estimate the number of fecal coliforms in water samples, the most likely range (MPN) technique become used and it turned into found that among the entire water samples, sixty-eight. five% had overall viable rely on and 39.9% have been fantastic for *Escherichia coli*. This looks at highlighted the poor hygienic situations of the water pleasant standards in this area of research. The associated endemic fitness troubles may be checked via taking appropriate preventive measures to forestall the predominant outbreak within the destiny(Yasin et al., 2012).

To determine the frequency of microbiological contamination of water in exceptional water filtration in Islamabad. This take a look at is descriptive move-sectional examine. Water samples have been accrued in sterilized bottles in line with the standard water sampling protocol from website and transported to Pakistan Council for studies in Water assets (PCRWR) for analysis. Microbiological fine of water turned into determined in phrases of total coliforms (< 2.0 MPN/100 ml) and *Escherichia coli* (< 2. zero MPN/100 ml). Microbiological infected water become described the pattern which had greater than 2. zero MPN consistent with one hundred ml of both total coliforms and *Escherichia coli.* Thirty-two WFP were analysed for microbiological contamination. *E.*

coli became present in eight (25.0%) water samples, at the same time as 24 (75.0%) water samples had been free from it. total coliforms had been present in thirteen (40.6%) of the samples of WFP, even as 19 (59.3%) samples had been loose from overall coliform. Faecal coliforms were found in eight (25. zero %) and absent in 24 (75.0%) samples. each *E. coli* and overall coliform had been found in eight (25.0%) samples. 9 (fifty-nine.3) WFP had been loose from *E. coli*, total coliform, and fecal coliform. Statistically, no great affiliation was found (p > zero.05) between microbiological infection and the sectors. Less than half of the water samples of the WFP had been infected while sure sectors confirmed extra common contamination than others(Hisam et al., 2014).

Water quality analysis has ever been the most prominent part of environmental standard management. The recent research included the appropriateness examination and preparation of groundwater quality for rural movements and valuing purposes Rawalpindi and Islamabad zone. A sum of 22 examples was collected from borewells and open wells, and these water tests were furthermore assessed for physical and complex qualities based on which diverse lists were established. Water quality file was revealed for normally water quality measurement from the perspective of human utilization. The results demonstrated that a more notable amount exhibited low quality for drinking due to over-misuse of groundwater quality, rural effect, and direct influx of foreign substances. Further, assessment of groundwater for its practicality for water system demonstrated that greater part of the groundwater was appropriate for water system purposes(Shabbir and Ahmad, 2015).

The weakness assessment is consistently an underlying advance toward manageable turn of events. Consequently, the regionalization of the evaluation to judiciously use and create water assets and anticipating the enhancement of the weakness status is vital and has pragmatic importance. The current examination was intended to break down the weakness status of the water asset framework in Rawalpindi and Islamabad with the assistance of Analytic Hierarchy Process (AHP) keeping in view the unpredictable, coordinated, thorough and progressive nature of weakness assessment of water assets. The weakness record created as a blend of climatic and financial components chose based on their importance, significance, and logical believability. The water assets in the two zones were found generally open to the financial elements upgrading the impact of climatic elements. The weakness of water assets is of uncommon importance and needs a ton of consideration of specialists and strategy producers(Shabbir and Ahmad, 2016).

1.15 Scope and Objectives

This study evaluates the various physical and chemical parameters of drinking water in Metro bus stations of twin cities Islamabad and Rawalpindi.

The objectives of this study were:

a) To assess the physiochemical parameters (pH, TDS, hardness, chloride, electrical conductivity, alkalinity, ORP, salts) and other microbiological elements such as *E coli* bacteria, total bacteria count, total coliform, *salmonella*, *shigella* concentration of the drinking water at Metrobus stations of Islamabad and Rawalpindi.
b) To check the hygiene level and assessment of drinking water present in Metrobus station of Islamabad and Rawalpindi.

CHAPTER 2

MATERIALS AND METHODS

2.1 Methodology

To determine the water quality of Islamabad and Rawalpindi Metro bus filter water cooler, quantitative research methods are used. The methodology modifies for the research work is shown in the flow chart below:

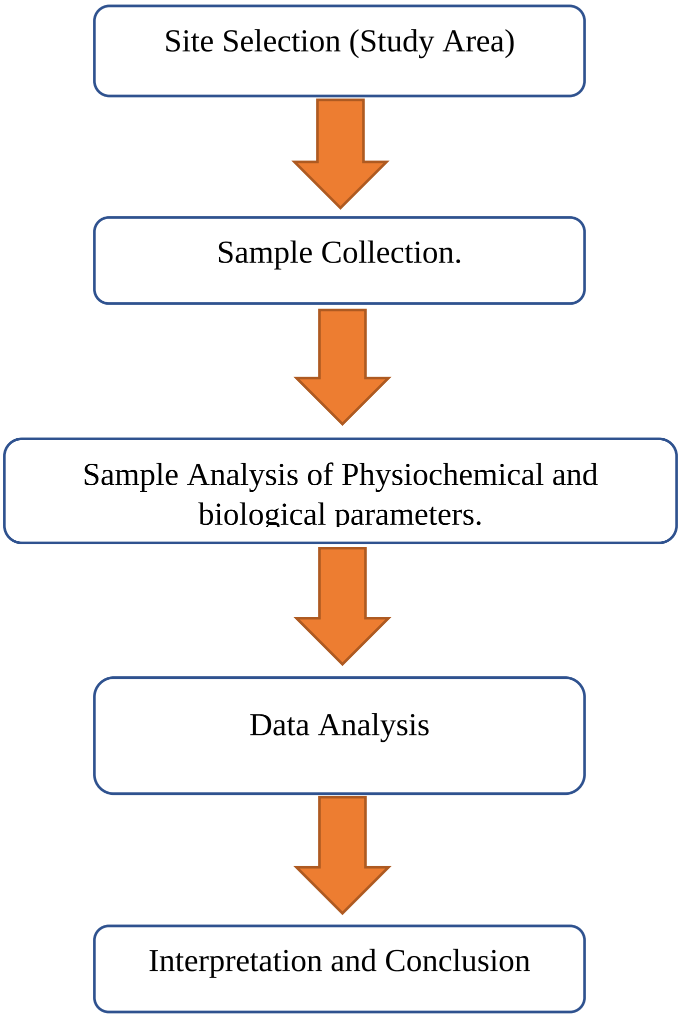

Figure2.1 Flow chart showing research work methodology

2.2 Study Area

The study area selected for the study was water coolers of Rawalpindi and Islamabad Metro bus station. The Islamabad city is situated at the northern side of the Potwar (Pothohar) Plateau at a height of 540 m (1,770 ft), south of scope of Himalayan lower regions known as the Margalla Hills. Islamabad exists in the little Islamabad Capital Territory which borders the Pakistani territories of Punjab and Khyber Pakhtunkhwa. Rawalpindi is a city located in the province of Punjab, it is adjacent to Pakistan’s capital of Islamabad, it1s located at latitude 33.626057, longitude 73.071442. The Rawalpindi-Islamabad Metro bus is a 22.5 km (14.0 mi) transport fast travel framework working in the Islamabad Rawalpindi Metropolitan territory of Pakistan. The Metro bus organization's first stage was opened on 4 June 2015, and extends 22 kilometers between Pak Secretariat, in Islamabad, and Saddar in Rawalpindi. The subsequent stage is at present under development and extended 25.6 kilometers between the Peshawar Moor Interchange and New Islamabad International Airport. The framework utilizes an Intelligent Transportation System and is overseen by the Punjab Mass Transit Authority. The 23.2km land has 10 transport stations in Rawalpindi and 14 in Islamabad. Water supply in Islamabad and Rawalpindi Metro bus station is the electronic water coolers that were introduced at each station to serve cold drinking water to peoples however they had lost their importance as power supply was discovered detached to them and the workers had to drink boiling water.

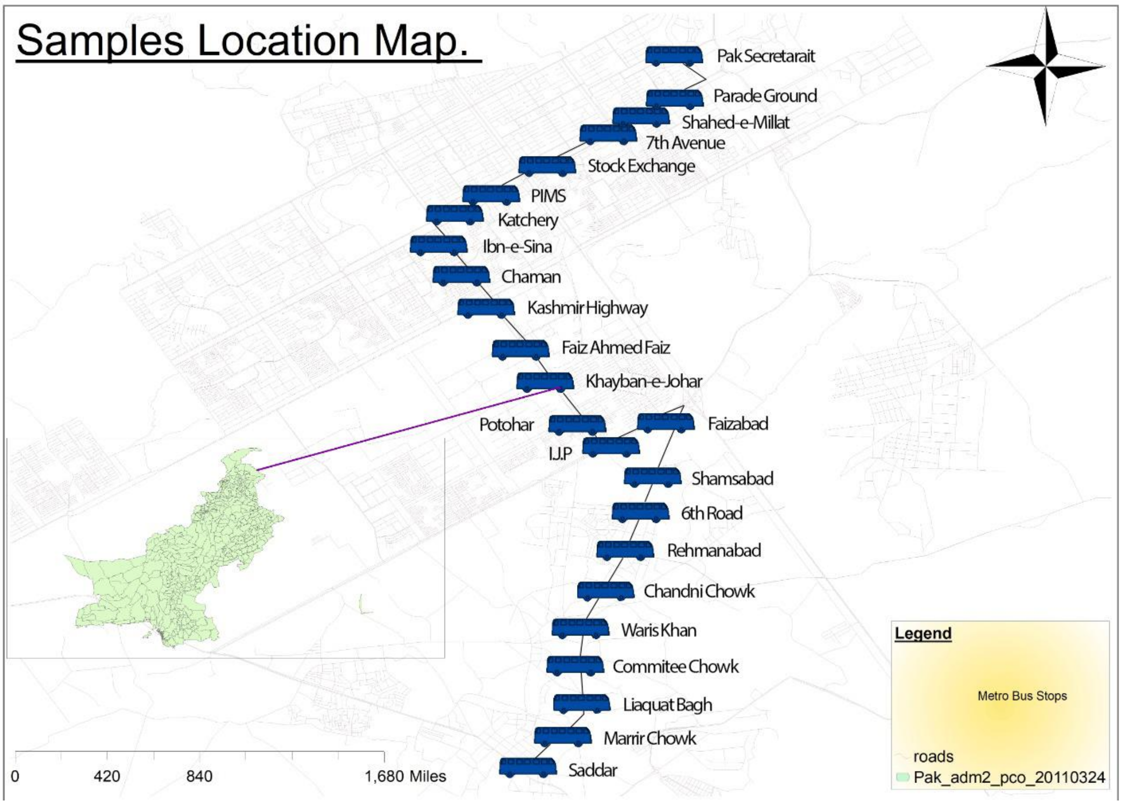

Figure 2.2 Map showing study area

2.3 Sampling Methodology

The samples were collected from Islamabad and Rawalpindi all water cooler of Metro bus stations. The investigation was led on sifted water gathered from water coolers of Rawalpindi and Islamabad Metro bus station. Each example was examined for subjective microbiological parameters, physical parameters, and chemical parameters of organic contamination. A sum of 24 water samples were collected from Islamabad and Rawalpindi Metro bus stations. Samples were collected independently for microbiological assessment and physiochemical examination. For microbiological assessment, each sample was gathered in 100 ml sterilized bottle. For physiochemical investigation 150 ml water was gathered per test in plastic bottles. All the samples were moved to the lab for examination. All the tests were carried out in the laboratory of Bahria University Islamabad Campus.

Figure 2.3 Sample collection from Metro bus station

2.4 Analysis of water quality parameters

A total of 14 water quality parameters were chosen to calculate the water quality index (WQI). Water samples were collected from all Metro stations of Islamabad and Rawalpindi and transported to laboratory for analysis.

Table 2.1 Methods used for sample analysis

Sr. No.	Parameters	Equipment and methods used
1	pH	Digital Multi-meter
2	Electrical Conductivity	Digital Multi-meter
3	Total Salts	Digital Multi-meter
4	Total Dissolved Solids	Digital Multi-meter
5	Turbidity	Turbidity Meter
6	Temperature	Digital Multi-meter
7	Total Hardness	Titration with E.D.T. A
8	Calcium	Titration with E.D.T. A
9	Magnesium	Titration with E.D.T. A
10	Total Sodium	Argentometric Titration
11	Total Chlorides	Argentometric Titration
12	Total Alkalinity	Acid-Base Titration
13	Carbonates	Acid-Base Titration
14	Total Bacteria	Plate count method on Nutrient Agar
15	*Salmonella* and *Shigella*	Plate count method on SS Agar
16	*E. Coli*, Total Coliforms	Plate count method on EMB Agar
17	Gram Staining	Microscopic Study

2.5 Physical Parameters

Physical parameters include pH, Temperature, Electrical Conductivity, Total Dissolved Solids, Turbidity, etc.

2.5.1 Temperature

Water temperature was calculated using a centigrade thermometer at the sampling station itself. Readings were noted by immersing a thermometer into the water sample and results were noted in degree centigrade.

2.5.2 pH, EC, TDS, and Salt

These three parameters, pH, EC and TDS, and Salts were calculated using a digital Meter. The digital meter was Hanna Instrument Model-HI 8424 which was standardized according to the manufacturer’s instruction, it is consists of four modes for calculating pH, EC, TDS, and Salts. Before calculating every sample, the electrode was first washed thoroughly with distilled water and then electrode was immersed in the sample water and was allowed to balance for about 1-2 minutes before taking the final reading.

2.5.3 Turbidity

The turbidity of water is depending on the presence of suspended particles. Turbidity shows the presence of suspended solid particles like silt, clay, organic matters, algae, and some microorganisms. We added water sample into small jar that was wipe with soft tissue and placed into the turbidity meter. Covered the sample cell and waited until the value of turbidity meter was stable. When the value of water sample stabilized, we noted the turbidity value of the water sample(Lindsay, 1960).

2.6 Chemical Parameters

Chemical parameters of water samples such as total alkalinity, total hardness, chlorides, carbonates, etc. were tested by using titration methods.

Figure 2.3 Chemical analysis performance

2.6.1 Total Hardness

Water Hardness is defined as the presence of calcium and magnesium concentrations in water. Total Hardness was estimated by EDTA Titration Standard Method. By WHO, calcium carbonate at concentrations below 60 mg/l in water is viewed as soft; 60–120 mg/l even as especially hard water, 120–180 mg/l is viewed being a hard water and greater than 180 mg/l is consider being so hard water. The permissible limit set by WHO for hardness of drinking water is 500 mg/l.

Instruments

- Burette
- Pipettes
- Volumetric flasks
- Stirrers
- Funnel

Procedure

The reagents used were:

i. 0.01M EDTA solution
ii. NH_4Cl Buffer solution
iii. Eriochrome Black-T (EBT) indicator

Take 50 ml water sample in a conical flask and add 2 ml of buffer solution (NH_4Cl). The pH of buffered solution should be around ±10. Added 2-3 drops of Eriochrome Black-T (EBT) indicator with standard EDTA solution and stir the flask continuously until the last reddish color changed to bluish-purple color. The formula used was:

$$\text{Total Hardness (mg/L)} = \frac{A\ X\ B\ X\ 1000}{ml\ of\ sample}$$

where,

A= mL of EDTA used for sample – mL of EDTA used for blank.

B= mg of $CaCO_3$ equivalent to 1mL of EDTA titrant (which is equal to 1 mg $CaCO_3$).

Calcium: Calcium is the major contributor causing the total hardness of water. Calcium is necessary for body as long as under the permissible limit set by WHO which is 100 mg/l.

Reagents Used

i. Standardized Solution: 0.01M EDTA
ii. Buffer Solution: 1N NaOH
iii. Indicator: Eriochrome Black-T (EBT)

Instruments

- Burette
- Pipettes
- Volumetric flasks
- Stirrers
- Funnel

Procedure

Method used for analysis of calcium concentration in the samples was EDTA Titration Standard Method (2017). In a conical flash 50 ml of sample water was taken, to this 2 ml of NaOH solution was added along with 2-3 drops of EBT. The solution was then titrated against standard EDTA solution until endpoint was reached i.e., colour changed from reddish-purple to blue. This test was first to run for a blank solution by using distilled water. The formula used was:

$$\text{Calcium (mg/L)} = \frac{A\ X\ B\ X\ 1000}{ml\ of\ sample}$$

where,

A= mL of EDTA used for sample – mL of EDTA used for blank.

B= mg of $CaCO_3$ equivalent to 1mL of EDTA titrant (which is equal to 1 mg $CaCO_3$)

Magnesium: Permissible limit for Mg in water as recommended by WHO is 30 mg/l. Mg was calculated as by taking difference between total hardness and calcium hardness.

2.6.2 Salts by Chemical Method

Chloride (Cl): Chloride ions are one of the major inorganic anions present in water. The main objective of measured of chloride ions can be used to determine salinity of different water sources. Total Chlorides were analyzed using Standard Silver nitrate titration method.

Reagents used.

i. Standard silver nitrate solution ($AgNO_3$)
ii. Potassium chromate indicator (K_2CrO_4)

Instruments

- Burette
- Pipettes
- Volumetric flasks
- Stirrers
- Funnel

Procedure

In a conical flask a 10 milliliter of water sample was taken. Then 2 to 3 drops of indicator, potassium chromate was added and titrated once more against 0.01N $AgNO_3$ solution until the color interchanged to a pinkish yellow. From the amount of silver nitrate used as a titrant, the amount of chloride present was calculated by using this formula:

$$\text{NaCl (mg/L)} = \frac{\text{V x N of AgNO3 x 1000 x 58.45}}{ml\ of\ sample}$$

Where,

V= volume of $AgNO_3$ consumed for a sample.

N= Given normality of $AgNO_3$ = 0.01 N

Molecular Weight of Cl= 35.5 g/mol

Sodium Chloride (NaCl): To measure the amount of sodium ion concentration in water, first Sodium Chloride (NaCl) concentration in water was measured using the same titration method which was used as for total chloride.

Reagents used.

i. Standard silver nitrate solution ($AgNO_3$)
ii. Potassium chromate indicator (K_2CrO_4)

Instruments

- Burette
- Pipettes
- Volumetric flasks
- Stirrers
- Funnel

Procedure

In a conical flask a 10 ml of water sample was taken. Then added 2 to 3 drops of drops of indicator, potassium chromate and titrated once more 0.01N AgNO3 solution until the color interchanged to a pinkish yellow. From the amount of silver nitrate used as a titrant using the formula, the amount of sodium chloride present was calculated:

$$\text{NaCl (mg/L)} = \frac{\text{V x N of AgNO3 x 1000 x 58.45}}{ml\ of\ sample}$$

Where,

V= volume of $AgNO_3$ consumed for sample

N= Given normality of $AgNO_3$ = 0.01 N

Molecular Weight of NaCl= 58.45 g/mol

Sodium (Na): To measure the amount of sodium ion concentration in water, number of total chlorides was subtracted from sodium chloride (NaCl) that giving the concentration of Sodium remaining in the sample.

2.6.3 Total Alkalinity

Water alkalinity is measure of its acid-neutralizing capacity. Alkalinity is due to primarily salts of weak acids or Strong bases. Total alkalinity was determined by acid titration using methyl-orange as an indicator.

Reagents used:

i. Standardized Acid (H_2SO_4)
ii. Methyl Orange Indicator

Instruments

- Burette
- Pipettes
- Volumetric flasks
- Stirrers
- Funnel

Procedure

50 ml of water sample was taken in a flask and then added 2 drops of methyl orange indicator and it was slowly titrated against 0.02M H_2SO_4 until the color changed from yellow to colourless. The volume of acid used was noted. The procedure was repeated again three times for each sample. All samples were tested in the same way,

$$\text{Total Alkalinity (mg/L)} = \frac{\text{Volume of acid used x 0.02M x 50000}}{\text{ml of sample}}$$

2.6.4 Carbonates

Carbonates are the salts of carbonic acids. To measure the amount of carbonates concentration in water.

Reagents Used

i. Standard Solution of 0.1 N HCL
ii. Methyl Orange Indicator

Instruments

- Burette
- Pipettes
- Volumetric flasks
- Stirrers
- Funnel

Procedure

A 10 ml of water sample was taken in a conical flask. Then added 2 to 3 drops of methyl orange as indicator and start titrated solution until the colour changed to a pale yellow to orangish-red. Amount of carbonates was calculated by first finding unknown molarity of the solution and then multiplying this value with molecular weight of each carbonate. Molarity is calculated by using the formula:

$$M_1V_1 = M_2V_2$$

$$M_1 = (M_2V_2)/ V_1$$

After finding molarity, this value is multiplied by molecular weight of the required carbonate, by using the formula:

$$\text{Amount per } dm_3 == M \times \text{Molecular Weight of chemical compound}$$

By using this method concentration of $NaHCO_3$, Na_2CO_3, HCO_3 and CO_3 was determined.

2.7 Microbiological parameters

Microbiological parameters are more important than physical and chemical parameters because microbiological parameters directly affect human health and cause different types of disease. Microbiological parameters are used to describe the presence of microorganisms in drinking water. Many microorganisms can cause illness when directly consumed by humans and animals.

2.7.1 Sample collection

1. First of all, cap was removed from the sample bottle by holding the exterior part of the cap between two fingers and the bottom of the bottle in the other hand. This avoids possible contamination from hands.

2. Carefully the bottle was filled to 100 ml. The sample must contain at least 100ml for the test to be run. Do not overfill the bottle and allow water to flow down the sides as contamination may occur.
3. Immediately caped the sample bottle tightly and turned off the flow of water.
4. Recorded the time, date, and location of sampling on the paperwork provided by the Lab. Delivered the sample with paperwork to the Bahira University Lab for analysis.
5. Samples need to arrive at the lab within 24 hours of the sample being taken to allow the lab time to analyze the sample within the mandated 30-hour timeframe.

A total of 24 samples of drinking water were collected from different stations and were analyzed bacteriologically to identify the presence of any biological colonies.

2.7.2 Types of bacteria

Four types of bacteria were tested in our whole water sample. These are the following:

2.7.2.1 Total Bacteria

It shows the number of microorganisms present in the drinking water sample. It gives a quantitative evaluation of the total number of bacterial colonies forming per milliliter of drinking water sample. The value of count is then compared with the standard value.

2.7.2.2 Total Coliforms (TC):

Coliforms are a group of bacteria found in soil, on vegetation, and in the intestines of warm-blooded animals and humans. They are not normally found in groundwater that is well protected from surface influences. Most are not disease-causing bacteria, but they serve as an indicator of the sanitary condition of a water supply. If coliform bacteria are present, it may be possible for *E. coli* or other disease-causing bacteria to enter the system. The presence of Total Coliforms in water samples because of their sensitivity to chlorine it can signify the existence of a biofilm or can serve as an indicator of treatment effectiveness.

2.7.2.3 *E. coli*:

E. coli is the most reliable indicator of enteric diseases and is therefore the indicator of choice to indicate existence of recent fecal contamination in drinking water systems. One exception is in tropical climates where *E. coli* may be existing and multiply in waters not directly subject to fecal pollution. Only some strains of *E. coli* bacteria can trigger disease and only under certain conditions. When a sample of water is tested for the existence of the indicator *E. coli*, results indicate mainly non-pathogenic strains of *E. coli*. A few strains of *E. coli* can be harmful while some compassionate strains of *E. coli* microorganisms are significant in making a sound intestinal tract. If pathogenic *E. coli* is present in water, it can cause around serious intestinal infection.

2.7.2.4 Salmonellosis and Shigella:

Salmonellosis is an infection triggered by the bacteria called *Salmonella*, which has been known to cause illness *salmonella* may be found in water sources such as private wells that have been polluted with the faces of infected humans or animals. Waste can enter the water through different ways, including sewage overflows, sewage systems that are not working properly, contaminated stormwater runoff, and agricultural runoff. Wells may be more hazardous to such contamination after flooding, particularly if the wells are shallow, have been dug or bored, or have been submerged by floodwater for a prolonged time. The most possible health risks associated with *Salmonella* bacteria are Gastroenteritis and typhoid fever. Older people, children, and individuals with comparatively weak immune systems are mostly affected by this type of bacteria.

Shigellosis is a transmittable disease produced by a cluster of bacteria recognized as *Shigella*. *Shigella* infection (shigellosis) is an intestinal sickness caused by a group of microscopic organisms known as *Shigella*. *Shigellosis* is one of the highly infectious types of diarrhea triggered by bacteria. The bacteria can go through the water across numerous ways, involving sewage overflows, sewage systems that are not functioning properly, and contaminated stormwater runoff. Wells might be susceptible to such pollution after flooding, especially if the wells are narrow, have been dug, have been submerged by floodwater for prolonged intervals of time. The most possible health risks related to *Shigella* bacteria include intestinal diseases including dysentery.

2.7.3 Media for Bacteria Testing:

Different types of nutrients are used in order to culture different microorganisms.

1. NA (Nutrients agar)
2. EMB (Eosin methyl blue agar)
3. SS (*Shigella* and *salmonella* agar)

2.7.4 Total Plate Count Method

In total plate count method, the sample is spread on agar media for bacterial growth and then analyzed. Different agar solutions are used for the detection of different types of bacteria. To regulate total bacteria, colonies are grown on nutrient agar. For the determination of *salmonella* and *shigella*, SS agar is used and for total coliforms and *E. coli*, EMB agar is used.

Materials Used

Materials used in this analysis are as:

1. Reagent glass bottles
2. Cotton plug
3. Glass cylinder
4. Nutrient agar (28g in 1 liter)
5. *Salmonella Shigella* agar (52g in 1 liter)
6. EMB agar (37.5g in 1 liter)
7. Spatula
8. Balance/ weight machine
9. Autoclave
10. Incubator
11. Laminar flow hood
12. Glass spreader
13. Spirit lamp
14. Methylated spirit
15. Micropipette tip
16. Petri plates

Preparation for Agar Solution

NA (Nutrients agar), EMB (Eosin methyl blue agar) and SS (*Shigella* and *salmonella*) are present in powder form. For microbiological testing of water samples, liquid solution is required. 28 grams NA for 1000 ml distilled water, 37.5 grams EMB for 1000 ml distilled water, and 52 grams SS for 1000 ml distilled water.

For the preparation of 400ml agar media for each agar, this formula gives the actual value for 400ml solution.

For Nutrient Agar (N.A)

$$\text{S.S} = \frac{28\text{g x }400\text{ml}}{1000ml}$$

$$\text{N.A} = 11.2\text{g}$$

*11.2g of N.A was dissolved in 400ml of distilled water to prepare the required 400ml of N.A agar solution.

For Eosin Methylene Blue Agar (E.M.B)

$$\text{E.M.B} = \frac{37.5\text{g x }400\text{ml}}{1000ml}$$

$$\text{E.M.B} = 15\text{g}$$

*15g of EMB agar was dissolved in 400ml of distilled water to prepare the required 400ml of EMB agar solution.

For *Salmonella Shigella* Agar (S.S)

$$\text{S.S} = \frac{51\text{g x }400\text{ml}}{1000ml}$$

$$\text{S.S} = 20.8\text{g}$$

*20.8g of SS agar was dissolved in 400ml of distilled water to prepare the required 400ml of SS agar solution.

Procedure

Prepared solutions of N.A, E.M.B, and S.S were present in glass reagent bottles. All three bottles of agar solution were placed inside the autoclave machine at 121°C for 30 minutes. Autoclave machine is used to decontaminate microorganisms and sterilize the instrument.

It took 2-3 hours to release the pressure built-up in the autoclave, and after approximately 3 hours, the solution was prepared to use. After the solutions were autoclaved and cooled slightly, 20ml of each agar media was poured in 24 sterilized Petri-plates and was permitted to solidify. 100µl volume from each sample was drawn up with the help of a micropipette tip and was inoculated on the surface of the pre-solidified agar plates by using a sterile L-shaped glass rod called spreader. All the procedure was performed inside the laminar flow hood to prevent the microbial contamination.

Figure 2.4 Performance of microbiological testing

After the sample water is absorbed inside the agar medium, the plates were covered, sealed, and then placed inside the incubator aerobically at 35°C for up to 18-24 hours. After incubation, the colonies on each plate were counted and results were reported as Colony Forming Units (CFU/ml) (Helmi et al., 2015).

Figure2.5 Petri dishes placed inside the incubator

2.7.5 Gram Staining

Gram staining is a technique in which 4 types of reagents are used to identify the two different types of bacteria which are Gram-positive bacteria and Gram-negative bacteria

Reagents

- Crystal violet
- Gram's Iodine
- Decolorizer (e.g., ethanol)
- Safranin

Instruments

- Spirit lamp
- Glass slides
- Distilled water
- Sterile loop
- Microscope

Procedure

1. Added the water drop on the slide and picked the bacterial colonies from Petri dish with the help of loop and spread on the water drop in 1.5 cm in diameter. The culture dried on the slide with the help of flame. During this time, Slides moved in a circular shape. Flame heat helped the cell adhesion on the glass slide. Taking slide in and out of flame formed ring pattern on glass slide.
2. Waited 10 to 60 seconds after added crystal violet stain on the bacterial culture; for prepared slides, pouring the stain on and off immediately is generally appropriate. With a stream of water from a faucet or a plastic water bottle, pour off the stain and gently clean the excess stain. After 10 seconds washed off the stain.
3. Added 2-3 drops of iodine solution on the smear and waited for 10 to 60 seconds. Poured off the iodine solution and washed the slide with running water.
4. Added a 1-2 drops of decolorizer so the solution of decolorizes was trickle down the slide and washed with water after 5 seconds. The exact moment to stop is when the solvent, as it runs over the slide, is no longer colored. In the gram-positive cells, further delay will cause excess decolonization, and the object of staining will be defeated.
5. Added 2-3 drops of Safranin and waited for 40 to 60 seconds, Washed the solution with the help of water.
6. Examined the finished slide under a microscope. There is a dense peptidoglycan layer and no outer lipid membrane in Gram-positive bacteria. Gram-negative bacteria have a thin layer of peptidoglycan and have an outer membrane of lipids. Gram-positive bacteria showed distinctive purple color when observed under a light microscope. Purple color showed because of crystal violet stain in the thick peptidoglycan layer of the cell wall. Gram-negative bacteria showed a pale reddish color when observed under a light microscope. Since the composition of their cell wall is unable to maintain the crystal violet stain that’s why gram-negative bacteria showed pale reddish color(Chan et al., 2007).

Figure 2.6 Slides tested under a light microscope

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Management of Water Cooler Placed at Metrobus Stations

A total of 24 number of samples were collected for 24 stations of Metrobus stations of twin cities of Islamabad and Rawalpindi. 24 bottles were collected for physiochemical analysis of water and 24 were collected for microbiological analysis of water. The sample were collected from water coolers placed at all Metrobus stations in Islamabad and Rawalpindi. The samples were collected to examine the present condition of drinking water provided to a large number of people at Metrobus stations.

Figure3.1 Samples for physiochemical and microbiological analysis

3.2 Water Quality Assessment

From these samples, we have checked the amount of contamination present in the drinking water provided to people drinking water from filter coolers present at stations of Metrobus Islamabad and Rawalpindi. To determine the water quality of samples collected from Metrobus stations of Islamabad and Rawalpindi, collected sample water was gone through physical and chemical analysis. The resulted values of each parameter were compared with the standard values set by the World Health Organization (WHO) and local standards such as National Drinking Water Quality Standard (NDWQS). The outcome of each parameter was between the safe limits set by the WHO and NDWQS.

3.3 Physical Analysis of Drinking Water Quality

To determine the water quality of samples collected from Metrobus stations of Islamabad and Rawalpindi, various physical parameters were analyzed such as total dissolved solids (TDS), turbidity, pH, electrical conductivity, salts, temperature, Oxidation-Reduction Potential (ORP), etc. Physical analysis was done in laboratory. The results of the physical parameters have been presented in the Table below.

Table 3.1 Result of physical parameters of water samples

Station/ Sample No.	**pH**	**°C**	**NTU**	**µS/cm**	**Conc.(mg/l)**	
		Temp.	Turbidity	EC	Salts	TDS
1	7.56	11.3	0.00	454	229	322
2	7.91	11.2	0.00	396	200	282
3	7.67	11.4	0.00	465	234	329
4	7.82	11.0	0.00	580	332	461
5	7.76	11.0	0.00	602	309	430
6	7.64	11.5	0.03	587	300	417
7	7.67	11.5	0.00	581	298	414
8	7.73	11.0	0.00	570	290	405
9	7.75	11.5	0.00	443	224	315
10	7.74	11.2	0.00	462	234	328
11	7.72	11.3	0.00	452	228	321
12	7.76	11.2	0.00	473	239	336
13	7.71	11.0	0.00	470	238	334
14	7.71	11.3	0.00	534	272	379
15	7.58	11.12	0.00	643	329	457

16	7.73	11.2	0.03	468	237	333
17	7.28	11.0	0.00	641	327	455
18	7.40	11.1	0.00	675	346	479
19	7.31	11.0	0.00	603	306	427
20	7.67	11.4	0.00	493	250	350
21	7.21	11.2	0.00	635	325	451
22	7.72	11.2	0.00	326	164	232
23	7.72	11.2	0.33	316	158	224
24	7.80	11.5	0.00	310	155	220
Min	7.21	11	0	310	155	220
Max	7.91	11.5	0.33	675	346	479
Standard	6.5-8.5	30 °C	<5	1000	200	500

3.3.1 Temperature

The temperature of water is a physical and ecological component that has important consequences on both living and non-living parts of environment, therefore influencing organisms and the execution of an ecosystem. The perfect water temperature is between 6°C and 12°C. Our water sample value lies between 11°C to 11.5°C. Which is desirable as it lies within the permissible limit. Though, they are all beyond the WHO standards for drinking water (25°C).

3.3.2 pH

pH is classed as one of the most important water quality parameters. A water sample that was collected from Metrobus station of Rawalpindi and Islamabad was checked for pH. level whether it is acidic, basic, or neutral. if the pH of water is below 7.0 it is acidic. Whereas, if the pH is greater than 7.0 it is alkaline. Acidic water can cause corrosion of metal pipes and a plumping system. Meanwhile, alkaline water shows disinfection in water(Napacho and Manyele, 2010).

The pH that is considered to be normal for drinking water as per defined by WHO and NDWQS guidelines is between 6.5 and 8.5. The pH values of all the drinking water samples are found to be in the range between 7.21 and 7.91, where the lowest value is from samples 21 and highest value is from sample 2 respectively. As it is filtered water, so its Ph is maintained in it to be neutral. The pH of all Metro bus stations is between the desirable range as per WHO drinking water standards.

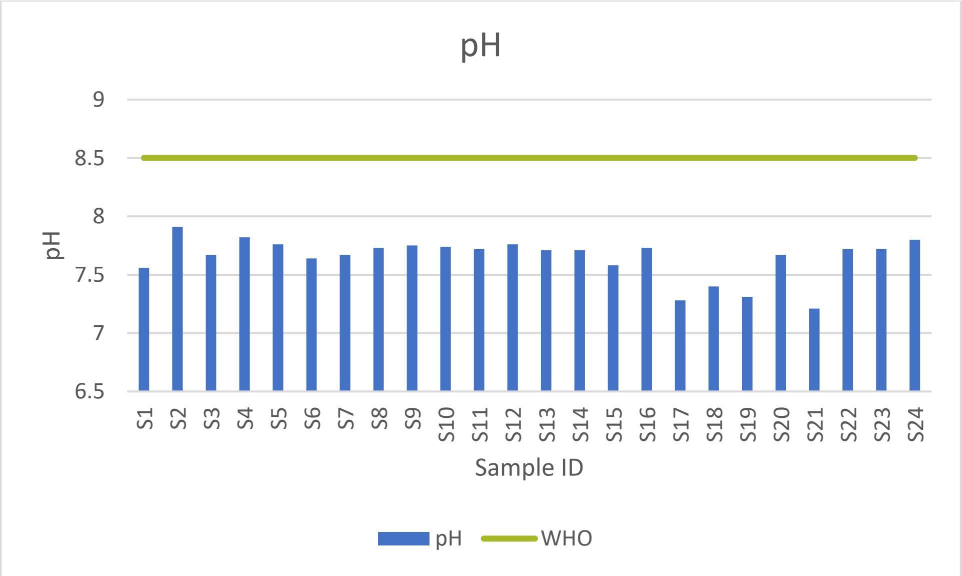

Figure 3.2 Results of pH for Metro bus stations

3.3.3 Electrical Conductivity

Electrical conductivity is the potential of water to carry an electric current. The existence of dissolved solids such as calcium, chloride, and magnesium are carried in water samples, they carry electric current across water. Electric conductivity does not directly impact human health. It is intended for many purposes such as resolve of mineralization rate and approximating the number of chemical substances used to treat this water. High conductivity electric may start dropping the aesthetic significance of the water by providing mineral taste to the water. It is critical to monitor the water conductivity for industrial and agricultural activity. Water with high conductivity could lead to corrosion of metal of equipment. It is also relevant to home appliances such as water heating systems and nozzles. Excessive conductivity can cause eradication of Food-plant and habitat-forming plant species. Electrical conductivity is an effective tool to determine the purity of water. EC depends on the number of salts prevailing in water. High EC is a sign of pollution, thus electrical conductivity measures the dilution of ions in water. Standard limit for EC is 300µS/cm defined by US EPA. our sample values lie between 310 to 675 which are undesirable and are not within permissible limit(Al-Badaii et al., 2013).

Permissible limit for EC in drinking water is 1000 µS/cm according to WHO. In this study, the EC analyzed for samples of Metro bus stations were ranged from 310 to 675 respectively as shown in the figure below, which concluded that EC of water samples taken from Metro bus stations are within permissible limits of WHO.

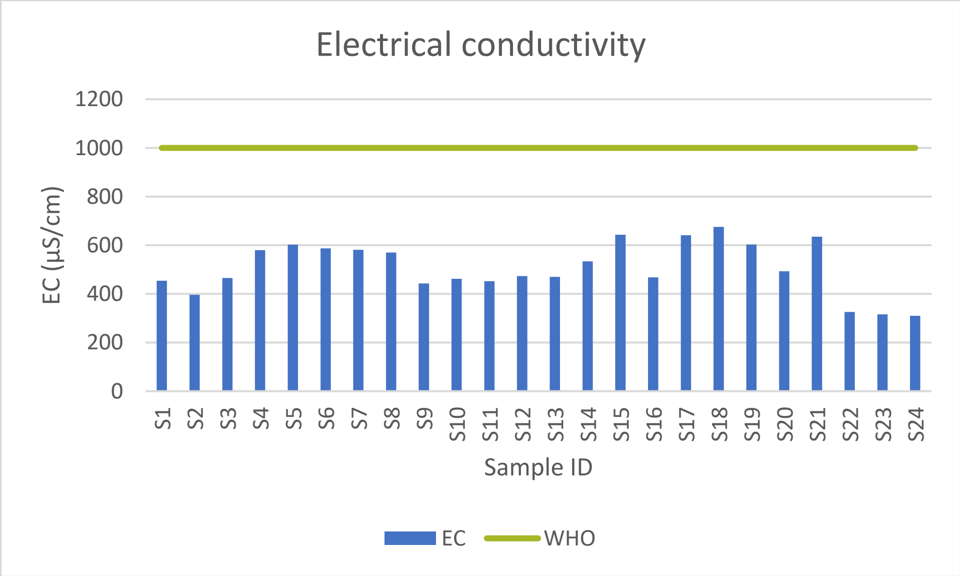

Figure 3.3 Results of electrical conductivity for Metro bus stations

3.3.4 Total Dissolved Solids

TDS are the inorganic materials and slight quantity of organic material, which are introduced as solution in water the standard or permissible value of the TDS defined by WHO is 500 mg/L Total dissolved solids primarily indicate the presence of several minerals in the water. It is the estimate of amounts of solids present in water.

The acceptable limit of TDS for drinking water is 500 mg/l. Our sample value lies between 220 to 479 which is within permissible limit. Permissible limit of TDS for drinking water according to WHO is 500 mg/l. The TDS analyzed for Metro bus stations drinking water were ranged from 220 to 479, which concluded that TDS of water samples taken from Metro bus stations are within permissible limits of WHO.

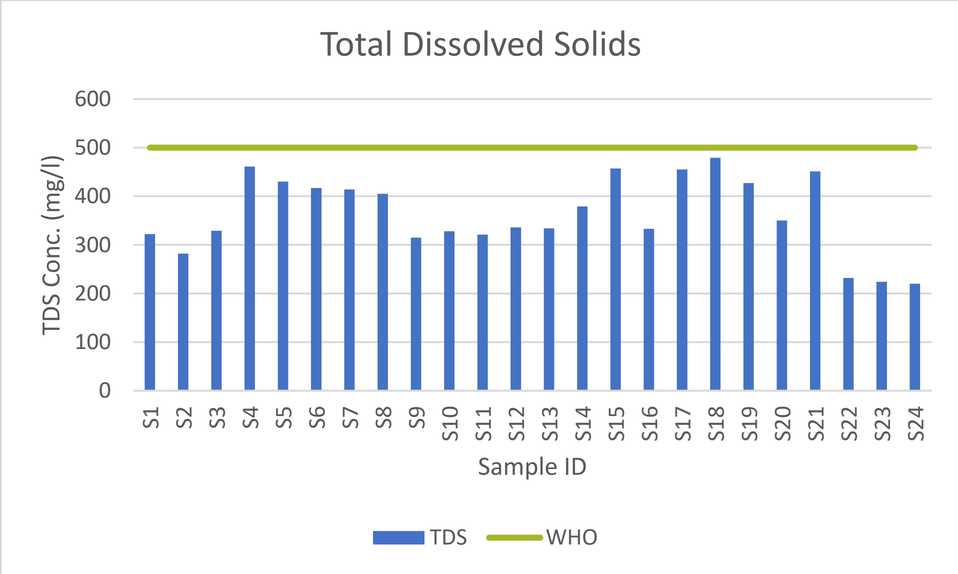

Figure 3.4 Results of TDS for Metro bus stations

3.3.5 Turbidity

Turbidity is the most significant factor as it impacts on the suitability of water to consumers. Turbidity is a water quality that belongs to the comparative clarity of water. Turbidity appears when fine suspended particles of clay, silt, organic and inorganic matter, and other microscopic organisms are collected by water as it goes through a watershed. Turbidity amounts are normally more in surface water compared to groundwater sources. Turbidity is an indicator of health hazards. Increase in turbidity leads to the vulnerability of gastrointestinal illness which also increases especially for vulnerable populations such as new-borns, the elderly, and people with weak immune systems(Mann et al., 2007).

According to WHO, the permissible limit for turbidity is <5 NTU. The turbidity analyzed for Metro bus stations drinking water were ranged from 0.00 to 0.33, which concluded that turbidity of water samples taken from Metro bus stations are within permissible limits of WHO.

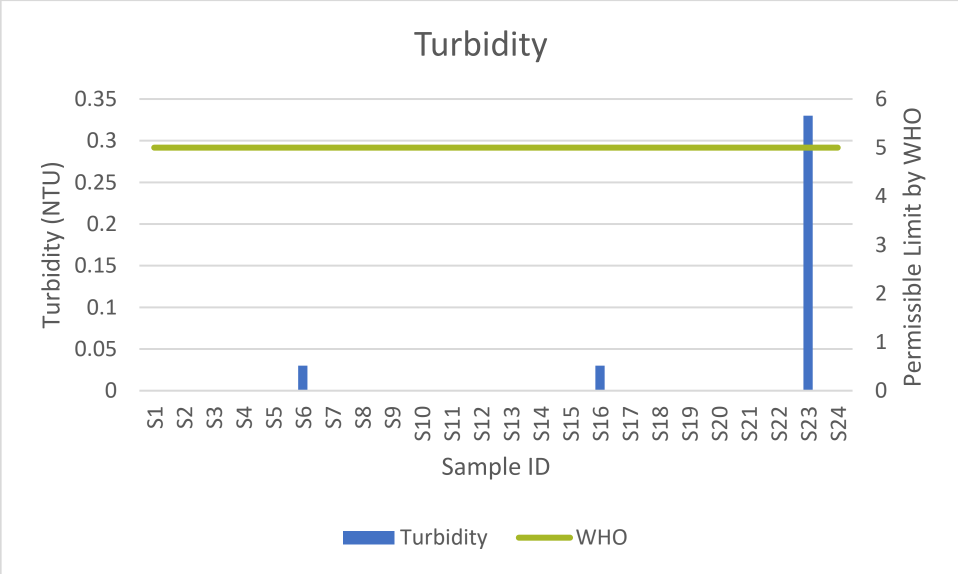

Figure 3.5 Results of turbidity for Metro bus stations

3.3.6 Total Salts

Dissolved salts like NaCl are the main cause of salinity in water. Salts concentration is directly proportional to TDS in water. The greater the concentration of salts greater will be the electric conductance and vice versa. According to WHO 200mg/l is the limit for salts in drinking water. Sodium is an important mineral in our diet. It is frequently found in the form of sodium chloride (salt). Salt produces no smell, and it dissolves easily in water and provides water a "salty" taste at concentrations greater than 180 milligrams per liter. Sodium is vital for ordinary functioning of the human body. It can be present in all body tissues and fluids, and it is not normally considered dangerous at normal levels of consumption from merged food and drinking water sources. Water containing salts is unsuitable for drinking purposes. It results in health effects like high blood pressure, cardiovascular, heart disease, and kidney problems(Olajire and Imeokparia, 2001).

As reported by WHO permissible limit for salts inside the drinking water is 200 mg/l. The salts analyzed for Metro bus stations drinking water were ranged from 155 to 346, which concluded that salts of water samples taken from some of the Metro bus stations are exceeding the permissible limits of WHO as shown in the figure below. Maximum salts were recorded in filter cooler of Metro bus station 18.

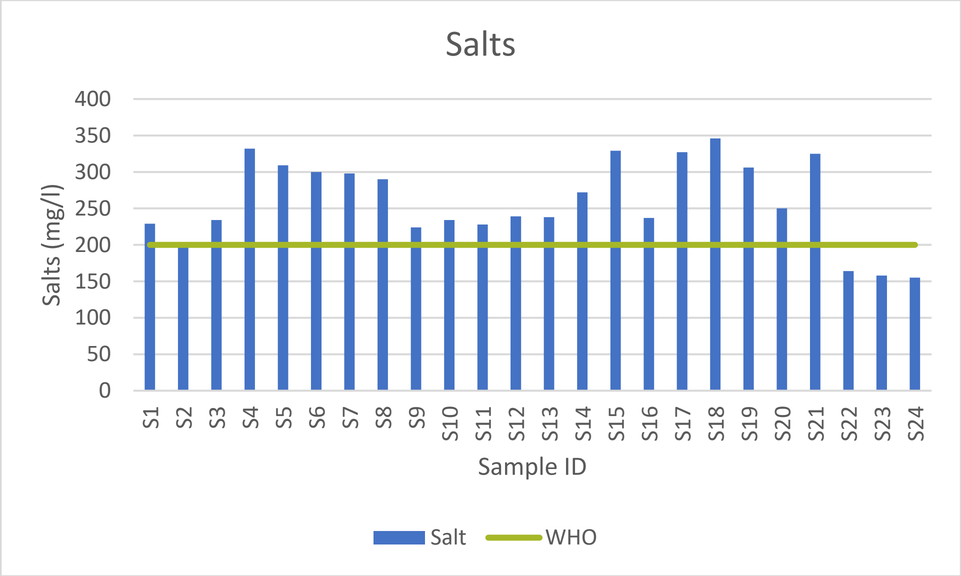

Figure 3.6 Results of salts for Metro bus stations

3.4 Chemical Analysis of Drinking Water Quality

To determine concentration of various elements like Na, Cl, Ca, Mg, Na, carbonates etc. Chemical analysis was done in laboratory and obtained results were tabulated. The results of the chemical parameters of the 24 samples of the Metro station of Islamabad and Rawalpindi have been presented in the Table below.

Table 3.2 Result of chemical parameters of water samples

	mg/l	mg/l	mg/l					Carbonates(mg/l)			
Samples	**T.A**	**T.H**	**Ca**	**Mg**	**NaCl**	**Na**	**Cl**	**$NaHCO_3$**	**Na_2CO_3**	**HCO_3**	**CO_3**
1	10.8	2.22	1.66	0.56	58.5	23.05	35.45	0.42	0.53	0.305	0.3
2	7.2	1.08	0.81	0.27	70.2	27.66	42.54	0.504	0.636	0.366	0.36
3	10.4	2.66	1.13	1.53	52.65	20.75	31.91	0.336	0.424	0.244	0.24
4	15.8	0.76	0.48	0.28	46.8	18.44	28.36	0.336	0.424	0.244	0.24
5	13.4	2.36	1.73	0.63	35.45	23.05	35.45	0.588	0.742	0.427	0.42
6	17.8	3.26	2.43	0.83	64.35	25.36	38.99	0.67	0.85	0.488	0.48
7	16.6	3.16	2.17	0.99	46.8	18.44	28.36	0.336	0.424	0.244	0.24
8	16	2.84	1.22	1.62	81.9	32.27	49.63	0.588	0.742	0.427	0.42
9	9.4	2	0.84	1.16	55.57	21.9	33.67	0.67	0.85	0.488	0.48
10	9.8	2.44	1.42	1.02	52.65	20.75	31.9	0.336	0.424	0.244	0.24
11	8.2	2.26	1.59	0.67	76.05	29.97	46.08	0.336	0.424	0.244	0.24
12	11.8	2.48	1.76	0.62	64.35	25.36	38.99	0.84	1.06	0.61	0.6

13	10.4	2.46	1.32	1.14	101.79	41.67	60.12	0.252	0.318	0.183	0.18
14	13.8	2.9	1.75	1.15	81.9	32.27	49.63	0.42	0.53	0.305	0.3
15	15.8	3.72	2.79	0.93	76.05	29.97	46.08	0.84	1.06	0.61	0.6
16	12	2.5	1.33	1.17	64.35	25.36	38.99	0.504	0.636	0.366	0.36
17	16.4	3.8	2.1	1.7	52.65	20.75	31.9	0.924	1.166	0.671	0.66
18	17.8	4.1	2.45	1.65	76.05	29.97	46.08	0.67	0.85	0.488	0.48
19	15.8	3.58	2.69	0.89	64.35	25.36	38.99	1.008	1.272	0.723	0.72
20	11.8	2.5	1.16	1.34	46.8	18.44	28.36	0.588	0.742	0.427	0.42
21	15.2	2.06	0.98	1.08	81.9	32.27	49.63	1.176	1.484	0.854	0.84
22	9.2	1.2	0.53	0.67	40.95	16.77	24.18	0.336	0.424	0.244	0.24
23	7.4	1.3	0.88	0.42	35.1	14.37	20.73	0.504	0.636	0.366	0.36
24	9	1.26	0.93	0.33	23.4	9.58	13.82	0.588	0.742	0.427	0.42
Min	7.2	0.76	0.48	0.27	23.4	9.58	**13.82**	0.252	0.318	0.183	0.18
Max	11.8	4.1	2.79	1.65	101.79	41.67	**60.12**	1.176	1.484	0.854	0.84
Standard	**200**	**500**	**75**	**50**	**ND**	**200**	**200**	**ND**	**ND**	**500**	**ND**

3.4.1 Chloride

The chloride intensity serves as a sign of contamination by sewage. People notified of higher concentrations of chloride in water are exposed to purge effects. Chloride is one of the main inorganic anions in water and effluent. The permissible limit of chloride in drinking water is 200 mg/l. Chloride salts in excess of 100 mg/l give salty taste to water. When combine with calcium and magnesium, may increase the corrosive activity of water.

The permissible limit to Cl inside the drinking water is 200 mg/l. The Cl concentrations of samples of Metro bus stations ranged between 13.82 to 60.12 mg/l. All the samples collected from Metro bus stations are within the defined limits of WHO.

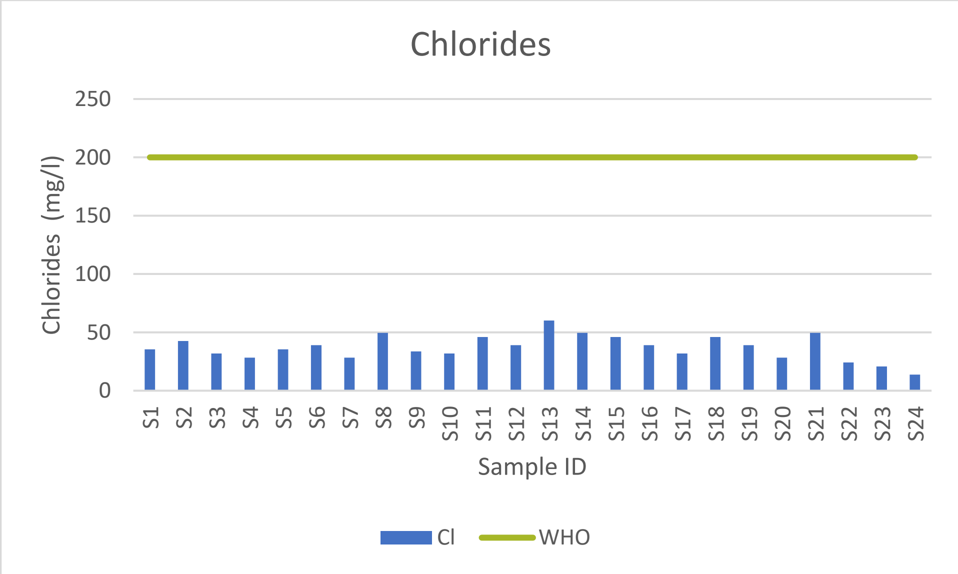

Figure 3.7 Results of chloride for Metro bus stations

3.4.2 Sodium

The permissible limits of Sodium inside drinking water is 200 mg/l. Sodium concentrations of samples of Metro bus stations ranged between 9.58 to 41.67 mg/l. All the samples collected from Metro bus stations are within the defined limits of WHO.

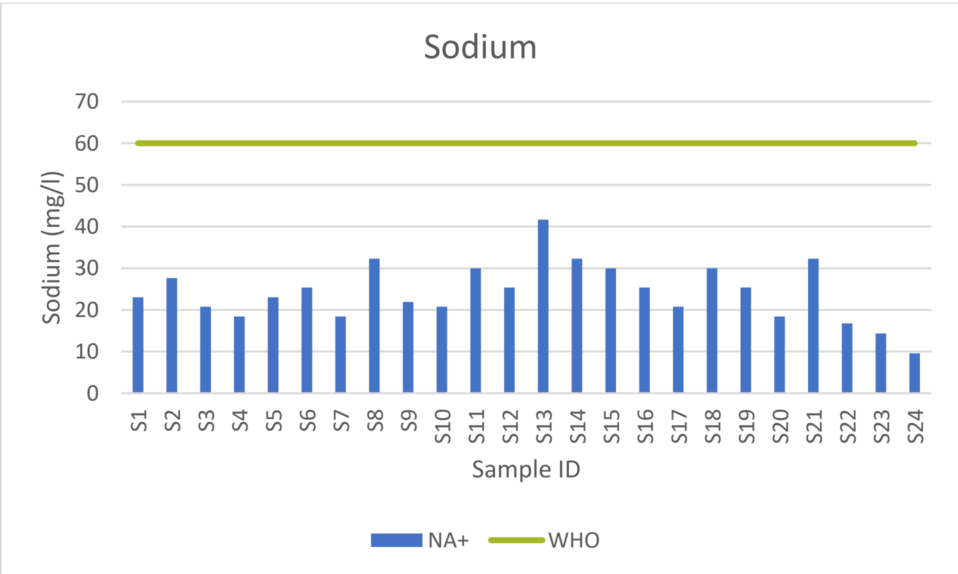

Figure 3.8 Results of sodium for Metro bus stations

3.4.3 Carbonates

Carbonates can only occur if the pH of the water above 8.3. This rarely found in natural waters. Carbonate hardness is triggered by the metals mixed with a type of alkalinity. Alkalinity is the capability of water to neutralize acids and is recognized to complexes such as carbonate, bicarbonate, hydroxide, and silicate, and phosphate. Carbonate hardness is often called temporary hardness because it can be eliminated by boiling water. Carbonated water has a lower pH than regular water, making it marginally acidic. Carbonated water has a lower pH considerably which diminishes enamel on teeth.

The existence of carbonate and sulphate salts of calcium and magnesium results in more than 3/4th of kidney stones which is mostly made up of calcium salt and usually appear as calcium oxalate and rarely as calcium phosphate(Sengupta, 2013).

The carbonates concentrations of samples of Metro bus stations ranged between 0.252 to 1.176 mg/l for $NaHCO_3$, 0.318 to 1.484 for Na_2CO_3, 0.183 to 0.854 for HCO_3, and 0.18 to 0.84 for CO_3. All the concentrations of samples collected from Metro bus stations are within the permissible limits.

3.4.4 Total Alkalinity

Total alkalinity is fundamentally a measure of water's ability to balance acids. It is used to determine protecting capacity of the water. The permissible limit stated by WHO for total alkalinity of drinking water is 300 mg/Alkalinity is an essential parameter as it calculates the water's capability to resist acidification. The main part of alkalinity in natural water is produced by carbonate, hydroxide, and bicarbonate. Alkalinity is not harmful itself to human beings. These composites outcome from suspension of mineral substances present in the soil and atmosphere.

The permissible limits for total alkalinity in drinking water is 200 mg/l. The total alkalinity of samples of Metro bus stations ranged between 7.2 to 11.8 mg/l. All the samples collected from Metro bus stations are way beyond the defined limits of WHO(Edition, 2011).

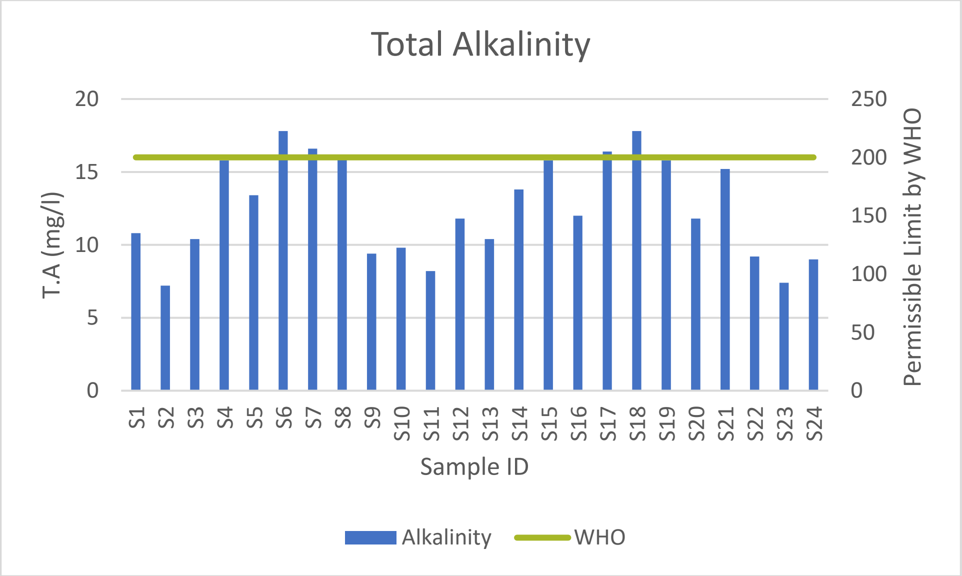

Figure 3.9 Results of total alkalinity for Metro bus stations

3.4.5 Total Hardness

The total hardness of water is not a particular constituent rather it is a variable and complex combination of cations and anions. Hardness is the state of water that avoids the lather formation with soap and increases the boiling points of water. Total Hardness is the constraint that is used to demonstrate the effect of dissolved minerals mainly Calcium and Magnesium in water. These two Collective minerals lead to the total hardness of water. The permissible limit of hardness for drinking water is 500 mg/l. The suitable limit of total hardness is 300 mg/L while maximum limit is 600 mg/L.

The permissible limit of total hardness of drinkable water is 500 mg/l. The total hardness of samples of Metro bus stations ranged between 0.76 to 4.1 mg/l. All the samples collected from Metro bus stations are way beyond the defined limits of WHO(Edition, 2011).

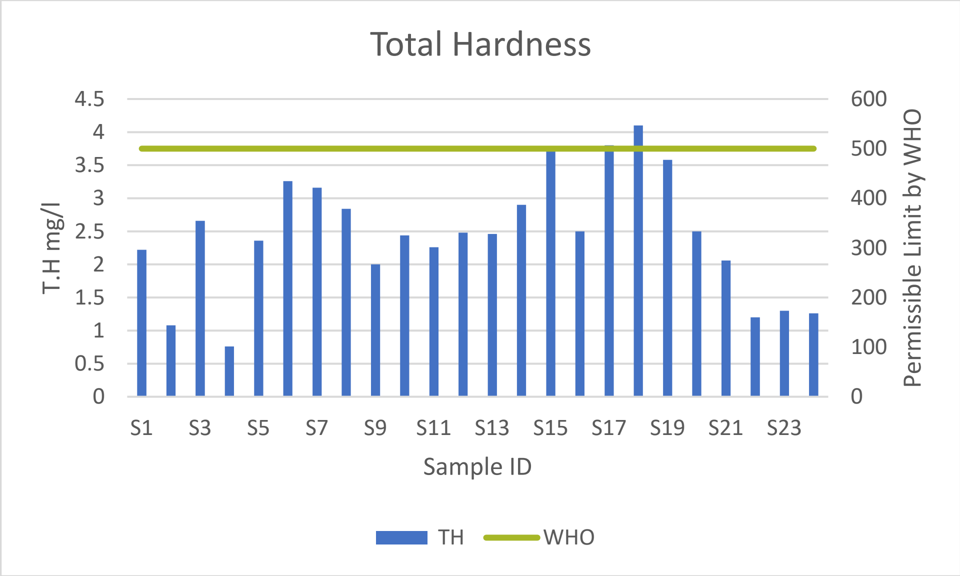

Figure 3.10 Results of total hardness for Metro bus stations

3.4.6 Calcium:

The permissible limits for calcium in drinking water is 100 mg/l. The calcium concentrations of samples of Metro bus stations ranged between 0.48 to 2.79 mg/l. All the samples collected from Metro bus stations are within the defined limits of WHO.

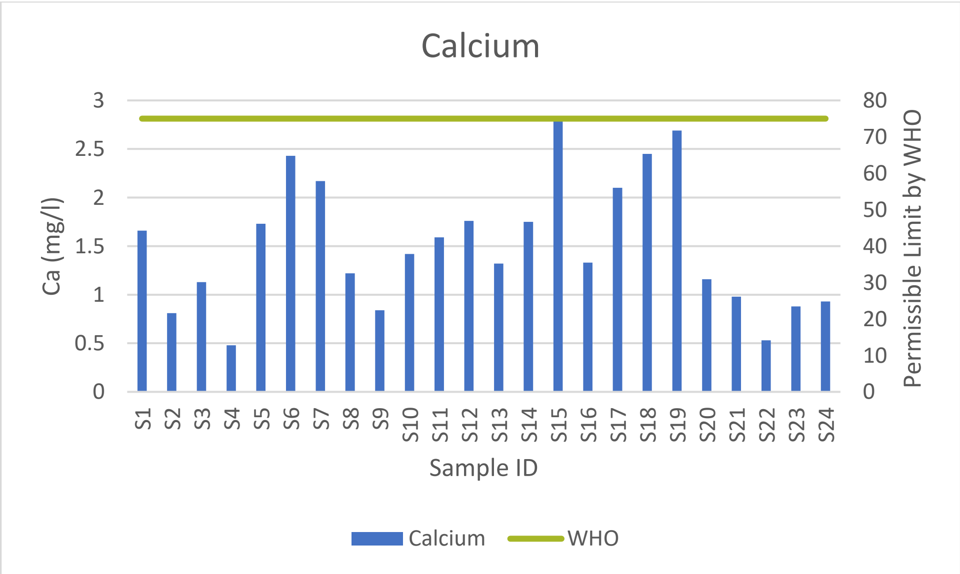

Figure 3.11 Results of calcium for Metro bus stations

3.4.7 Magnesium:

The permissible limits for magnesium in drinking water is 30 mg/l. The magnesium concentrations of samples of Metro bus stations ranged between 0.27 to 1.65 mg/l. All the samples collected from Metro bus stations are within the defined limits of WHO.

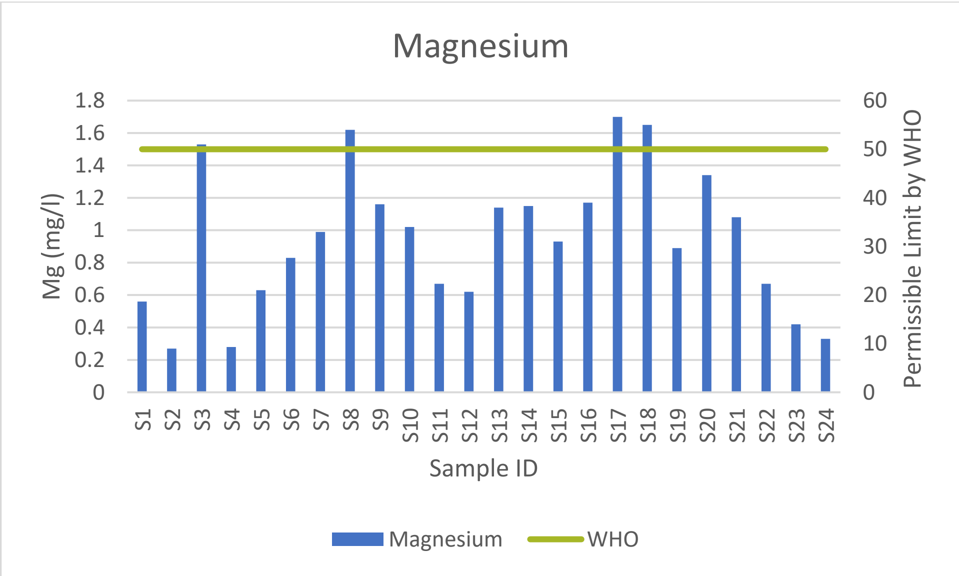

Figure 3.12 Results of magnesium for Metro bus stations

3.5 Microbiological Analysis of Drinking Water Quality

It is a microbiological analytical process that works on samples of water and from these samples regulates the concentration of bacteria. It is then potential to draw attention about the appropriateness of the water for help from these concentrations. This procedure is used, for example, to normally confirm that water is secure for human intake or that cleaning and recreational waters is protected to use.

3.5.1 Total bacterial count

The bacteria count is revealed simply by counting the number of colonies with the results reported per 100 ml in counts. The filters that are used have a grid which makes the task of counting the colonies simplest. The plate count method relies on bacteria growing a colony on a nutrient medium so that the colony becomes visible to the naked eye and the number of colonies on a plate can be counted.

Table 3.3 Results of microbiological parameters of water samples

	CFU/ml		
Samples	**NA**	**EMB**	**SS**
1	0	0	0
2	13	0	0
3	6	0	0
4	11	0	0
5	17	0	0
6	5	0	0
7	38	0	12
8	9	0	0
9	18	0	0
10	15	0	0
11	14	0	0
12	0	0	0
13	15	0	0
14	9	0	0
15	22	0	3
16	7	0	0
17	56	0	0
18	20	0	0
19	26	0	5
20	22	0	0
21	8	0	0
22	30	0	0
23	13	0	0
24	49	0	0
Min	0	0	0
Max	56	0	12
Standard	**>500**	**0**	**0**

On average water sample taken from Metro bus stations of Islamabad and Rawalpindi were having less microbial growth. This shows that the water is clean except from the station 7, 15 and 19 in which microbial growth was observed on the SS agar. This can be a possibility that the source of bacterial contamination can be human waste. Another reason could be possible is that that pipelines and filter coolers are neither maintained, clean nor checked for leakage.

3.5.2 Gram staining:

Gram staining is a technique used to identify the two different types of bacteria which are Gram-positive bacteria, Gram-negative bacteria. After performing the gram staining, the slides were examined under the microscope to check whether the colonies picked up by us were of gram-positive or gram-negative bacteria. Some of the samples contain +ive or -ive bacteria and some contain both in it.

Table 3.4 Results for gram staining of water samples

Samples	Colony Color	Colony Shape	+ive	-ive
1	White	Round	✓	
2	White	Irregular	✓	
3	White	Round	✓	
4	White	Round	✓	
5	White	Irregular	✓	
6	White	Round		✓
7	White	Round	✓	
8	Orange	Round		✓
9	White	Irregular		✓
10	White	Round	✓	
11A	White	Irregular		✓
11B	Orange	Round	✓	
12	White	Irregular	✓	
13	White	Round	✓	
14A	White	Round	✓	

14B	**Orange**	**Round**		✓
15	**White**	**Irregular**	✓	
16	**White**	**Round**	✓	
17A	**White**	**Round**	✓	
17B	**Yellow**	**Round**		
18	**White**	**Round**	✓	
19	**White**	**Round**		✓
20	**White**	**Round**	✓	
21A	**White**	**Irregular**	✓	
21B	**Orange**	**Round**	✓	
21C	**Yellow**	**Round**		✓
22	**White**	**Irregular**	✓	
23	**White**	**Round**	✓	
24	**White**	**Round**	✓	

CONCLUSION

To test the water quality, water samples were collected from various filtration coolers from Metro bus stations of Islamabad and Rawalpindi. The physiochemical and microbiological analysis results of the filtration plants were compared with the WHO drinking water standards.

Following conclusions are drawn from the study:

1) All the physical parameters were within the permissible limits of WHO standards except for the fact that some of the samples have a high concentration of salts.

2) In microbiological analysis it was observed that the Total Bacteria was within optimum range , *E. Coli* / Total Coliforms were absent, *Salmonella / Shigella* were present in three samples. By considering microbiological parameters, most of the station's water contains +iv bacteria and very few of them contain negative bacteria. This shows that the filtered water of the Metro station is suitable for drinking purpose.

3) While in case of chemical parameters all the samples are within the permissible limits given by WHO. It clearly shows that the water is clean.

4) The overall result of the study showed that the concentration of all the physicochemical and microbiological parameters were within the permissible limits of WHO.

RECOMMENDATIONS

- Although all the parameters were within the standard limits, but if the filtration process is enhanced the water quality of the Metro bus stations will be improved.

- Each Metro station has its own borehole under it. The borehole water after passing through pipelines to filter coolers can be contaminated and may cause deterioration of water quality, so proper monitoring of pipelines must be carried out which otherwise can contaminate the filtered water.

- Comparative analysis on the boreholes water (source of water) and filter cooler water of Metro bus stations for drinking water quality must be conducted.

- Punjab Mass-transit Authority (PMA) should focus on the cleaning and maintenance of water pipelines.

- A comprehensive study must be conducted in future to find the source of pollutants in the groundwater.

- The filters of filter coolers must be changed regularly before the due dates.

- Public awareness campaigns must be launched to raise awareness among people about safe drinking water and health issues related to contaminated drinking water.

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