CHARACTERIZATION OF DRINKING WATER QUALITY IN KABUL CITY, AFGHANISTAN

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DECLARATION

I hereby declare that the work presented in the following thesis is my own effort, except where otherwise acknowledged and that the thesis is my own composition No part of the thesis has been previously presented for any other degree

Date 02-Aug-2016

(Noorul Hoda)

*This academic work is dedicated to
my all family members, especially to my
beloved parents, who always wished and
tried for my bright future*

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All praises and thanks be to Almighty ALLAH alone the most merciful, the kind, and every grace of ALLAH be on the last Prophet MUHAMMAD (peace be upon him)

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ABSTRACT

Increase in the incidence of water-borne diseases in Kabul city, compelled to assess the drinking water quality in the city Kabul city is divided into seven zones based on water distribution system according to Afghanistan Urban Water Supply and Sewerage Corporation (AUWSSC) division During the study total 85 water samples were collected from three types of drinking water sources (water storage tanks distribution networks and deep wells) at different locations and were assessed for physicochemical and bacterial quality Physicochemical analyses were performed according to the Standard Methods while bacterial analysis was performed by using DelAgua single incubator test kit The results obtained were compared with WHO and Afghanistan National Standard Agency (ANSA) standards for drinking water quality The study showed that 36 5 % samples contained higher electrical conductivity (EC) than the permissible limits set by WHO and ANSA Similarly, bacterial analysis showed that 11 76 % of water samples were contaminated with total coliform bacteria whereas 4 7 % of drinking water samples contaminated with fecal coliform bacteria Coliform contamination indicates the mixing of drinking water with the sewage water due to old rusty pipes and seepage of contaminants to the ground water Regular monitoring and treatment of the drinking water before use is recommended to avoid waterborne diseases while long term policy related to provision of clean drinking water by the local and national level government may be devised

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AUWSSC	Afghanistan Urban Water Supply and Sewerage Corporation
ANSA	Afghanistan National Standard Agency
EIA	Environmental Impact Assessment
UNFCCC	United Nation Framework Council for Climate Change
NEPA	National Environmental Protection Agency
UNEP	United Nation Environmental Protection
WHO	World Health Organization
DACAAR	Danish Committee for Aid to Afghan Refugees
GMWs	Groundwater Monitoring Wells
UNICEF	United Nations International Children's Emergency Fund
JMP	Joint Monitoring Program
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
EC	Electrical Conductivity

CHAPTER 1

INTRODUCTION

Water is the basic necessity for all human beings. In holy Quran it is stated "we have kept alive everything from water". About the 70 % of the earth surface is surrounded by water. The 2.8 % of fresh water is available for human needs. The other 97.2 % of water is very salty in oceans to use for more purposes. But the most of the fresh water are frozen (Viman *et al.*, 2010).

Water pollution has two main sources 1- Point sources and 2- Non point sources. The sum of these point and non-point pollutants sources are represent the load of total waste in the water. Also the water resources may polluted by the one or more than one following sources 1-Atomospheric dissolved gases 2- weathering of soil and rock minerals 3- decomposition of animal and vegetable materials, and 4- Industrial effluents, sewage and municipal wastes (Agarwal, 2009).

WHO considers that drinking-water should be suitable for human consumption and for all usual domestic purposes including personal hygiene (Bartram *et al.*, 2003). Drinking water is more crucial than food for human survival. Everyone has access to the some sources of water, but that water is not always safe and clean to use. But natural sources such as streams and open wells contaminated by animals and human wastes (black & King, 2009). However water can to be harmful to life. The health of individuals, populations and also whole ecosystem can be threatened by chemical and physical hazards through changes in water quality (the properties of freshwater resources) and water quantity (access to freshwater). If the quality and quantity of water is insufficient it has impact on health. There are five infectious diseases associated to water 1-water borne diseases 2- water carried disease 3- water wash diseases 4- water based diseases 5- vector based water related diseases

All these types have potential to cause illnesses and death anywhere around the world (Slack, 2014)

Indeed, treatment of water can remove the three types of contaminants in waste water (microbial, inorganic and organic contaminants) Waste water composed of two components, one is soluble and other one is particulate The particulate component is named the total suspended solids (TSS) Both these soluble and particulate fractions are will be compound of organic and inorganic materials Potable water has two major sources such as surface waters (rivers and lakes) and ground water Surface water treatment need many stages, because of open to direct environmental input, ground water is comparatively safe and clean and its treatment need fewer steps (Horan, 2014)

Surface waters include dissolved and suspended inorganic and organic substances The difference between dissolved and suspended substances is based on filtration Soil particles (clay, silt and sand), algae, plankton, microbes and other substances are components of suspended sediments Suspended sediments, sized from 0 004 mm (clay) to 1 0 mm (sand) When there are more amounts of suspended sediments on water it has the higher measure of turbidity The measuring of hydrogen ion concentration in water body is called pH the pH scale range from 1 to 14 When have low value of pH are more acidic and with high values are more alkaline Total dissolved solids (TDS) can be determined by the measurement of electrical conductivity (EC) (Chapman *et al* 2014)

Ground water makes up the crucial component of the hydrological cycle and derived from precipitation, surface runoff and standing water bodies Groundwater resources are i- Recharge and discharge to groundwater ii- Rainfall recharge iii- Groundwater-stream interactions and iv- Groundwater management Groundwater is also used for public utilization and it has high quality (West & Odling 2014)

Indeed, exact management of water sources and access to drinking water may decrease child deaths' and may increase on age average Approximately, access to improved water may decrease 36 % human death on 2025 compare to 2004 in Afghanistan The central statistical office information showed that 16 % Kochi people 20 % rural families and 58 % urban families use drinkable water in Afghanistan (NEPA 2012) In 2011 estimation showed that 768 million people around the universe do not use improved sources of drinking water By year late 2011, 89 % people have used improved potable water sources, 55 % people enjoyed from comforts and associated health benefits (WHO-UNICEF 2013) According to Khaama Press, (2013) reported, that 73 % people of Afghanistan have not access to safe drinking water, Almost 95 % have not access to sufficient hygiene Even 25 % people of Kabul have direct access to potable water (Jawad 2013)

The most important city in the study area is Kabul the largest city capital of the country with the highest water necessity One of the priorities of the government should be the water supply Drinking water for this city should be provided in medium and long term from both groundwater and surface water (Lashkaripour & Hussaini 2008) Currently estimation shows that 30% of the population use public shallow wells with hand pumps, 20% receive water from distribution networks and 50% use private shallow wells (Banks 2002)

Kabul has never had a global water supply system but rather several local systems, fed by largely independent sources The first water supply network of Kabul City was designed and constructed more than a hundred years ago (1890s) and was Paghman Water Supply Network Karez in the Paghman district was the source of water, located about15 km away from Kabul city Water flowed by gravitation through some 18 km of cast-iron pipe to Kabul City This water was distributed to the Royal Palace and as well to the main government buildings, houses and some streets of the city At the present time this network is not functioning It is estimated that some 50-60% of the network has been damaged during the past 20 year's war, especially during the post-Soviet civil war Most of the people use their own private wells, which have formed the basis of supply for the majority population over the past 20 years (Banks, 2002)

Afghanistan Mortality Survey (2010) showed that 54 % families have access to safe drinking water The 77 % of urban families have access to improved drinkable water and in rural areas this %age is about 49 % Only one-fifth (20 %) families have improved toilets facilities (APHI. 2010) Polluted water cause many diseases The estimation showed that 26 4 % of Afghanistan children had diarrhea The 62 9 % of the population used improved drinkable water sources (Varkey *et al*, 2015) Some world health organization investigators accepted that 80 % sources of human's diseases are polluted water or transmitted by polluted water Therefore we must avoid water contamination and its useless use (Royan, 2014)

Kabul city has the highest diarrheal widespread rates about 34 % Diarrheal diseases are transmitted by polluted water soil and food which have been polluted by human's excrements There is no system for waste disposal in Kabul Kabul residents utilize 53 % water from drill wells for drinking and other purposes The winter of 2005 was lengthy and had a heavy snow and recorded on the Hindu Kush in decades The result was floods and sewage mixed with spring water runoff its' contaminated the water table of Kabul and around the country (Kakar *et al*, 2008) An avoiding integrated management with collaboration of all relevant agencies is the preferred approach to insuring drinking water safety (WHO 2004)

Objectives

- Assessment of physicochemical characteristics of drinking water sources in Kabul city
- Assessment of bacterial contamination (Total coliform and Fecal coliform) in drinking water samples
- To provide a document and information to the policy makers for future management of drinking water sources in Kabul

Significance of the study

Access to safe drinking water is a fundamental right. In this regard this study will help in bringing awareness among the masses as well as government officials about the drinking water quality in the city and will be able to devise proper policy and measures for its treatment and provision of clean water to the inhabitants of Kabul city.

a

b

c

Figure 1(a,b,c) Some leakages in Karta-e-Naw and Pul-e-Khoshk areas

CHAPTER 2

LITERATURE REVIEW

Ahmed *et al*., (2015) investigated some physicochemical and bacterial characteristics of drinking water and its potential health impacts in academic institutions of Abbottabad, Pakistan. According to their assessment 63.5 % of the samples were beyond the permissible limits of WHO standards for drinking water. Coliforms were found in 66.6 % of total water samples and suggested proper monitoring and purification of the water.

Oladipo & Adeboye (2015) performed physicochemical and bacterial analysis of well water used for drinking and domestic purposes in Ogbomosho Nigeria. They analyzed the water for turbidity, pH, total hardness, TDS, TSS, chloride contents, biological oxygen demand (BOD) and chemical oxygen demand (COD) as well as total bacterial counts. The result showed that the water were contaminated and needed treatment before use.

Matre & Zodpe (2014) assessed the bacterial and physicochemical parameters of drinking water in Akola district India. Some physicochemical parameters such as color, odor, pH, TDS, turbidity, hardness, pH, alkalinity, fluorides, irons and nitrate were studied by following Standard Methods. Samples from hand pumps, tap water, bore wells, tube wells and open wells were collected. According to their findings the water was contaminated and needed treatment before use.

Danish & Rajesh (2013) studied some physicochemical characteristics of drinking water sources in the Amravati district of, India. Physicochemical parameters determined such as pH, EC, total hardness, temporary hardness, BOD, COD, calcium, magnesium and alkalinity. The bottles were treated with dilute mineral acid solutions for two days before sampling. Most of the parameters were found in excess of the allowed limits.

Digha & Ekanem (2015) assessed the water quality and effects of population density on water in Calabar Municipality Cross River State, Nigeria. The samples were collected from

06 boreholes and investigated color, turbidity EC and temperature, calcium, magnesium potassium, sodium, total hardness nitrate nitrite sulphate florid chloride ammonium, manganese, iron, lead, copper and zinc in the water The study showed that groundwater was suitable for irrigation but water samples collected around Ldiba, Essien town, Ikot Omin and Ikot Iffanga were not suitable for drinking purposes

Olukemi (2013) analyzed the effect of Moringa oliefera seeds on bacterial quality and physicochemical characteristics of drinking water in rural communities of Ondo southwestern of Nigeria and used the pour plate technique to conclude the existence of bacterial pathogens In this study analyzed some physicochemical patterns such as odor color temperature pH, turbidity, chloride and nitrate From various streams at different locations in rural communities samples were collected within the three local government areas (Ile Oluji/Oke Igbo, Odigbo and Ondo East) in the State In these rural communities the main sources of drinking water were these streams The study showed that the water had low quality

Babatuyi *et al*, (2014), examined the bacterial and physicochemical analysis of Ochaja natural spring water Water samples were collected in sterilized bottles The serial dilution and plating on Nutrient Agar (NA) determined the total viable count of bacteria For determination of total and fecal coliform they used pour plate and spread plate methods The total viable organisms and fecal coliform range was from 2.3×10^3 cfu/ml and 1.25×10^3 cfu/ml The fecal coliform and total viable counts were no consequential distinguish ($P<0.05$) There was low level of turbidity and nitrate also had the high level of phosphorus The findings of the physicochemical characteristics were within the satisfactory limit of WHO

Onojah *et al* (2013) investigated physicochemical and bacterial assay of sachet water samples marketed in Kogi state of University Compound Anyigba For this study they used sachet water samples and these samples were collected from five different sources in 100 ml amount sterilized plastic disposable bottles Bacterial examination of samples revealed the presence of pathogens such as yeast, color odor taste E coli, Bacillus species etc Chemical analysis revealed the presence of metals ranging from Pb, Fe and Cr The study showed that the water was not suitable for drinking

Sabae *et al* (2014) analyzed the seasonal and regional variation of physicochemical and bacterial parameters of surface water in El-Bahr El-Pherony Menoufia Egypt 28 samples were collected for analysis during January-September 2013 Physicochemical parameters i e pH temperature, dissolved oxygen (DO) turbidity and BOD as well as total coliform, E-coli Fecal coliform, Fecal Streptococci (FS) and some pathogenic bacteria were analyzed For bacterial analysis spread plate method was used The result showed sewage pollution and suggested regular monitoring for bacterial contamination of the water

Naji *et al* (2011) analyzed the physicochemical and bacterial parameters of drinking water collected samples in Hilla City Iraq They collected water samples for bacterial analysis according to APHA (1998) and using sterile borosilicate glass bottles for water sampling They used various culture media for isolation of bacteria such as Mac Conkey agar (Hi-media) for coliform count, nutrient agar (Oxide) for total aerobic bacterial count and brain-heart infusion agar (Hi-media) for fecal streptococci count

Hamid *et al* (2013) investigated the intensive report of total analyses of drinking water in Lahore, Pakistan Investigations conducted by collected water samples from tube wells and taps water from various locations/towns of Lahore In this study some physicochemical parameters of water were analyzed such pH temperature color odor turbidity, TSS total hardness, TDS, EC, chloride, fluorides nitrates arsenic and lead and from this assessment curried out that physicochemical properties of drinking water are appropriate to the WHO standard for drinking water in Pakistan

Diya'uddeen *et al* (2014) assessed the physicochemical and bacterial quality of river Galma around Dakace industrial Estate, Zaria of Nigeria They used plastic bottles for water sampling and those bottles were prewashed For microbiological analysis they used spread plate method Temperature and pH was determined on in situ Assessment showed that the water is not suitable for agriculture and domestic use without some physical and chemical purification Because of the total coliform and total heterotrophic bacteria (THB) crossed the WHO standard of drinking water In this analysis samples collected from four locations during four months

Chrysanthus, (2014) analyzed the bacterial quality of alternative water sources in Bambui and Bambili residential areas north-west region Cameroon In this analysis estimated the bacterial quality of spring water and well water sources, because this water sources fulfill their daily needs for water 18 water samples were randomly collected for this analysis in sterilized bottles and the samples were transported at 4°C in ice container In this assessment multiple tube fermentation technique was used Therefore they need pure water and free of microbes and other organisms which are harmful to human beings This study exhibited that 95 % well water samples have the low value of microbiological quality and it does not match to the WHO standard for drinking water

Pavendan *et al* (2011) assessed the physicochemical and microbial properties of drinking water from different water sources of Tiruchirappalli district of south India The index for healthy society is water quality There are some factors that quantitatively and qualitatively influence water resources such as Industrialization, modern agriculture practices, and urbanization 60 water samples from three different sources such as (bore wells, open wells and corporation water of the study area) were collected The assessment showed that open wells water is very contaminated and had the high value of total dissolved solids, total hardness and total alkalinity The fluoride presence in bore wells' water crossed the WHO limit for drinking water, recorded the microbial contamination up to 12 % of bore wells, 11 1 % of open wells and 6 3 % of corporation water samples

Alfa & Ajayi (2014) analyzed spring water of Osan-Ekiti Nigeria for knowing its physicochemical and bacterial characteristics this analysis performed on five collected samples of spring water from several sites Sterilized bottles were used for water sampling pH and EC were measured with the help of conductivity meter From hygienic point of view the result of this study showed that spring water have the trend to cause diseases and spring water is not suitable for human used

Al-Bayatti *et al*, (2012) studied the physicochemical and bacterial parameters of Tigris River which is near to water purification stations in Baghdad Iraq The water samples for bacterial analysis were collected in 250 ml sterilized glass bottles and for physicochemical analysis collection of water samples were done with 1 litter glass bottles They analyzed some physicochemical characteristics such as pH temperature EC, DO, TDS, BOD and salinity total coliform, fecal coliform, E coli and Pseudomonas aeruginosa) were analyzed as well The result curried out from this study showed that counts of Total Coliform and E coli are over the WHO permissible limit in all stations and at all seasons Therefore must try to avoid contaminants discharged into Tigris River

Roohul-Amin *et al* (2012) assessed microbial properties of the drinking water and water distribution system in new urban Peshawar Samples were collected from 10 different places The physicochemical parameters such as (pH EC turbidity and TSS) and bacterial parameters such as (Total & fecal coliform and E coli) were assessed in this study Total coliform bacteria was analyzed by Most Probable Number (MPN) method, fecal coliform was done by inoculation method, E coli was determined by streaking method The chemicals and microbes are the severe problem to the environment Estimation showed that 70 % rural population of Pakistan have no access to clean potable water and 40-60 % of urban people have access to clean water for drinking Almost there is not exist the filtration system before distribution of water, and they crossed the WHO standard of drinking water

Omoigberale *et al*, (2013) has studied the seasonal variation in bacterial quality of Ebutte River in ehor community EDO state Nigeria In this study they used the basic microbiological technique 30 samples from 5 different locations were collected monthly during six months in rainy seasons Pour plate method was used for Total coliform bacteria analysis, Fecal coliform bacteria analyzed with most probable number (MPN) method Study showed that the major sources of water pollution are animal, human and agricultural activities The result showed that Ebutte river water is not appropriate directly for human use, because it cause a many diseases to human health

Saxena *et al*. (2011) analyzed the water quality under different environmental condition and its physicochemical and bacterial parameters in Ahmedabad, Gujarat India Such as pH, COD BOD TDS and DO The study also conducted to assess the changes in initial characteristics in the water samples over a significant period of time, under several environmental conditions composed unusual materials. study showed that several environmental conditions such as sunlight causes the elimination of microbes from water due to photo-degradation process

Okoye & Adiele (2014) carried out from physicochemical and bacterial study of ground water of Ezinihitte Mbaise local government area of Imo state, Nigeria, water samples from eleven boreholes of various towns were collected For determination of heavy metals the samples preserved by adding 5 mL HNO3, to prevent from adhering metals to the walls of containers Water samples were collected in 2 litter prewashed polyethylene containers Several standard methods were used for the analysis of gravimetric method for TDS total alkalinity by potentiometric titration, total acidity by potentiometric titration. and total hardness (TH), calcium and magnesium were analyzed with EDTA titrations method

Chloride was determined by Mohr's Argent-o-metric method nitrate was analyzed by cadmium reduction method sulfate was determined by turbid-metric method and phosphate was analyzed by reactive (ortho) phosphate ascorbic acid method Trace metals such as(cadmium chromium copper iron nickel lead and zinc) determined using atomic absorption spectrophotometer (AAS) At eight boreholes water was impaired by growth of bacteria the study showed that water must boiled before drinking

UNICEF estimated that only 12 % of Afghan population have access to sanitation and 23 % have access to improved drinking water (Rahimi 2011) Water is one of the biggest concerns comparing to the sanitation at the same level because the groundwater table is reduced due to drought Few houses covered by connected water supply system estimated that about 16 % of people have access to water supply system The main sources of water are shallow wells but the biological quality is deteriorated by wastewater because of no care to avoid infiltration

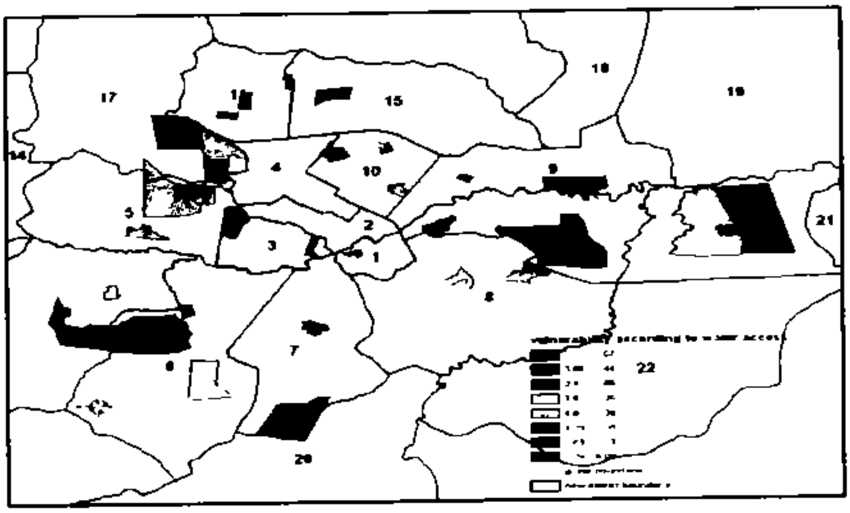

Figure 2 Level of vulnerability to water access per municipality Nahia (district) of Kabul city

Source (ACF 2006)

Around half of the families in Kabul used water from piped sources and about 72.7 % is no drinking water treatment. Most of the households (88.1%) used open ground toilets (Aluisio *et al.*, 2015). Ministry of public health reported 3,245 cases of acute watery diarrhea in Kabul city alone from 25 May to 16 June 2005. Analysis of 228 water samples from different locations of Kabul city showed that 28.5 of the samples were positive for fecal coliforms (MPH, 2008). As survey has shown that Kabul city has the highest diarrheal prevalence rate among six major urban areas. Approximately 40 % of Afghan population has access to clean potable water (Kakar et al., 2008). About 500,000 people of Kabul found access to an improved and newly installed water supply.

DACAAR groundwater monitoring program operated the national groundwater monitoring wells (GMW's) network of 120 stations in 19 provinces of Afghanistan. 11 GMW's network stations out of the 120 were in Kabul province. In this study water level and some physicochemical parameters such as pH, temperature and EC were measured. They determined bacterial parameters using photometer (8000) during every six months. Analysis of drinking water points of Kabul Basin showed that only in 18.36% samples EC values were higher than the WHO limit of 1500 µS/cm (Saffi, 2011).

Assessment and mitigation of water related environmental health impacts in the Bagrami district of Kabul province has been done by 39 collected samples from five various locations. In year 2003, 21 out of 37 villages had cholera, it showed %age of 62 %. And in year 2006, 26 out of 37 villages had an outbreak of cholera it showed %age of 70 %. This indicates that cholera outbreaks were widespread in Bagrami district. The results showed that 36.5% water samples contained high level of E. coli, indicating fecal contamination (Ahmadi, 2008).

2.1. WATER QUALITY

Water quality includes the condition of water and its physicochemical and bacterial characteristics, usually with its suitability for a particular purpose such as (drinking and swimming) Some substances like pesticides or fertilizer affect water quality and have ability to negatively affect marine life when exist in certain amount Essential components of good water quality are dissolved salts and minerals which they assist maintain the health and liveliness of the organisms that depend on this ecosystem service (Genevieve & James, 2008)

The primary concern for developing countries is microbiological contamination of water The major challenges for developing countries are inadequate water supply The result of joint monitoring program (JMP), which was implemented by WHO and UNICEF, reported that all over the world 783 million people have not access to improved drinking water Approximately 187 million people utilize surface water for drinking purposes (Sorlini *et al* 2013) Access to improved drinking water is crucial as a health and development issue at the national, regional and local level (WHO, 2004) For minimization of waterborne diseases and to deal with all aspects of water quality challenges, it is necessary to focus on water quality management (Krenkel, 2012)

2.2. PHYSICOCHEMICAL CHARACTERISTICS OF WATER

Some important physicochemical parameters of drinking water quality are, color, odor, pH temperature, turbidity and EC These characteristics and their impacts on water quality are discussed below

2.2.1 Color

Whenever drinking water has color, it means suspended matters are present in Therefore the more suspended matter in water the greater is the color In unusual conditions however, naturally color can arise from the presence of colloidal Iron/Manganese in water (Sabo & Christopher, 2014). Drinking-water must be colorless. For the purposes of careful observation of community water supplies, it is simply useful to note the presence or absence of seeable color at the time of sampling. Indeed, further inspection is needed when changes occur in the color of water and the appearance of new color (WHO, 1997). Corrosion of copper plumbing is caused green or blue water. Certain metals such as lead or copper that can get into drinking water from corrosion may cause a health problem. Manganese in the water and sediments in the pipes usually cause black and dark brown water. Manganese does not cause a threat to health of human beings. Iron rust usually poses Brown, red, orange or yellow water. The main source of rusty water is galvanized iron, cast or steel iron pipes in home or business. Milky white or cloudy water often caused by very small air bubbles and it has not a human health threat (US Fact Sheet, 2011).

2.2.2 Odor

The presence of organic substances in water may cause odor in water. Increased biological activity may cause some odors, while others are indicative of industrial pollution (WHO, 1997). Petroleum, gasoline, turpentine, fuel, or solvent odors are unusual, but can be potentially serious. Occurring of hydrogen sulfide in water supply can cause sulfur or rotten egg odor. Adding chlorine to the water in plumbing system may cause the chlorine, chemical, or medicinal taste or odors, commonly it is not an immediate health threat (US *Fact Sheet*, 2011).

2.2.3 pH

pH is one of the most important chemical factors of drinking water which determine the suitability of water for different purposes, including toxicity to animals and plants

(Venkatesharaju *et al*., 2010). The negative common logarithm of the hydrogen ion activity is named the pH of solution. pH = -log (H⁺)

If the relative proportion of hydroxyl ions is greater than the hydrogen ions then the water is basic while if hydrogen ions are dominant then the water is acidic (Genevieve & James, 2008). The palatability of water can be affected by highest degree of pH but the corrosive effect on distribution systems is a more immediate problem (EPA, 2001). The pH of water is usually altered by soil before getting into the stream. It can be measured by using pH meters, standard dyes or paper pH indicator strips (Singer *et al*., 2012).

2.2.4 Temperature

One of the most important physical parameters of water in aquatic environment is temperature, since it regulates bacterial and physicochemical activities (Khan *et al*., 2012). Temperature determines the level of DO and bacterial activity in water (Ukpong & Peter, 2012). It is influencing freshwater ecosystems and management measures, spatial and temporal distribution of organisms (Masood *et al*., 2015).

Living organisms can be affected by changes in temperature. Variations in temperature can cause changes to some of the key components of water (form or their concentration) (EPA, 2001). In aquatic environment one of the limiting factors is temperature. The organisms can be stressed and die when water temperature is outside the range for long while. The amount of oxygen which water can hold can be affected by temperature. Cold water has more ability to holds more oxygen than warm water and oxygen is necessary to survive aquatic animals. The rate of photosynthesis, reproduction and metabolic activities can be affected by temperature. A characteristic annual cycle, with higher values during the summer (dry season) and lower values in the winter (rainy season) has shown by water temperature (Omaka *et al*., 2014).

2.2.5 Turbidity

Particulates in water cause turbidity. Measurement unit of turbidity is NTUs (nephelometric turbidity units) or sometimes is JTUs (Jackson turbidity units) (Satterfield, 2006). Measurement of cloudiness or murkiness of water through suspended particles is called turbidity. Surface water and shallow wells sources of water have the high turbidity. Organic particles such as decomposed plant and animal matter and inorganic particles such as (silt, clay and natural chemical compounds like calcium carbonate etc.) are the main sources to cause turbidity. It is possible that turbidity can range from less than 1 NTU to more than 1 000 NTU. Water of 5 NTU, is visibly cloudy and will be murky with 25 NTU. Drinking turbid water can be risky for population especially risky for people with compromised immune systems, including people who have organs transplant, cancer and are taking chemotherapy or radiation therapy and HIV or AIDS (MWSMH, 2011). To monitor the effects of turbidity within local watersheds, recommended that the correlation between suspended sediment and NTUs be examined by the range of discharge recordings, to examine local effects, this be used as a baseline (Henley *et al.*, 2000).

2.2.6 Electrical conductivity (EC)

The measurement of water capacity with which electrical current can pass is called EC. It can be measured accurately in the field using a portable conductivity meter. The number of ions in solution can increase EC (Moore *et al.*, 2008). Measurement of EC of surface water is preferred to perform in situ, and for ground water is preferred down-hole or flow-through-chamber measurements. Transportation of wells water sample to land surface can change its temperature and affect water EC (Radtke *et al.*, 2005).

Different waters like ground water, water drained from agricultural fields, municipal waste water and rain water will have different EC. Therefore, groundwater seepage can be determined by EC (CWT, 2004) The measuring unit for EC is micro or milli Siemens/centimeter (µS/cm or mS/cm)

2.3. BACTERIAL CHARACTERISTICS OF WATER

The water quality characteristics also depend on the presence of different microorganisms in drinking water The main categories include coliform group total coliform and fecal coliform These microorganisms and their impact on water quality are discussed below

2.3.1 Coliform

Large groups of various types of bacteria from the same family including in coliform bacteria Most of these bacteria are finding in soils surface water and vegetation Some coliform bacteria result from fecal sources Most coliform bacteria are harmless to humans, but some of them can cause mild illnesses and a few coliform bacteria can cause serious waterborne diseases (Saha *et al*, 2011)

Most of coliform bacteria do not cause illnesses However, in water testing these bacteria are used as indicator, because their presence determines disease causing pathogens There is some disease causing' organisms or pathogens that can present in water

- Bacteria, that could cause diarrhea and vomiting
- Protozoa, could cause dysentery
- Viruses that could case Polio and hepatitis
- Helminthes (tapeworm and roundworm) which could cause chronic diarrhea

For determination of all disease leading organisms or pathogens in drinking water is complex, time consuming and expensive (NCDHHH 2009) Whenever water contain of coliform bacteria, water is not suitable for drinking purposes As a precautionary measure, when extra testing confirms the safety of the water or advised by the authorities, boiling of water should be conducted, at a rolling boil for one minute before its consumption Reduction or elimination of bacteria and other harmful diseases causing microorganisms can be performed, from water by disinfection and distillation In some cases addition to disinfection, filtration will be required (GoS 2008) There are three groups of coliform bacteria (Total coliform, fecal coliform and E coli) Each has a various level of risks

2.3 2 Total coliform

Total coliform are common in the environment (soil or vegetation) and are generally harmless If detect only total coliform bacteria in drinking water in the lab the source is probably environmental and fecal contamination is unlikely However when environmental contamination could to enter the system, pathogens can get in also It is important to find and determine the source of the contamination (WSDH 2011)

Total coliform bacteria are determiners and commonly easy to grow A margin of safety has been provided by their testing When there are coliforms pathogens may not be present but in some cases it is wise to look for problems (Treyens, 2009) The main source of pathogens in drinking water is due to contamination from human or animal waste

- unsuitably treated septic and sewage discharges
- Leaching of animal manure
- Storm water runoff
- Domestic animals or wildlife

For Drinking Water maximum acceptable concentration = no total coliform or E coli should be detected after test for every 100 ml of drinking water sample

2.3 3 Fecal coliform

The subgroup of total coliform bacteria is fecal coliform bacteria They exist in the intestines and excrement of human and animals Indeed the presence of fecal coliform often

CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY AREA

Kabul, a historical city is located in the administrative province of Kabul is also the capital of Afghanistan It is situated on the banks of Kabul River at 34° 32' North 69° 10' East with an altitude of 1800 meters This elevation makes it one of the highest capital cities in the world The area of Kabul city is 344 km^2 (CSOA, 2013) Kabul in Afghanistan occupies a landlocked territory It is surrounded by lofty mountains, in the east by Koh-e-Paghman mountain range, in the west by the Koh-e-Qrough mountain ranges, while from north-eastern side by Koh-e-Shirdarwaza Mountains Kabul occupies a central and strategic location at a crucial juncture where the east-west and north-south trade routes are intersecting (Figure 3)

Kabul city has 22 municipality districts or Nahia Kabul city has been divided into 7 water distributary zones (zone 1, 2, 3, 4, 5 6 and 7) by AUWSSC Water supply system of Kabul city has three main water supply projects (Afshar project Logar project and Alaudin project) Afghanistan population reported in 2015 was 32 5 million of which almost 10 % (3 6 million) lives in Kabul and makes it the only city in Afghanistan with more than 1 million populations (WPR, 2015) water should be conducted, at a rolling boil for one minute before its consumption. Reduction or elimination of bacteria and other harmful diseases causing microorganisms can be performed from water by disinfection and distillation. In some cases addition to disinfection, filtration will be required (GoS 2008). There are three groups of coliform bacteria (Total coliform, fecal coliform and E. coli). Each has a various level of risks.

2.3.2 Total coliform

Total coliform are common in the environment (soil or vegetation) and are generally harmless. If detect only total coliform bacteria in drinking water in the lab, the source is probably environmental and fecal contamination is unlikely. However, when environmental contamination could to enter the system, pathogens can get in also. It is important to find and determine the source of the contamination (WSDH 2011).

Total coliform bacteria are determiners and commonly easy to grow. A margin of safety has been provided by their testing. When there are coliforms, pathogens may not be present, but in some cases it is wise to look for problems (Treyens 2009). The main source of pathogens in drinking water is due to contamination from human or animal waste.

- unsuitably treated septic and sewage discharges
- Leaching of animal manure
- Storm water runoff
- Domestic animals or wildlife

For Drinking Water maximum acceptable concentration = no total coliform or E.coli should be detected after test for every 100 ml of drinking water sample.

2.3.3 Fecal coliform

The subgroup of total coliform bacteria is fecal coliform bacteria. They exist in the intestines and excrement of human and animals. Indeed, the presence of fecal coliform often point out the recent fecal contamination in a drinking water sample It means, when pathogens are exist there is a greater risk (WSDH 2011)

Fecal coliforms bacteria usually found in the gut of animals Whenever determine fecal coliform in water, it means that water contamination is resulted from sewage effluent (Treyens, 2009) Many fecal coliform bacteria are unharmed, but some of them can cause mild to serious sickness (Saha *et al*, 2011)

2 3.4 Escherichia coli

E coli is a subgroup of the fecal coliform bacteria Many E coli bacteria are unharmed and live in the intestines of human and warm-blooded animals However, some strains can cause sickness Recently, fecal contamination has been determined by presence of E coli in drinking water It means there is a greater risk that pathogens are present (WSDH, 2011)

E coli is an abbreviation form of Escherichia coli a genus of bacteria The reality is that its' originates only in warm-blooded animals makes E coli a better determiner than total coliform of the potential for human sicknesses Therefore for both total coliform and E coli the common relative inexpensive test for bacteria will has been shown the result (Saha *et al*, 2011)

CHAPTER 3

MATERIALS AND METHODS

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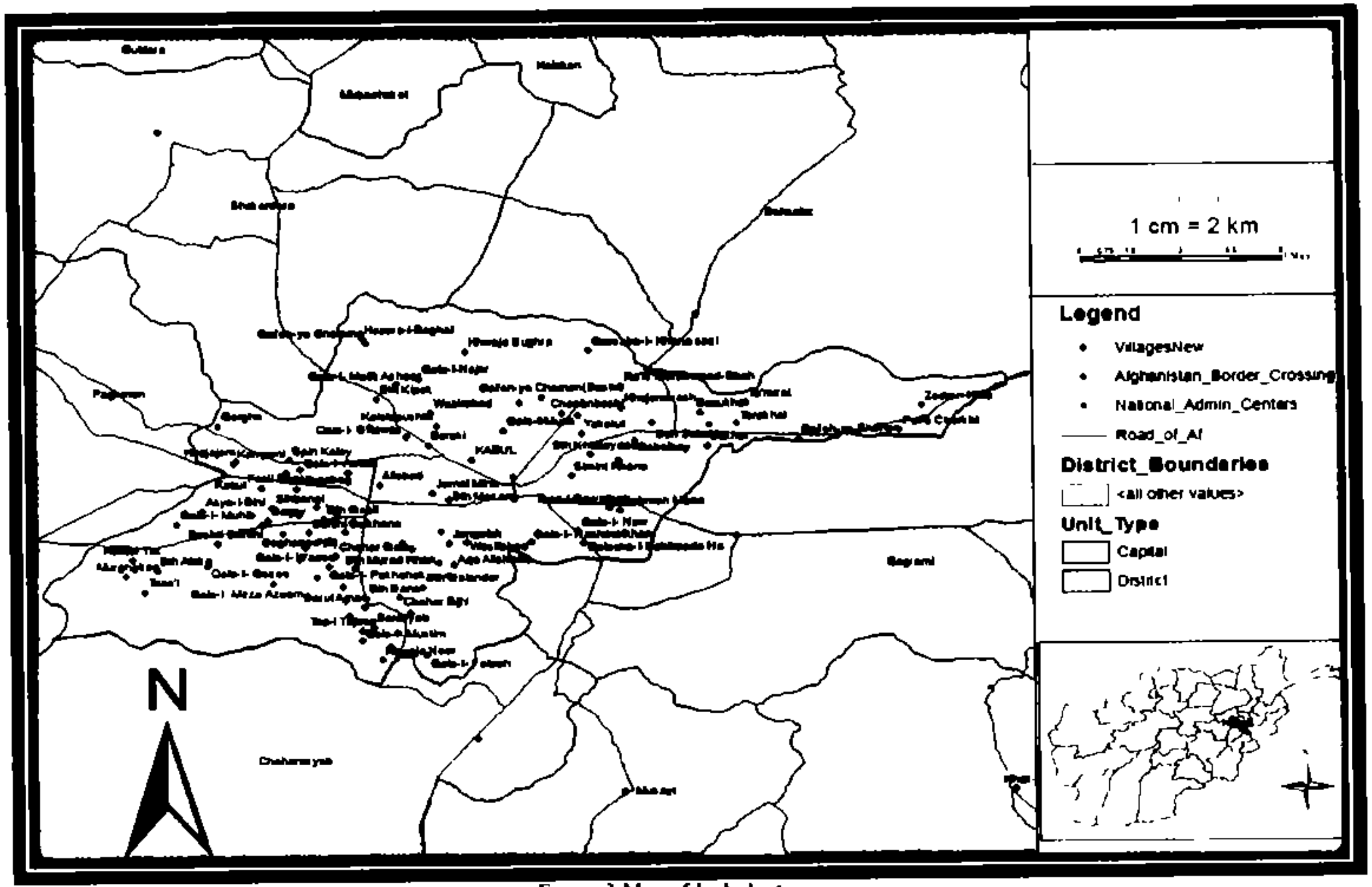


Figure 3 Map of Kabul city

3.2 WATER SAMPLING

Water sampling was carried out from October to December 2015 and subject to physicochemical and bacterial analysis The experimental protocol included both chemical and bacterial analysis of water samples collected from three types of sources (Figure 4)

For drinking water samples collection total 10 locations were selected based on AUWSSC watery zones divisions and Kabul city water supply projects represented as zone1, zone2, zone3, zone4 zone5, zone6, zone7 Afshar project Alaudin project and Logar project (Figure 5)

Total 85 water samples were collected in 500 ml clean bottles from three different sources i e deep wells, water storage tanks and water distribution networks or house connections from selected areas of Kabul city The selected area were Sayed Jamaludin University Alaudin, Project office, Front of Mohsani Islamic University Near to Kabul Zoo Passport office, Pul Artal, Naqash, Kart-e-Naw Pul Khoshk Bagh Bala Kart-e-Parwan 2, Kart-e-Mamorin, Se Bangi, Fazel Bik, Zone office Khair Khana, Sarak Bidel 500 Family Khairkhana 2nd phase, Kabul University Jamal Mena, Pul Artal Andrabi, Zone office Paykob Naswar, Taimani Projah Taimani Qal-e-Fathullah Sarak 5 projah Taimani Kart-e-Naw, Kart-e-Naw, Tap-e-Kart-e-Naw Familyhi Askari Kart-e-Naw Bagrami, Project office, Bagrami, Logar river, Ali Abad, Alaudin Project office Dehmazang, Near to Russian Embassy, Front of Mohsani Islamic University Habiba High School Dehmurad Khan, Bagh Bala, Kart-e-Aryana, Kart-e-Mamorin Zone office Khair Khana, Kaserulestefada School, Khair Khana, Khairkhana. 2nd phase Shahre Kona Kot-e-Sangi Dehbori (Figure 6)

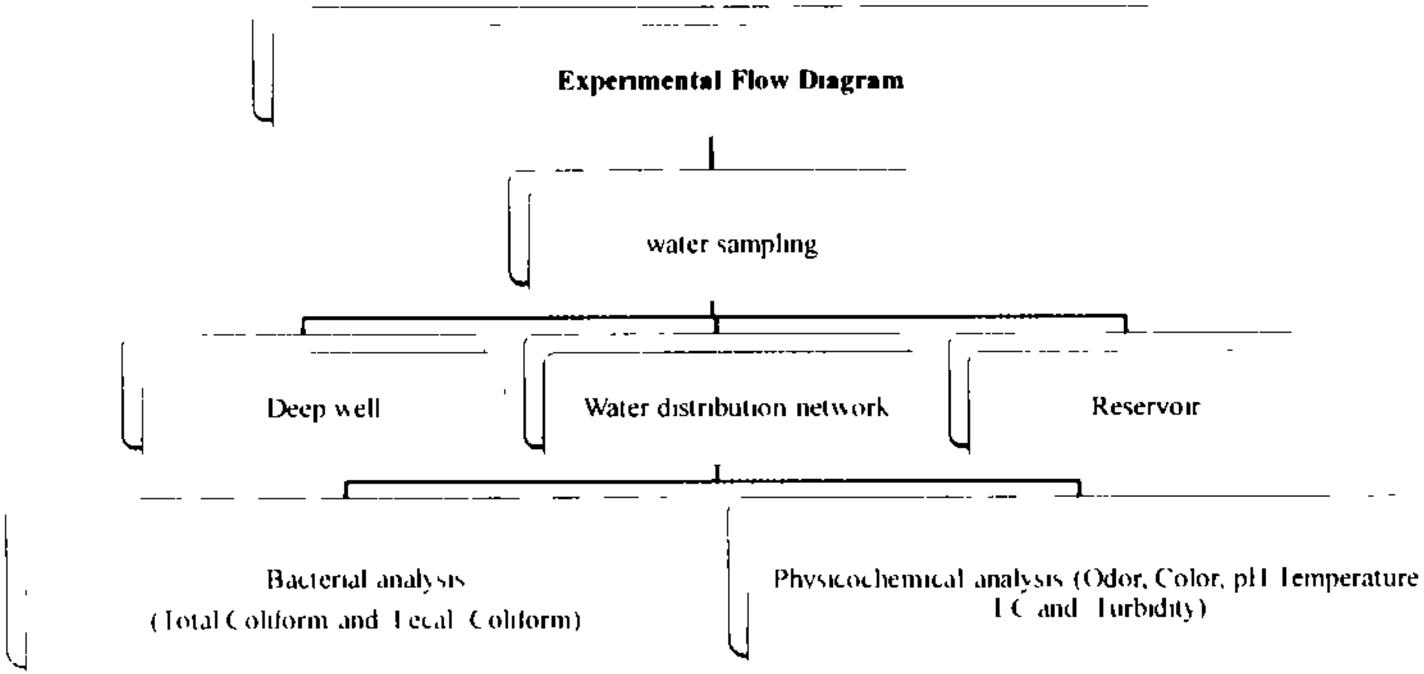


Figure 4 Experimental flow diagram

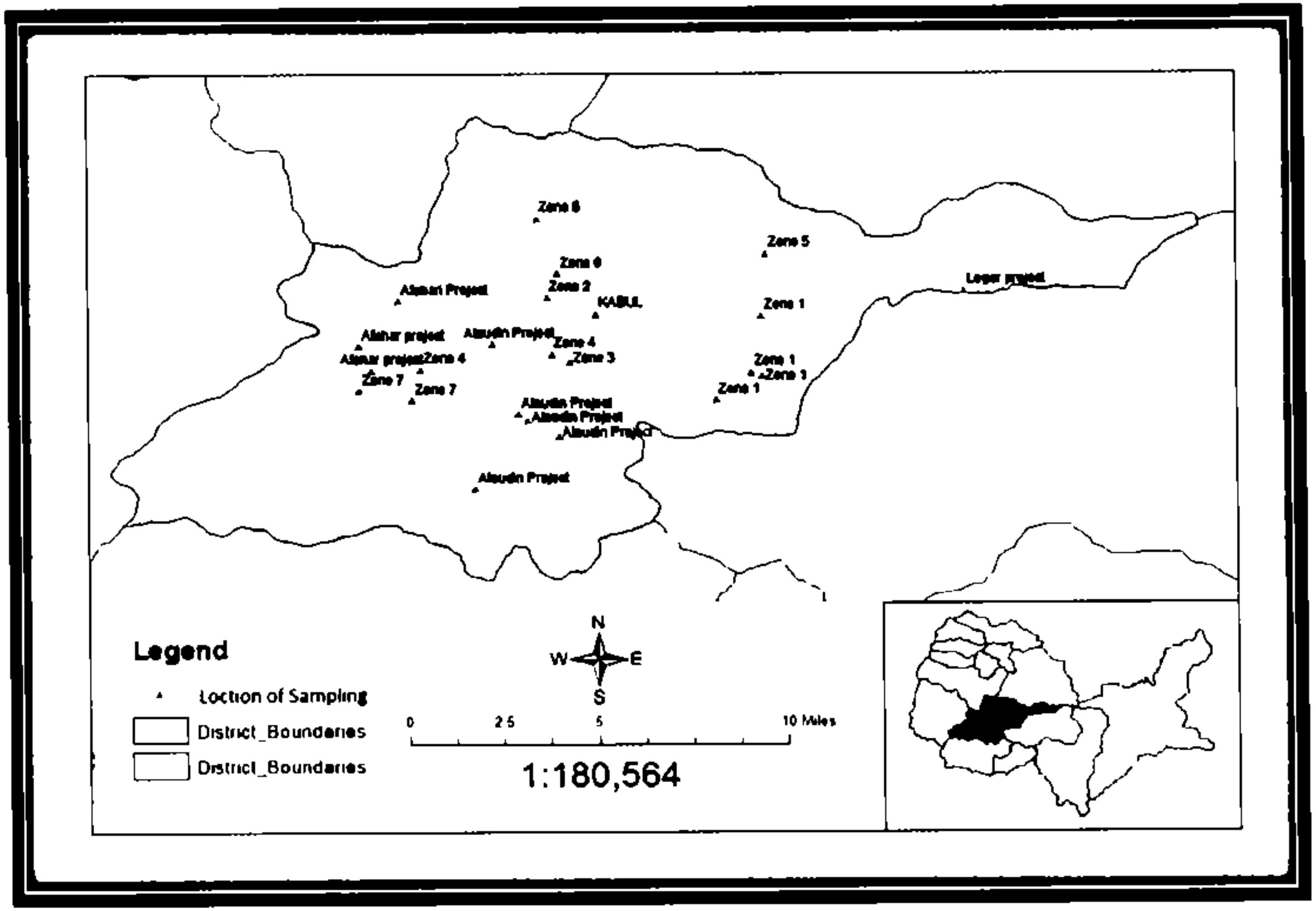


Figure 5 Pictorial view of water sampling zones and projects

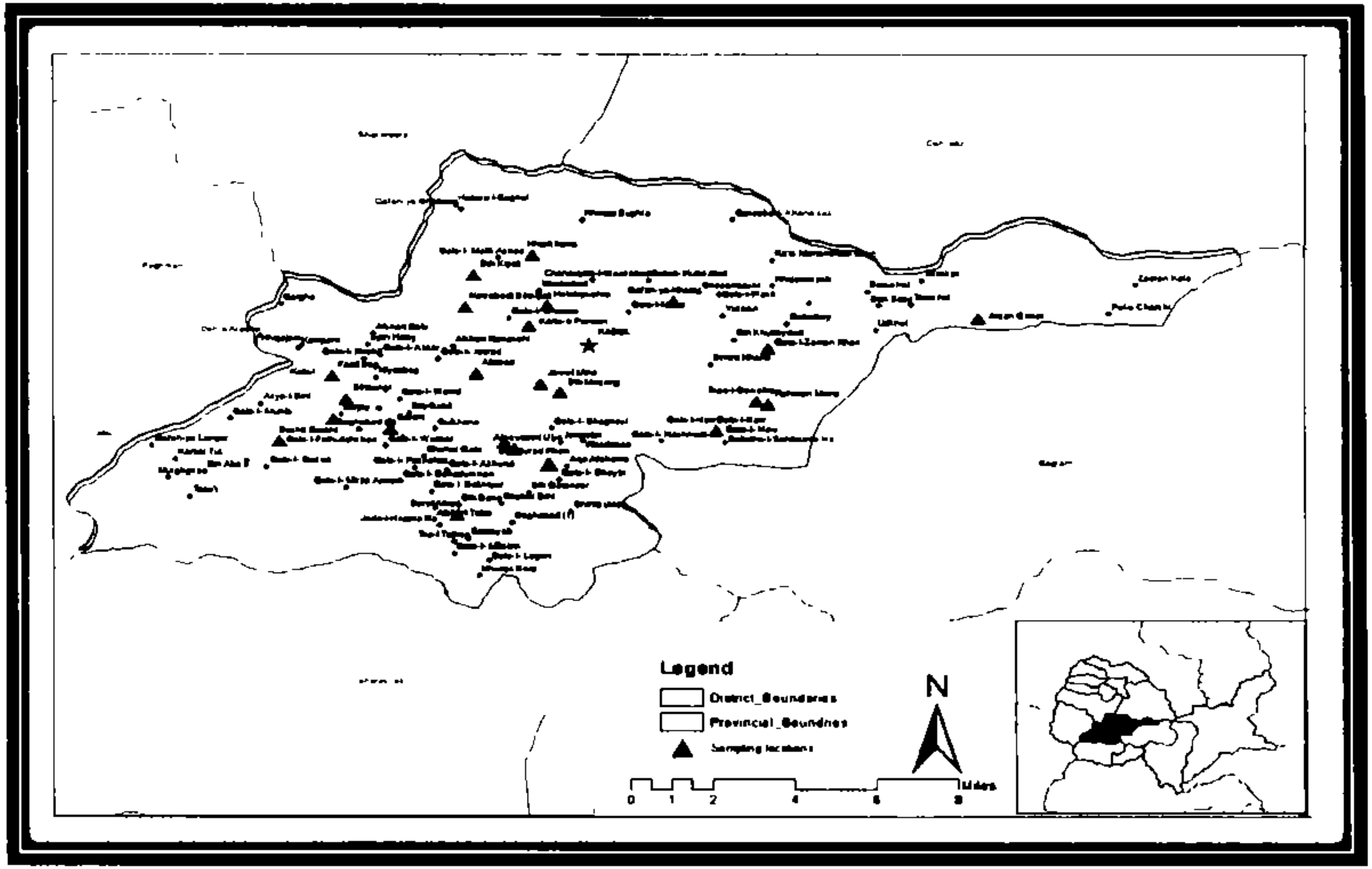
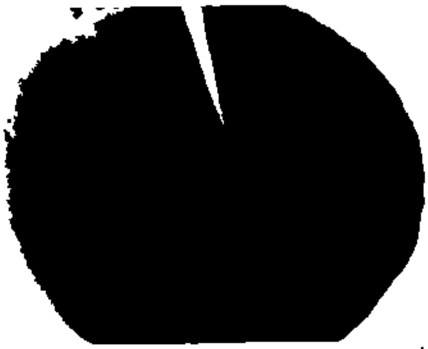


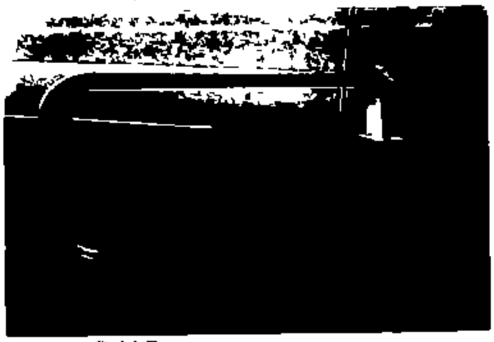
Figure 6 Detail map of sampled water locations

Water sampling was carried out according to the Standard Methods. Both for physicochemical and bacterial analysis samples were collected in 500 ml sterile SCHOTT Duran glass bottles and were properly labeled. The samples were transported in cold box (≤ 4°C) to prevent any physicochemical or biological change to AUWSSC laboratory for further analysis.

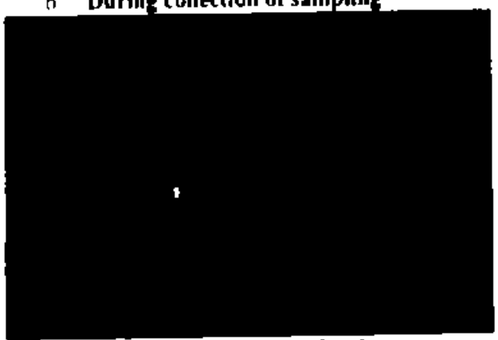


a. Sampling from water storage tank

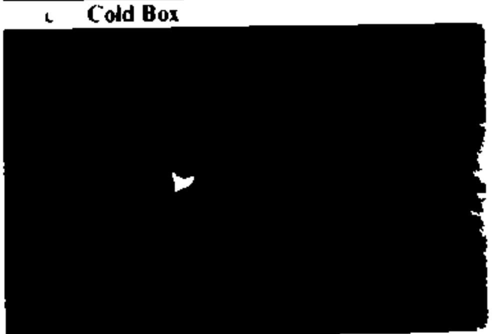
b. During collection of sampling



c. Cold Box



d. SCHOTT Duran glass bottles



e. Portable propane butane burner

f. Water sample collection

Figure 7 Pictorial view of water sampling process and water collection equipment

3.3 REAGENTS AND MEDIA

All chemicals and reagents used were of high quality analytical grade High quality deionized distilled water was used for reagents and media preparations

3.4 PHYSICOCHEMICAL ANALYSES

Temperature, color odor, pH, and EC of water samples were measured on the spot by using respective electrodes Turbidity was measured by using Turbidimeter (HACH 2100)

3.5 BACTERIAL ANALYSIS

Water samples were analyzed for bacterial contamination by membrane filter method In this procedure coliform density was reported conventionally as the membrane filter count per 100 mL and analysis was done by DelAgua single incubator test kit Bacterial data was compared with WHO and ANSA standards

3.5.1 Presumptive Tests for Total and Fecal Coliform

A direct count of total coliforms and fecal coliforms present in a given sample of water yielded by membrane filter method A measured 100 ml volume of water was filtered, under vacuum, through a gridded membrane filter (0 45 μm pore size) Bacteria were retained on the surface of the membrane which was placed on a suitable selective medium in a sterile container and incubated at an appropriate temperature (total coliform at 37 °C and fecal coliform at 44 °C within 24 hours) When there was presence of total coliforms or fecal coliforms in the water sample, characteristic colonies were formed and were counted directly

3.5.2 Confirmation Tests for Total and Fecal Coliform

To confirm the membrane results for total coliforms each colony (or a representative number of colonies) was sub-cultured in a tube of lactose peptone water and was incubated at

37°C for 48 hours Gas production within this period confirmed the presence of total coliforms

For confirmation of fecal coliforms membranes each colony (or a representative number of colonies) was sub-cultured in a tube of lactose peptone water and a tube of tryptone water Tubes were incubated at 44 °C for 24 hours Growth with the production of gas in the lactose peptone water confirmed the presence of fecal coliforms

Table 1 Standards for physicochemical parameters of drinking water

Parameters	WHO, 2011	ANSA 2011
Color	Non Objectionable/Acceptable	Non Objectionable/Acceptable
Odor	Non Objectionable Acceptable	Non Objectionable/Acceptable
pH	6 5-8 5	6 5-8 5
Turbidity	≤5NTU	<5NTU
EC	1500 µS/cm	1500 µS cm
Temperature	NA	NA

Table 2 Standards for bacterial parameters

Parameters	WHO, 2011	ANSA, 2011
Total coliform	0/100 ml	0 100 mL
Fecal Coliform	0/100 ml	0/100 ml
E Coli	0 100 ml	0/100 mL

Figure 8 DelAgua single incubator test kit

Figure 9 Bacterial analysis instruments and equipment

CHAPTER 4

RESULTS AND DISCUSSION

4.1 PHYSICOCHEMICAL ANALYSIS

Color and odor of all the water samples were found non-objectionable acceptable

4.1 1 pH

Mean pH values of collected water samples from Zone 1 were found in the range of 7 96 to 8 05 Lowest pH value was of water storage tank of Kart-e-Naw whereas highest pH value was recorded for water distribution network sample of Familyhayi Askari Kart-e-Naw Mean pH values of collected water samples from Zone 2 were found to range from 8 1-8 3 Mean pH values of analyzed samples from Zone 3 were ranged from 7 1 to 8 1 with maximum pH recorded in deep well water sample of Pul-e-Artal and minimum pH was recorded in water distribution network of Kart-e-Ariana In Zone 4 the mean pH values were found to range from 7 9-8 1 Mean pH values of collected water samples from Zone 5 were found to range from 7 94-8 3 with minimum pH recorded in water distribution network of Khairkhana, 2nd phase and the maximum pH was recorded in deep well water of Zone office Khair Khana pH values of collected water samples from Zone 6 were ranged from 7 6 to 7 9 Mean pH values of water samples from Zone 7 Whereas Mean pH values of collected water samples from Afshar project were ranged from 7 73 to 7 98 therefore there were not significant changes in all collected water samples Mean pH values of analyzed water samples from Alaudin project were ranged from 7 75-8 07 with the lowest pH was of deep well water of Sayid Jamaludin University and highest pH was noted in the water storage tank of Ali Abad Mean pH values of collected water samples from Logar project were ranged from 7 9-8 1 (Table 3, Figure 10)

Table 3 pH values of drinking water samples of Kabul city

Sources	Location	pH	Sources	Location	pH
WST	Kart-e-Naw	7 99	DW	Se Bangi Fazel Bik	7 82
WST	Kart-e-Naw	7 96	DW	Se Bangi, Fazel Bik	7 98
DN	Tapa-e-Kart-e-Naw	7 98	DW	Se Bangi Fazel Bik	7 77
WST	Kart-e-Naw	8 04	DW	Se Bangi, Fazel Bik	7 73
WST	Kart-e-Naw	7 99	DW	Near to Kabul Zoo	7 82
DN	Tapa-e-Kart-e-Naw	8 03	DW	Sayed Jamaludin University	7 75
DN	Familyhai Askari,	8 05	DW	Alaudin Project office	7 77
WST	Bagh Bala	8 1	WST	Alaudin, Project office	8 04
DN	Kart-e-Parwan 2	8 2	DW	Mohsani University	7 9
DN	Kart-e-Aryana	8 2	DW	Passport office	7 84
DN	Kart-e-Mamorin	8 2	DW	Dehmurad Khan	7 9
WST	Bagh Bala	8 2	DW	Dehmurad Khan	7 88
DN	Kart-e-Aryana	8 3	WST	Ali Abad	8 07
DN	Kart-e-Mamorin	8 3	DW	Alaudin Project office	8 02
DW	Pul Artal	7 9	WST	Alaudin, Project office	7 96
DW	Pul Artal	7 79	DW	Dehmazang	7 89
DN	Naqash	8 01	DW	Near to Russian Embassy	7 9
DN	Kart-e-Aryana	8	DW	Mohsani University	7 93
DW	Pul Artal	7 1	DW	Habibia High School	8 02
DW	Pul Artal	7 8	DW	Dehmurad Khan	8 01
DN	Kart-e-Aryana	8 1	WST	Bagrami, Project office	7 98
DN	Andrabi	8	DW	Bagrami, Logar river	7 98
DN	Kabul University	7 9	DW	Bagrami Logar river	7 97
DN	Shahre Kona	8	DW	Bagrami Logar river	7 95
DN	Jamal Mena	7 9	DW	Bagrami, Logar river	7 97
DN	Shahre Kona	8 1	DW	Bagrami, Logar river	7 96
DN	Kot-e-Sangi	8	DW	Bagrami, Logar river	7 9
DN	Dehbori	8	DW	Bagrami Logar river	7 86
DW	Zone office, Khair Khana	8 1	DW	Bagrami, Logar river	7 85
DW	Sarak Bidel, Khair Khana	8 08	DW	Bagrami Logar river	7 9
DW	500 Family, Khair Khana	8 08	DW	Bagrami, Logar river	7 92
DN	Khairkhana, 2nd phase	7 94	WST	Bagrami, Project office	8 12
DW	Zone office, Khair Khana	8 3	DW	Bagrami, Logar river	8 09
DW	Khair Khana	8 1	DW	Bagrami, Logar river	8 07
DN	Khairkhana, 2nd phase	8	DW	Bagrami, Logar river	8 07
DW	Zone office, Taimani	7 8	DW	Bagrami, Logar river	8 12
DW	Projah Taimani	7 6	DW	Bagrami, Logar river	8 07
DW	Qal-e-Fathullah	7 9	DW	Bagrami, Logar river	8 04
DN	Sarak 5 projah Taimani	7 8	DW	Bagrami Logar river	8 02
DW	Pul khoshk	7 8	DW	Bagrami, Logar river	8 02
DN	Kocha Emam Raza	7 8	DW	Bagrami, Logar river	7 99
DN	Kocha Sayda	8	DW	Bagrami, Logar river	7 98
DN	Kocha Rasalt	7 9			

DN Distribution network DW Deep well WST water storage tank

The study showed that except few most of the samples pH values were within WHO and ANSA permissible limits. Few variations in pH values might be due to leakages in water distribution network through which domestic waste water or sewage and other pollutants enter the water distribution system and cause changes in pH values therefore make them acidic or alkaline.

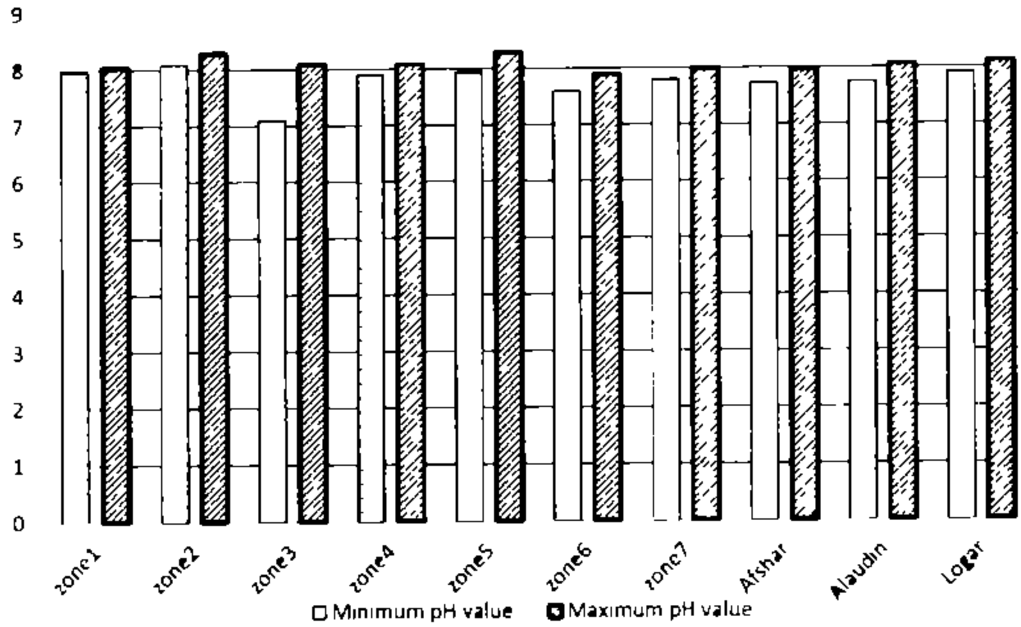


Figure 10 Comparison of pH per each water collection zone and project

4.1.2 Electrical Conductivity (EC)

This study result showed that 31 out of 85 samples EC values exceeded the permissible limits of WHO standards. Drinking water samples collected from zone1 mean EC values were in range of 1470.84-1942.2 µS/cm. The highest EC value was recorded in water storage tank of Karta-e-Naw whereas the lowest value was also recorded in water storage tank of Karta-e-Naw. Mean EC values of collected water samples from Zone2 were found within the range of 333.3-409.5 µS/cm. The highest EC value was recorded in water distribution network of Karta-e-Mamorin and the lowest EC value was found in water storage tank of Bagh-e-Bala. Drinking water samples collected from Zone3 mean EC values were recorded in the range of 1103 52-1328 58 µS/cm Mean EC values of collected water samples from Zone4 were in range of 832-1755 71 µS cm The lowest EC value was recorded in water distribution network of Dehbori whereas the highest EC value was found in water distribution network of Kabul University Drinking water samples collected from Zone5 mean EC values were found within the range of 772 73-1371 23 uS/cm The minimum EC value was recorded in deep well water of Kaser-ul-estefada School Khairkhana and the highest EC value was found in water distribution network of 2nd Phase Khairkhana (Figure 11)

Table 4 EC values of drinking water samples of Kabul city

Sources	Location	EC µS cm	Sources	Location	EC µS/cm
WST	Kart-e-Naw	11536 7	DW	Se Bangi, Fazel Bik	818 72
WST	Kart-e-Naw	1470 84	DW	Se Bangi, Fazel Bik	822 29
DN	Tapa-e-Kart-e-Naw	1548 7	DW	Se Bangi Fazel Bik	822 29
WST	Kart-e-Naw	1942 2	DW	Se Bangi, Fazel Bik	823 48
WST	Kart-e-Naw	1937	DW	Near to Kabul Zoo	893 2
DN	Tapa-e-Kart-e-Naw	1926 6	DW	Sayed Jamaludin University	1351 9
DN	Familyhai Askari	1934 4	DW	Alaudin Project office	1146 88
WST	Bagh Bala	333 3	WST	Alaudin, Project office	1155 84
DN	Kart-e-Parwan 2	344 96	DW	Mohsani University	1362 71
DN	Kart-e-Aryana	355 04	DW	Passport office	1791 8
DN	Kart-e-Mamorin	349 44	DW	Dehmurad Khan	1123 95
R	Bagh Bala	405 6	DW	Dehmurad Khan	1188 72
DN	Kart-e-Aryana	401 7	WST	Ali Abad	1099 91
DN	Kart-e-Mamorin	409 5	DW	Alaudin, Project office	1291 43
DW	Pul Artal	1148 08	WST	Alaudin, Project office	1300
DW	Pul Artal	1314 4	DW	Dehmazang	1596
DN	Naqash	1159 51	DW	Near to Russian Embassy	1761 5
DN	Kart-e-Aryana	1130 88	DW	Mohsani University	1524 9
DW	Pul Artal	1103 52	DW	Habibia High School	1019 2
DW	Pul Artal	1278 97	DW	Dehmurad Khan	980 2
DN	Kart-e-Aryana	1328 58	WST	Bagrami Project office	1619 52
DN	Andrabi	1289 86	DW	Bagrami Logar river	1794 24
DN	Kabul University	1755 71	DW	Bagrami Logar river	1850 24
DN	Shahre Kona	1293 49	DW	Bagrami, Logar river	1870 4
DN	Jamal Mena	1485 88	DW	Bagrami, Logar river	1560 66
DN	Shahre Kona	1358 9	DW	Bagrami, Logar river	1297 32
DN	Kot-e-Sangi	1384 5	DW	Bagrami Logar river	1214 1
DN	Dehbori	832	DW	Bagrami Logar river	1357 74
DW	Zone office Khair Khana	897 26	DW	Bagrami Logar river	1342 92

DW	Sarak Bidel, Khair Khana	1000 92	DW	Bagrami Logar river	1356 6
DW	500 Family, Khair Khana	898 45	DW	Bagrami Logar river	1576 62
DN	Khairkhana, 2nd phase	1193 57	WS1	Bagrami Project office	1732 9
DW	Zone office, Khair Khana	1004 15	DW	Bagrami Logar river	2134 6
DW	Khair Khana	772 73	DW	Bagrami Logar river	2172 3
DN	Khairkhana, 2nd phase	1371 23	DW	Bagrami Logar river	2168 4
DW	Zone office, Taimani	1786 89	DW	Bagrami Logar river	1609 4
DW	Projah Taimani	3780 76	DW	Bagrami Logar river	1636 7
DW	Qal-e-Fathullah	1430 96	DW	Bagrami Logar river	1596 4
DN	Sarak 5 projah Taimani	1581	DW	Bagrami Logar river	1587 3
DW	Pul khoshk	818 72	DW	Bagrami Logar river	1609 3
DN	Kocha Emam Raza	817 53	DW	Bagrami Logar river	1758 9
DN	Kocha Sayda	825 86	DW	Bagrami Logar river	1806 14
DN	Kocha Rasalt	854 36			

DN Distribution network, DW Deep well WS1 Water storage tank

Mean EC values of collected water samples from Zone6 were found in range of 1430 96 to 3780 76 µS/cm The lowest EC value was noted in deep well water of Qala-e-Fathullah whereas the highest EC value was found in deep well water of Proja-e-Taimani Drinking water samples collected from Zone7 mean EC values were found within the range from 817 53 to 854 36 µS/cm There were not significant change among collected water samples of Zone 7 whereas, the minimum EC value was recorded in water distribution network of Kocah-e-Imamreza, Pul-e-Khoshk and the maximum EC value was also found in water distribution network of Kocha-e-Risalat Pul-e-Khoshk Mean EC values of collected drinking water samples from Afshar Project were found to range from 818 72 to 823 48 µS/cm The highest EC value was found in deep well water of Sibangi, Fazalbig whereas the lowest EC value was also recorded in deep well water of Sibangi, Fazalbig Drinking water samples collected from Alaudin project mean EC values were noted to range from 893 2-1791 8 µS/cm The maximum EC value was found in deep well water of Passport office whereas the minimum EC value was recorded in deep well water near Kabul Zoo Mean EC values of collected drinking water samples from Logar project were ranged from 1214 1 to 2172 3 μS/cm The lowest EC value was found in deep well water of Bagrami, Logar river and the highest EC value was also recorded in deep well water of Bagrami, Logar river (Figure 11)

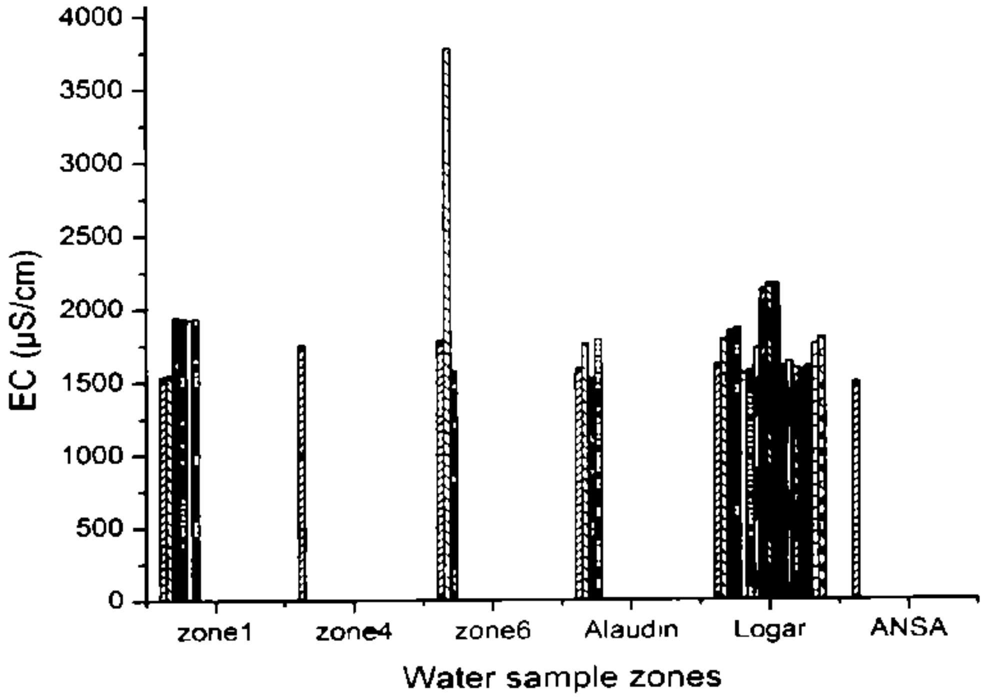


Figure 11 Waterv zones and projects with high EC values

It can be seen that the EC values of 31 47 % drinking water samples were found beyond the permissible limit of WHO and ANSA All drinking water collected samples from Zone2, Zone 3, Zone5, Zone7 and Afshar project were found within the permissible limit of WHO and ANSA whereas majority of the samples collected from Zone1 Zone4, Zone6 Alaudin project and Logar project were found in excess of the permissible limit of WHO and ANSA (Table 4)

4.1.3 Turbidity

The study showed that all the water samples were within the permissible limit of WHO and ANSA (Table 5)

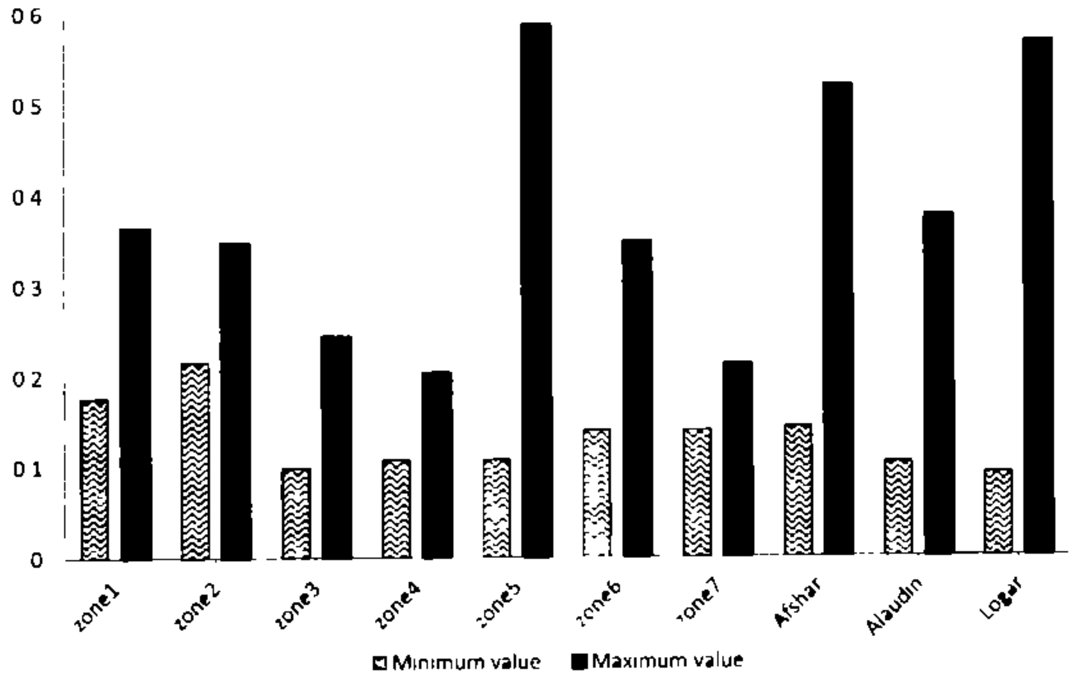


Figure 12 Comparison of Turbidity per each water collection Zone and project

Drinking water samples collected from Zone1 mean turbidity values were found to range from 0 176 to 0 364 NTU Mean turbidity values of collected drinking water samples from Zone2 were found within the range of 0 216 to 0 348 NTU Drinking water samples collected from Zone3 mean turbidity values were found to range from 0 1-0 244 NTU Analysis of collected drinking water samples from Zone4 showed mean turbidity values within the range from 0 108 to 0 204 NTU

Table 5 Turbidity values of drinking water samples from Kabul city

Source	Location	Turbidity (NTU)	Source	Location	Turbidity (NTU)
WST	Kart-e-Naw	0.364	DW	Se Bangi, Fazel Bik	0.216
WST	Kart-e-Naw	0.204	DW	Se Bangi, Fazel Bik	0.144
DN	Tapa-e-Kart-e-Naw	0.308	DW	Se Bangi, Fazel Bik	0.52
WST	Kart-e-Naw	0.176	DW	Se Bangi Fazel Bik	0.376
WST	Kart-e-Naw	0.224	DW	Near to Kabul Zoo	0.316
DN	Tapa-e-Kart-e-Naw	0.312	DW	Sayed Jamaludin University	0.376
DN	Familyhai Askari	0.248	DW	Alaudin Project office	0.104
WST	Bagh Bala	0.348	WST	Alaudin Project office	0.132
DN	Kart-e-Parwan 2	0.216	DW	Mohsani University	0.264
DN	Kart-e-Aryana	0.244	DW	Passport office	0.368
DN	Kart-e-Mamorin	0.236	DW	Dehmurad Khan	0.12
WST	Bagh Bala	0.224	DW	Dehmurad Khan	0.308
DN	Kart-e-Aryana	0.312	WST	Ali Abad	0.348
DN	Kart-e-Mamorin	0.276	DW	Alaudin Project office	0.212
DW	Pul Artal	0.228	WST	Alaudin Project office	0.272
DW	Pul Artal	0.188	DW	Dehmazang	0.176
DN	Naqash	0.244	DW	Near to Russian Embassy	0.139
DN	Kart-e-Aryana	0.1	DW	Mohsani University	0.376
DW	Pul Artal	0.152	DW	Habibia High School	0.22
DW	Pul Artal	0.18	DW	Dehmurad Khan	0.176
DN	Kart-e-Aryana	0.112	WST	Bagrami, Project office	0.14
DN	Andrabi	0.22	DW	Bagrami, Logar river	0.092
DN	Kabul University	0.124	DW	Bagrami Logar river	0.092
DN	Shahre Kona	0.108	DW	Bagrami Logar river	0.152
DN	Jamal Mena	0.18	DW	Bagrami Logar river	0.18
DN	Shahre Kona	0.168	DW	Bagrami, Logar river	0.132
DN	Kot-e-Sangi	0.204	DW	Bagrami Logar river	0.112
DN	Dehbori	0.152	DW	Bagrami, Logar river	0.1
DW	Zone office, Khair Khana	0.228	DW	Bagrami Logar river	0.156
DW	Sarak Bidel Khair Khana	0.108	DW	Bagrami Logar river	0.172
DW	500 Family, Khair Khana	0.384	DW	Bagrami, Logar river	0.22
DN	Khairkhana, 2nd phase	0.588	WST	Bagrami Project office	0.104
DW	Zone office, Khair Khana	0.272	DW	Bagrami Logar river	0.136
DW	Khair Khana	0.3	DW	Bagrami Logar river	0.168
DN	Khairkhana, 2nd phase	0.392	DW	Bagrami, Logar river	0.384
DW	Zone office, Taimani	0.216	DW	Bagrami Logar river	0.212
DW	Projah Taimani	0.348	DW	Bagrami, Logar river	0.568
DW	Qal-e-Fathullah	0.14	DW	Bagrami Logar river	0.36
DN	Sarak 5 projah Taimani	0.312	DW	Bagrami Logar river	0.092
DW	Pul khoshk	0.152	DW	Bagrami Logar river	0.212
DN	Kocha Emam Raza	0.18	DW	Bagrami Logar river	0.128
DN	Kocha Sayda	0.212	DW	Bagrami, Logar river	0.216
DN	Kocha Rasalt	0.14			

DN Distribution network, DW Deep well WST Water storage tank

Mean turbidity values of collected drinking water samples from Zone5 were found to range from 0 108 to 0 588 NTU Water samples collected from Zone6 mean turbidity values were recorded within the range from 0 14 to 0 348 NTU Drinking water samples collected from Zone7 mean turbidity values were found to range from 0 14 to 0 212 NTU Mean turbidity values of collected water samples from Afshar project were reported from 0 144-0 52 NTU Drinking water samples collected from Alaudin project mean turbidity values were found within the range 0 104 to 0 376 NTU Mean turbidity values of drinking water samples from Logar project were found within 0 092 to 0 568 NTU (Figure 12)

The Safe Drinking Water Act (SDWA) regulates the level of turbidity in drinking water, as higher turbidity levels are usually associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria (Aron 2014)

4.1.4 Temperature

The mean temperature values of collected drinking water samples from Zone1 were found within the range from 15 to 17 °C Drinking water samples collected from zone2 mean temperature values were to range from 14 5 to 17 °C Mean temperature values of collected drinking water samples from Zone 3 were recorded to range from 14 5 to 16 5 °C (Table 6, Figure 13)

Table 6 Temperature values of drinking water samples of Kabul city

Sources	Location	T °C	Sources	Location	T °C
WST	Kart-e-Naw	15.5	DW	Se Bangi Fazel Bik	15.7
WST	Kart-e-Naw	17	DW	Se Bangi Fazel Bik	15.8
DN	Tapa-e-Kart-e-Naw	16	DW	Se Bangi, Fazel Bik	15.7
WST	Kart-e-Naw	15	DW	Se Bangi, Fazel Bik	15.8
WST	Kart-e-Naw	15	DW	Near to Kabul Zoo	18
DN	Tapa-e-Kart-e-Naw	16	DW	Sayed Jamaludin University	19
DN	Familyhai Askari,	16.5	DW	Alaudin Project office	19
WST	Bagh Bala	17	WST	Alaudin, Project office	18.5
DN	Kart-e-Parwan 2	16	DW	Mohsani University	15
DN	Kart-e-Aryana	16	DW	Passport office	15.5
DN	Kart-e-Mamorin	16.5	DW	Dehmurad Khan	15
WST	Bagh Bala	15	DW	Dehmurad Khan	16
DN	Kart-e-Aryana	14.5	WST	Ali Abad	11
DN	Kart-e-Mamorin	15	DW	Alaudin, Project office	11.5
DW	Pul Artal	16	WST	Alaudin, Project office	11.7
DW	Pul Artal	15.5	DW	Dehmazang	11
DN	Naqash	16	DW	Near to Russian Embassy	11.8
DN	Kart-e-Aryana	16.5	DW	Mohsani University	12.1
DW	Pul Artal	14.5	DW	Habibia High School	12.2
DW	Pul Artal	15.3	DW	Dehmurad Khan	11.9
DN	Kart-e-Aryana	14.9	WST	Bagrami Project office	19.5
DN	Andrabi	15.2	DW	Bagrami Logar river	19.3
DN	Kabul University	14.7	DW	Bagrami, Logar river	18.8
DN	Shahre Kohna	14.9	DW	Bagrami, Logar river	18.8
DN	Jamal Mena	15.5	DW	Bagrami, Logar river	18
DN	Shahre Kohna	14	DW	Bagrami Logar river	18.1
DN	Kot-e-Sangi	14	DW	Bagrami, Logar river	18.1
DN	Dehbori	14.5	DW	Bagrami Logar river	18
DW	Zone office Khair Khana	16.5	DW	Bagrami Logar river	18.2
DW	Sarak Bidel Khair Khana	18.5	DW	Bagrami, Logar river	18
DW	500 Family, Khair Khana	16.1	DW	Bagrami, Logar river	18.2
DN	Khairkhana, 2nd phase	16.2	WST	Bagrami, Project office	11.8
DW	Zone office, Khair Khana	10.8	DW	Bagrami, Logar river	11.9
DW	Khair Khana	10.7	DW	Bagrami Logar river	11.9
DN	Khairkhana, 2nd phase	11.4	DW	Bagrami, Logar river	11.7
DW	Zone office, Taimani	13.4	DW	Bagrami, Logar river	12.1
DW	Projah Taimani	13.8	DW	Bagrami, Logar river	11.7
DW	Qal-e-Fathullah	13.8	DW	Bagrami, Logar river	11.7
DN	Sarak 5 projah Taimani	13.9	DW	Bagrami, Logar river	11.8
DW	Pul khoshk	15.7	DW	Bagrami Logar river	11.5
DN	Kocha Emam Raza	15.6	DW	Bagrami, Logar river	11.6
DN	Kocha Sayda	15.6	DW	Bagrami, Logar river	11.3
DN	Kocha Rasalt	14			

DN Distribution network, DW Deep well, WST Water storage tank

The samples from zone4 mean temperature values were found in a range between 14-15.5 °C. Mean temperature values of drinking water samples collected from zone5 were noted in the range of 10.7-18.5 °C. Collected samples from zone6 mean temperature values were found within the range from 13.4-13.9 °C. Drinking water collected samples from Zone7 mean temperature value were found to range from 14 to 15.7 °C. Mean temperature values of water samples from Afshar project were not found within significant changes in temperature values and range from 15.7 to 15.8 °C (Table 6, Figure 13). The collected water samples from Alaudin project samples mean temperature values were noted within the range 11-19 °C. Drinking water samples collected from Logar project mean temperature values were found to range from 11.3-19.5°C.

One of the most important physical parameters of water in aquatic environment is temperature, since it regulates bacterial and physicochemical activities (Khan et al., 2012). Temperature is one of the important and major factors influencing freshwater ecosystems and management measures spatial and temporal distributions of organisms (Masood et al. 2015).

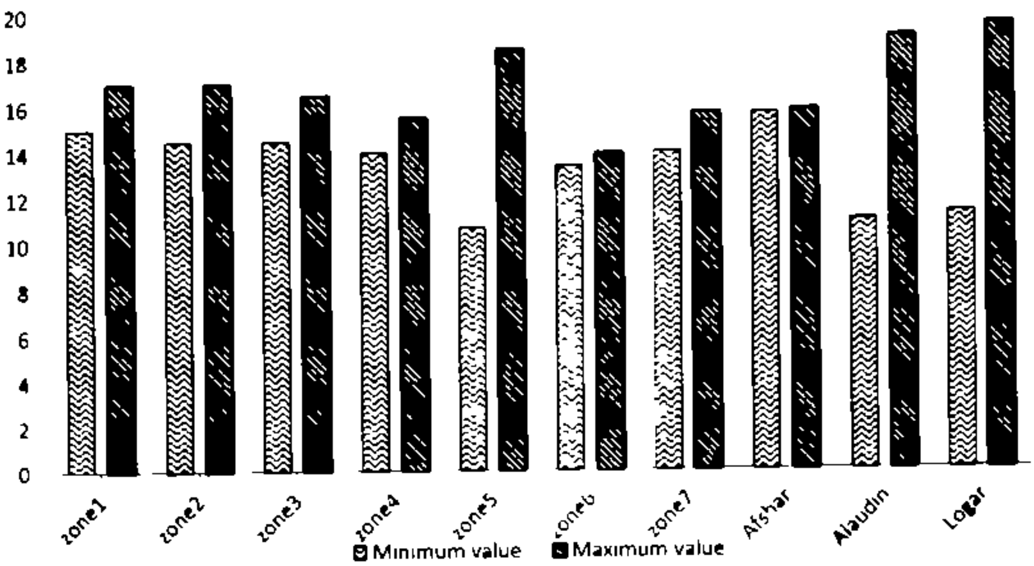


Figure 13 Comparison of Temperature per each water collection zone and project

4.2 BACTERIAL ANALYSIS

For the presence of total coliforms and fecal coliforms the bacterial analysis was done and results are listed in Table 7

Drinking water samples collected from Zone1 of Kabul city were analyzed for total coliform and fecal coliform The result showed that all the samples in this Zone were found free from fecal contamination whereas, only one water sample contained total coliform colonies (4 CFU/100mL) In Zone2 water samples no fecal contamination was found whereas the total coliform bacteria were found in range of 63-150 CFU/100mL In Zone3 water samples no coliforms were found

Table 7 Bacterial analysis of drinking water samples of Kabul city (cfu/100 ml)

Source	Location	TC	FC	Source	Location	TC	FC
WST	Kart-e-Naw	0	0	DW	Se Bangi, Fazel Bik	0	0
WST	Kart-e-Naw	0	0	DW	Se Bangi, Fazel Bik	0	0
DN	Tapa-e-Kart-e-Naw	4	0	DW	Se Bangi, Fazel Bik	0	0
WST	Kart-e-Naw	0	0	DW	Se Bangi, Fazel Bik	0	0
WST	Kart-e-Naw	0	0	DW	Near to Kabul Zoo	0	0
DN	Tapa-e-Kart-e-Naw	0	0	DW	Sayed Jamaludin University	0	0
DN	Famulyhai Askari,	0	0	DW	Alaudin Project office	0	0
WST	Bagh Bala	85	0	WSI	Alaudin Project office	0	0
DN	Kart-e-Parwan 2	70	0	DW	Mohsani University	0	0
DN	Kart-e-Aryana	63	0	DW	Passport office	0	0
DN	Kart-e-Mamorin	72	0	DW	Dehmurad Khan	0	0
WST	Bagh Bala	0	0	DW	Dehmurad Khan	0	0
DN	Kart-e-Aryana	150	50	WSI	Ali Abad	0	0
DN	Kart-e-Mamorin	60	28	DW	Alaudin Project office	0	0
DW	Pul Artal	0	0	WSI	Alaudin Project office	46	7
DW	Pul Artal	0	0	DW	Dehmazang	0	0
DN	Naqash	0	0	DW	Near to Russian Embassy	0	0
DN	Kart-e-Aryana	0	0	DW	Mohsani University	0	0
DW	Pul Artal	0	0	DW	Habibia High School	0	0
DW	Pul Artal	0	0	DW	Dehmurad Khan	0	0
DN	Kart-e-Aryana	0	0	WSI	Bagrami Project office	0	0
DN	Andrabi	0	0	DW	Bagrami Logar river	0	0
DN	Kabul University	0	0	DW	Bagrami Logar river	0	0
DN	Shahre Kohna	0	0	DW	Bagrami Logar river	0	0
DN	Jamal Mena	0	0	DW	Bagrami Logar river	0	
DN	Shahre Kohna	0	0	DW	Bagrami, Logar river	0	0
DN	Kot-e-Sangi	40	2	DW	Bagrami Logar river	0	0
DN	Dehbori	0	0	DW	Bagrami Logar river	0	0
DW	Zone office Khair Khana	0	0	DW	Bagrami Logar river	0	0
DW	Sarak Bidel, Khair Khana	0	0	DW	Bagrami Logar river	0	0
DW	500 Family, Khair Khana	150	0	DW	Bagrami Logar river	0	0
DN	Khairkhana, 2nd phase	0	0	WSI	Bagrami Project office	0	0
DW	Zone office, Khair Khana	0	0	DW	Bagrami, Logar river	0	0
DW	Khair Khana	0	0	DW	Bagrami Logar river	0	0
DN	Khairkhana, 2nd phase	0	0	DW	Bagrami Logar river	0	0
DW	Zone office, Taimani	0	0	DW	Bagrami Logar river	0	0
DW	Projah Taimani	0	0	DW	Bagrami Logar river	0	0
DW	Qal-e-Fathullah	0	0	DW	Bagrami Logar river	0	0
DN	Sarak 5 projah Taimani	0	0	DW	Bagrami, Logar river	0	0
DW	Pul khoshk	0	0	DW	Bagrami, Logar river	0	0
DN	Kocha-e-Emam Raza	0	0	DW	Bagrami Logar river	0	0
DN	Kocha-e- Sayida	0	0	DW	Bagrami, Logar river	0	0
DN	Kocha-e-Risalat	0	0				

DN Distribution network, DW Deep well WST Water storage tank

Water analysis of Zone4 showed that only one sample from Kota-e-Sangi contaminated both fecal as well as total coliform. Samples from Zone5 were found free of fecal contamination except one sample from water distribution network of Khairkhana-2nd Phase which contained total coliform. The analysis results of drinking water samples from Zone6, Zone7, Afshar project and Logar project were found free from both fecal and total contaminations. Only one samples from Alaudin project contained both fecal coliform and total coliform (Table 7, Figure 14&15)

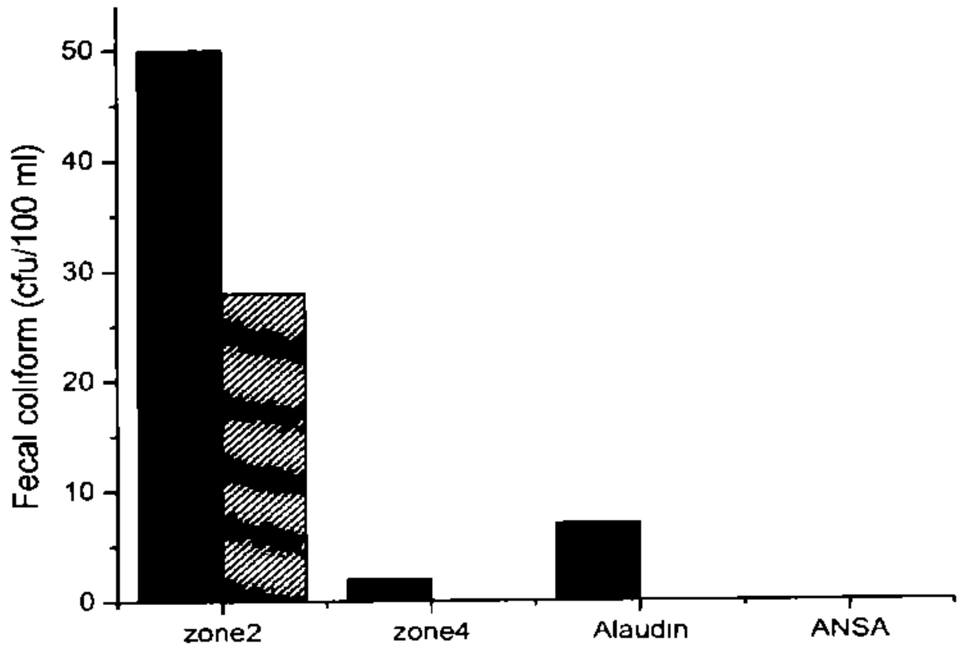


Figure 14 Water sample zones and projects with fecal coliform contamination

Present study results showed that 11.764 % of drinking water samples were contaminated with total coliform bacteria whereas, the 4.7 % of the samples were found contaminated with fecal coliform bacteria (Figure 16)

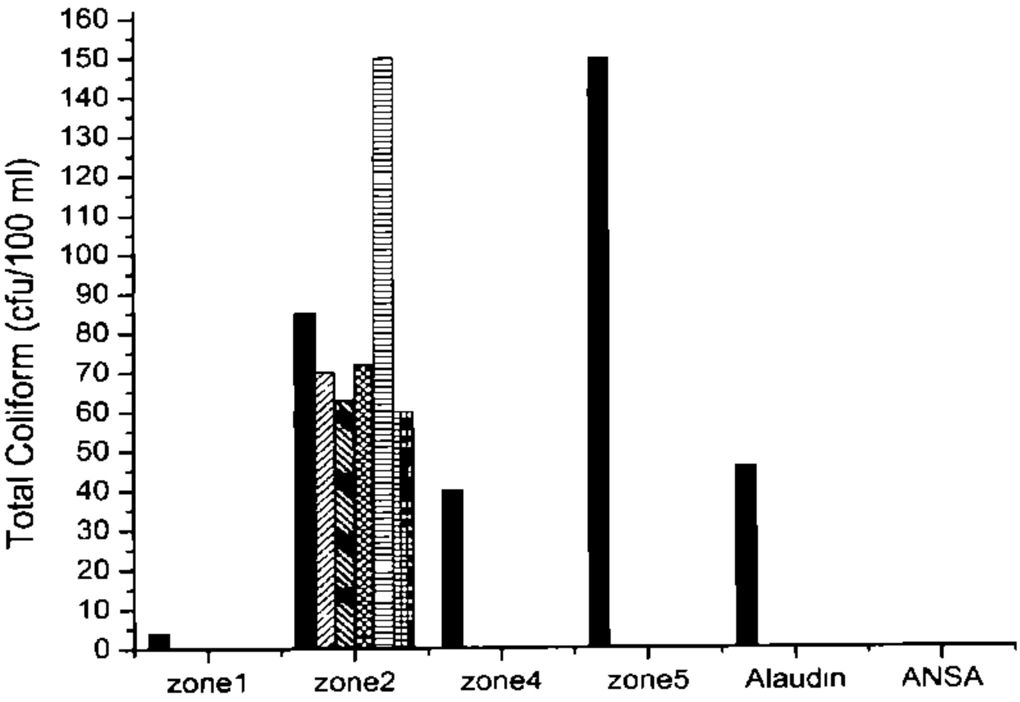


Figure 15 Water sample zones and projects with Total coliform contamination

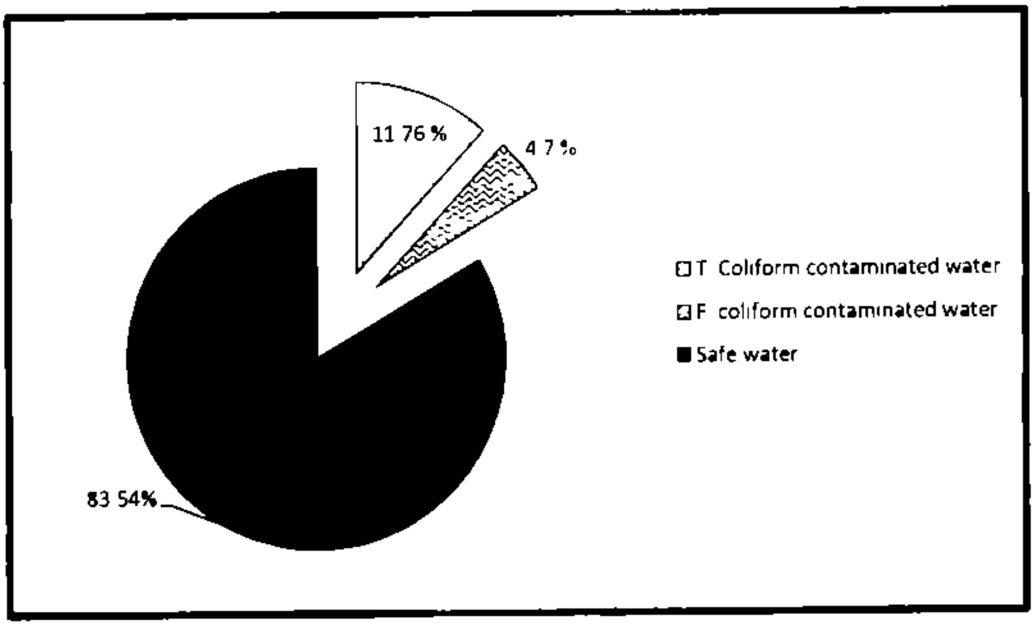


Figure 16 Diagram of contaminated water with total coliform and fecal coliform

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

a. Conclusions

The study showed more variation among physicochemical and biological parameters in the samples collected from various locations of Kabul city. Based on the data obtained from analysis of deep well water, water storage tank and water distribution network, it can be concluded that pH, turbidity and temperature were within the permissible limits of WHO and ANSA for drinking water while EC for 36.47% of water samples from different locations in Kabul city was higher than the limits. Similarly the bacterial analysis results showed that 11.76 % drinking water samples were found contaminated with total coliform bacteria whereas, 4.7 % of drinking water samples were found contaminated with fecal coliform bacteria.

The presence of fecal coliform is indicative of water receiving sewage effluents and fecal materials. Furthermore, lack of suitable sewage disposal facilities mostly causes fecal contamination of well, distribution networks and water storage tanks. The old water distribution network is the main problem in drinking water contamination, because Kabul city water distribution network was installed about 40 years ago and due to leakages in water distribution pipes and absence of suitable sewerage system for domestic waste water, mixing and contamination of drinking water occurs. In the study area, water storage tanks were not properly covered, water distribution pipelines passing through waste waters, presence of septic tanks and absorbent wells, existence of poorly chlorination system, piles of garbage were found in several points of Kabul city without any proper management that can cause water contamination. Lack of proper laboratory by NEPA for measuring and monitoring of water quality and lack of professional staff for water management system were found some basic reasons for the deteriorating water quality

b. Recommendations

As a result of the above study and findings the following recommendations are given

- To achieve the goal of sustainable development cooperation between government and public must be strengthened The government should maintain proper water distribution network and they should install a new network all over the Kabul city to substitute the old one
- The responsible departments must maintain the drinking water quality within the recommended limits of WHO and ANSA standards
- Government should establish outfit laboratories for measurement of pollutants level in water body They should also install water filtration plants and for distribution of safe drinking water they should perform well-timed chlorination
- Responsible departments should protect drinking water sources from waste water and other contaminants And drinking water should be stored in well protected water storage tanks
- For waste water disposal they should apply suitable scientific methods
- Properly purification of drinking water is necessary before supplying to consumers Municipal water supplies should regularly be analyzed for coliform bacteria, indicator of fecal materials in drinking water Ministry of public health must improve a data regarding the epidemiological aspects of waterborne diseases
- To build the awareness of consumers about the significance of water quality, media, responsible department's publications and educational institutions must be used

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