DRINKING WATER QUALITY ANALYSIS IN KUPONDOLE

SUMIT SHRIVASTAV

T.U. REGISTRATION: 5-2-15-2093-2006

T.U. EXAMINATION ROLL: 13103

BATCH: 2066/067

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN ZOOLOGY WITH SPECIAL PAPER PARASITOLOGY

SUBMITTED TO

CENTRAL DEPARTMENT OF ZOOLOGY

INSTITUTE OF SCIENCE AND TECHNOLOGY

TRIBHUVAN UNIVERSITY

KIRTIPUR, KATHMANDU

NEPAL

AUGUST, 2019

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

Date 2 Aug 2019

....

Sumit Shrivastav

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.
०१-४३३१८९६
01-4331896
Email: info@cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

RECOMMENDATIONS

This is to recommend that the thesis entitled "**DRINKING WATER QUALITY ANALYSIS IN KUPONDOLE**" has been carried out by **SUMIT SHRIVASTAV** for the partial fulfillment of Master's Degree of Science in Zoology with special paper Parasitology. This is his/her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any degree in any institutions.

Date: 2 Aug 2019

Janak Raj Subedi
Lecturer
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY

प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY

कीर्तिपुर, काठमाडौं, नेपाल।
Kirtipur, Kathmandu, Nepal.

०१-४३३१८९६
01-4331896
Email: info@cdztu.edu.np

पत्र संख्या :-
च.नं. Ref.No.:-

LETTER OF APPROVAL

On the recommendation of supervisor "**JANAK RAJ SUBEDI**" this thesis submitted by "**SUMIT SHRIVASTAV**" entitled "**DRINKING WATER QUALITY ANALYSIS IN KUPONDOLE**" is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Parasitology.

Date 2 Aug 2019

Prof. Dr. Tej Bahadur Thapa
Head of Department
Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
०१-४३३१८९६
01-4331896
Email: info@cdztu.edu.np

प्राणी शास्त्र केन्द्रीय विभाग
CENTRAL DEPARTMENT OF ZOOLOGY
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.

पत्र संख्या :-
च.नं. Ref.No.:-

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by **SUMIT SHRIVASTAV** entitled **"DRINKING WATER QUALITY ANALYSIS IN KUPONDOLE"** has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Parasitology.

EVALUATION COMMITTEE

....	....
Supervisor	Head of Department
Janak Raj Subedi	Prof. Dr. Tej Bahadur Thapa
Central Department of Zoology	Central Department of Zoology
Tribhuvan University	Tribhuvan University
Kirtipur, Kathmandu, Nepal	Kirtipur, Kathmandu, Nepal
....	....
External Examiner	Internal Examiner
Binod Lekhak	Prof. Dr. Mahendra Maharjan

Date: 6 Aug 2019

ACKNOWLEDGMENT

I wish to acknowledge with profound gratitude my supervisor, Mr. Janak Raj Subedi for his advice, constructive criticisms, painstaking efforts and the tireless support he has provided to me during the preparation and execution of this work.

I am also deeply grateful to the entire staff of Central Dept. of Zoology, TU for their generous support and guidance during my studies. Special thanks go to the lectures, readers and professors in the department for introducing me to this very important and interesting discipline of Biological Science.

I would also like to express my gratitude to the concerned officials of Kathmandu Upatyaka Khanepani Limited (KUKL) for providing necessary information.

I would like to most sincerely thank my classmates for the moral support and encouragement that they accorded to me during the programme.

To my family, I appreciate your encouraging words and the time you offered to listen and advise me tirelessly. Dad and Mom, I hope this will make you proud more than you already are.

Above all I thank God; I believe you gave me this amazing opportunity to continue glorifying your name. I hope this work will make a change for the better.

God bless you all

Sumit Shrivastav

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

ACRONYMS AND ABBREVATIONS

ADB	Asian Development Bank
APHA	American Public Health Association
BIS	Bureau of Indian Statistics
BMC	Beverage Marketing Corporation
CBS	Central Bureau of Statistics
CFU	Colony Forming Units
DoHS	Department of Health Services
DISVI	Italian International Co-operation
EDTA	Ethylene Diamine Tetra Acetic Acid
EMB	Eosin Methylene Blue
ENPHO	Environment and Public Health Organization
FAR	Food Act Regulation
ICIMOD	International Center for Integrated Mountain Development
JICA	Japan International Co-operation Agency
KUKL	Kathmandu Upatyaka Khanepani Limited
MLD	Million Liters per Day
MOH	Ministry of Health
MPN	Most Probable Number
NDWQS	Nepal Drinking Water Quality Standards
NRDC	National Resources Defense Council
NTU	Nephelometric Turbidity Unit
PET	Poly-Ethylene Terephthalate
pH	Percentage of Hydrogen Ion Concentration
PVC	Poly Vinyl Chloride
UN	United Nations
UNICEF	United Nation Children Fund
VDC	Village Development Committee
WHO	World Health Organization

ABSTRACT

Water encompasses a major part of the earth's hydrosphere and is principal to all life. Access to clean and safe water is one of the most important basic human rights. Present study was therefore conducted to assess quality of drinking water of Kupondole from May 2019 to June 2019. A total of 100 water samples were randomly collected from five sources pipeline, well, tanker, tube well and boring. The physico-chemical and bacteriological parameters were analysed following standards of American Public Health Association. All the physico-chemical parameters were found to be within Nepal Drinking Water Quality Standard acceptable limits except turbidity (6.44 NTU) and iron (1.7 mg/L) which were found to exceed the limits set by World Health Organisation. Similarly, from the bacteriological point of view, 91% of the total samples were contaminated with coliforms also the presence of coliform in different sources were found to be highly significant ($p<0.05$). Hence, drinking water of Kupondole was found physico-chemically suitable for drinking but bacteriologically was not suitable for drinking unless treated.

1. INTRODUCTION

1.1. BACKGROUND

Water is a transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth's streams, lakes, and oceans, and the fluids of most living organisms. It is vital for all known forms of life, even though it provides no calories or organic nutrients. Water is the name of the liquid state of H_2O at standard ambient temperature and pressure. It forms precipitation in the form of rain and aerosols in the form of fog. Clouds are formed from suspended droplets of water and ice, its solid state. When finely divided, crystalline ice may precipitate in the form of snow. The gaseous state of water is steam or water vapor. Water moves continually through the water cycle of evaporation, transpiration (evapotranspiration), condensation, precipitation, and runoff, usually reaching the sea (wikipedia.org).

Water plays an important role in the world economy. Much of long-distance trade of commodities (such as oil and natural gas) and manufactured products is transported by boats through seas, rivers, lakes, and canals. Large quantities of water, ice, and steam are used for cooling and heating, in industry and homes. Water is an excellent solvent for a wide variety of chemical substances; as such it is widely used in industrial processes, and in cooking and washing. Water is also central to many sports and other forms of entertainment, such as swimming, pleasure boating, boat racing, surfing, sport fishing, and diving. Economic growth and development is also influenced by the availability of water used for irrigation, domestic purposes, hydropower and fishing (Hammer and Mackichan, 1981).

Water is inescapably crucial to endure life. Water encompasses a major part of the earth's hydrosphere and is principal to all life. Of the whole 3% of fresh water on the earth, 77% are the glaciers, 22% are underground, 0.33% are lakes, 0.18% are soil moisture, 0.03% are rivers and 0.03% are in the atmosphere (wikipedia.org). As fresh water resources are further stretched to meet the demands of industry, agriculture and an ever expanding population, the shortage of safe and accessible drinking water is estimated to become the major challenge in many parts of the world (Wikipedia.org).

Access to clean and safe water is one of the most important basic human rights and the habitation of a region is largely dependent on the availability of fresh water (Muller and Kfir, 2003). The quality of water for drinking has deteriorated because of the inadequacy of treatment plants, direct discharge of untreated sewage into rivers and inefficient management of the piped water distribution system (UNEP, 2001).

Water fit for human consumption is called drinking water or potable water. Water that is not potable may be made potable by filtration or distillation, or by a range of other methods. Chlorine is a skin and mucous membrane irritant that is used to make water safe for bathing or drinking. Water for bathing may be maintained in satisfactory microbiological condition using chemical disinfectants such as chlorine or ozone or by the use of ultraviolet light. This natural resource is becoming scarcer in certain places, and its availability is a major social and economic concern.

Currently, about a billion people around the world routinely drink unhealthy water. In 2000, the United Nations established the Millennium Development Goals for water to halve by 2015 the proportion of people worldwide without access to safe water and sanitation. Progress toward that goal was uneven, and in 2015 the UN committed to the following targets set by the Sustainable Development Goals of achieving universal access to safe and affordable water and sanitation by 2030. Poor water quality and bad sanitation are deadly; some five million deaths a year are caused by water-related diseases (WHO, 2017).

Diseases caused by contaminated water are among the ten most prevalent water borne diseases in Nepal (DoHS, 1998). Diarrhoea being a water related disease is one of the most prevalent in Nepal. The mortality rate due to the diarrhoea was 0.34 per 1000 children under five years of age, while the case of fatality rate was 2.56 per 1,000 (CBS, 2001). A report from Teku Hospital displays that 16.5 % of total deaths were due to water-borne disease (Metcalf, 2000). The most important pathogenic bacteria transmitted by the water route are *Salmonella typhi*, the organism causing typhoid fever, and *Vibrio cholerae*, the organism causing cholera (Madigan *et al.,* 1997). Ideally, drinking water should not contain any microorganisms known to be pathogenic or any bacteria indicative of faecal pollution. Detection of faecal indicator bacteria in drinking water provides a very sensitive method of quality assessment and it is not possible to examine water for every possible pathogen that might be present (WHO, 1993).

1.2. Water Sources

Water sources are natural sources of water that are potentially useful. 97% of the water on the Earth is salt water and only three percent is fresh water. Freshwater is found mainly as groundwater, with only a small fraction present above ground or in the air. Kathmandu valley possess a very peculiar and broad water sources. The water in Kathmandu valley can be obtained from following sources.

Rain water

It is regarded as the purest form of water and is trustable source unless intercepted by any form of contamination.

Ground water

Groundwater is fresh water located in the subsurface pore space of soil and rocks. On satisfying the normal parameters of quality, it is considered as preferable source.

Surface water

Surface water is water in a river, lake or fresh water wetland. It is prone to contamination and is not preferable for human consumption unless purified.

Stone spouts

These are the flow of ground water sources in horizontal brick channel. Use of these are still in some places of valley for drinking and domestic purpose.

Well (Deep and Shallow)

A well is an excavation created in the ground by digging, driving, or drilling to access water. These are satisfactory sources of water supply.

Deep boring

Boring is drilling a hole or narrow tunnel in the earth. Water is generally of higher quality and are not susceptible to any external contamination.

1.3. Fresh Water Scarcity

Maximum volume of water is seized as marine water. There is shortage of fresh water. Lakes and rivers are the primary sources of fresh water for human consumption but they only contain 0.26% of fresh water reserves and most of that is used for agriculture and industry (Gleick, 1993; Shiklomanov, 1993; Chapagain and Hoekstra, 2004). The remaining 30% stored as ground water, provides approximately 23% of the water used for the human consumption (Pimentel *et al*., 2004). 41% of the world's population lives in areas characterized by either water stress or water scarcity (Global Environment Facility, 2002). Approximately, 1.1 billion people face chronic shortages of safe water for drinking and sanitation (United Nations, 2003; WHO/UNICEF, 2000).The condition is even worse in developing countries. In fact, 30% of the rural populations in many developing countries still obtain water from rivers dug pits, and other unsanitary sources (Olmstead, 2003).

Nepal being very rich in biodiversity and water resources and having more than 6000 rivers and rivulets, the people lack fresh water. The average annual surplus within the country is projected at about 174 billion cubic meters. Nevertheless, the management of this resource is very poor due to which many cities and towns of this country are facing severe scarcity. Kathmandu suffers a severe drinking water crisis, which is more in the dry seasons. Kathmandu Upatyaka Khanepani Limited (KUKL) is an authorized water supplier of the valley which produces about 120 million liters per day (MLD) in pouring season and 80 MLD in desiccated season whereas the demand is around 320MLD. The KUKL supplies 40% of its water from surface water sources while the rest 60% comes from the underground sources (KUKL,2018).

The municipal water supplies are inconsistent and unreliable. Not only the shortages in quantity, but also the compromised quality of municipal tap water has become a major public health issue. Throughout Nepal, people are exposed to severe health threats resulting from water contamination by sewage, agriculture and industry owing to the impact of sewage, typhoid, dysentery, and cholera are endemic every summer (Khadka, 1993).

1.4. Water Quality

Though water is vivacious for life, it also assists as the commonest route of transmission of a number of many infectious diseases. Thus, water quality must be confirmed before drinking and the water we drink must be safe and healthy. Water is called to be safe and healthy for human if it meets the WHO guidelines of national standards on drinking water quality for physical, chemical and microbiological characteristics.

The water quality is mirrored by numerous physical, chemical and biological conditions which in turn are prejudiced by natural and anthropogenic sources (ADB/ICIMOD). Water quality features like alkalinity, hardness, dissolved oxygen, chloride, total dissolved solid, etc. add to the appealing value of water, while features like ammonia, lead, arsenic, nitrate etc. may cause contrary health effects. While water having high or low pH, greater extent of turbidity etc. is also disagreeable to use. Suitable amount of chloride content and hardness are desirable but higher content of the same makes the water unappealing. Similarly higher content of phosphate, nitrate, ammonia, iron, are also inappropriate. Some other chemical constituents like arsenic, lead etc. may be poisonous (WHO, 2017).

From biological corner, determining the bacterial quality of drinking water is the single most important water quality test. Bacterial contaminants such as E. coli and fecal coliform in drinking water represents acute health risk. Drinking water should be free from any kinds of pathogens, parasites as well as opportunistic microflora/fauna. Besides being number of micro-organisms in water that may pose health menace, coliforms are used to assess water quality. Coliforms are gram negative rod shaped bacteria capable of growth in presence of bile salts and able to ferment lactose at 35-37^{0} C with the production of acid, gas and aldehyde within 24-48 hours. They are oxidase negative and non-spore forming. Coliforms can be found in the aquatic environment, in soil and on vegetation (DoP, 2002).

While coliforms themselves are not normally causes of serious illness, their presence is used to indicate that other pathogenic organisms of fecal origin may be present. The total coliform test is considered an indicator, since the presence of bacteria in this group indicates the possibility, but not the certainty, that disease organisms may also be present in the water.

When total coliforms are absent, there is a very low probability of disease organisms being present in the water. These organisms are prolific in the soil. Their presence does not necessarily imply contamination from wastewater nor the presence of other sanitation based health risks. The presence of total coliform by itself does not imply an imminent health risk but does indicate the need for an analysis of all water system facilities and their operations to determine how these organisms entered the water system. The ability of the total coliform test to reliably predict the bacterial safety of drinking water relative to the hundreds of possible diseases is critical since it is impossible, in a practical sense, to frequently check for every type of disease causing organism.

According to WHO (2002), unsafe water supply is a major problem and fecal contamination of water sources and treated water is a persistent problem worldwide. Globally, 1.1 billion people rely on unsafe drinking water sources from lakes, rivers and open wells. The majority of these are in Asia (20%) and Sub-Saharan Africa (42%) (WHO/ UNICEF, 2000; WHO/ UNICEF, 2004). The WHO has estimated that up to 80% of all sickness and disease in the world is caused by inadequate sanitation, pollution or unavailability of water. Hence it is necessary to purify and disinfect water before it is available for drinking.

1.5. Drinking Water Quality Guidelines

Drinking water quality standards describes the quality parameters set for drinking water. Despite the truth that every human on this planet needs drinking water to survive and that water may contain many harmful constituents, there are no universally recognized and accepted international standards for drinking water (Shmueli and Deborah, 1999).The water supplier is responsible at all times for regular quality control, for operational monitoring and for ensuring good operating practice. Guidelines for Drinking Water Quality holds several water purification companies accountable when water doesn't meet quality standards. This method enforces all policies and encourages proper infrastructure, whether piped or non-piped, treatment plants, storage reservoirs and distribution systems.

Similarly, Government of Nepal has also issued the notice of implementation of National Drinking Water Quality Standards, 2062 under the provision of Water Resources Act, 2049, Clause 18 and Sub Clause 01

Table 1. WHO and NDWQS Guideline Value and Range

Characteristics	Parameters	Unit	WHO	NDWQS
Physical	Temperature	°C	-	-
	Colour	TCU	-	5-15
	pH	-	6.5-8.5	6.5-8.5
	Electrical Conductivity	µs/cm	1500	1500
	Turbidity	NTU	5	10
	Total Dissolved Solids	mg/L	600	1000
Chemical	Mg-Hardness	mg/L	-	-
	Ca-Hardness	mg/L	200	200
	Total Hardness	mg/L	500	500
	Chloride	mg/L	250	250
	Ammonia	mg/L	1.5	1.5
	Nitrate	mg/L	50	50
	Nitrite	mg/L	3	-
	Iron	mg/L	0.3	3
	Arsenic	mg/L	0.01	0.5
Bacteriological	Total Coliform	Cfu	Nil	Nil
	E.coli	Cfu	Nil	Nil

1.6. STATEMENT OF THE PROBLEM

Water quality is directly related with public health. More than 80% of deaths is caused due to water borne diseases. The water supply and quality in Kupondole is terrible due to centralization of Nepalese population day by day. The people of Kupondole are mostly driven by the unreliable and quality compromised pipeline supply, tanker water and well water. Thus it may be hazardous to health of people of Kupondole. So, it’s high time to test the quality and monitor the water. However, very few studies have been carried out to assess their quality and there are no agencies that regularly monitor their quality.

1.7. JUSTIFICATION

Quality and safe drinking water is fundamental right of human being. But, is the water that we drink is qualitative and safe? The answer is obviously “NO”, as shown by the statistics from water borne diseases and mortality. Driven by the perception of purity, people have right to use quality water. The question is not: why to check the quality of water, it is: why not? People have the right to know the quality of water that they perceive to be pure. Hence, this study is justifiable.

1.8. OBJECTIVES OF THE STUDY

The objectives of the study was categorized as

1.8.1. General Objective

- To analyze the quality of drinking water of Kupondole, Lalitpur.

1.8.2. Specific Objectives

- To analyze the Physico-chemical parameters of drinking water of Kupondole, Lalitpur.
- To determine the presence of Coliform in drinking water of Kupondole, Lalitpur.

2. LITERATURE REVIEW

Water quality is one of the major concern of human health. The drinking water should be safe, qualitative and healthy. Keeping in mind the qualitative value of water, different studies were carried out to figure out the status of drinking water in Nepal. The review of the studies were highly acknowledged and understood.

ENPHO (1989) conducted a study on the quality of drinking water of Kathmandu valley by taking 472 samples at 58 sampling points, 44 water taps, 7 storage, and 7 water treatment plants which showed existence of bacterial contamination in most of the sampling points. Sharma (1978) analyzed the household drinking water in 39 localities of Kathmandu valley and found coliforms ranging from 4 to 460 cfu per 100 ml. Similarly, Ground water, a major source of drinking water in Kathmandu valley indicates high level of iron, magnesium and ammonia (JICA, 1990). ENPHO/DIVSI (1990) conducted a study on water quality of 21 stone spouts of Kathmandu city and the results showed heavy bacterial contamination in 81% of the total samples along with the presence of fecal contamination. ENPHO/DIVSI (1992) conducted a one year monitoring on microbiological quality of water supply in Kathmandu. Water samples were collected from 39 taps and 6 treatment plants which showed that 18% of the treatment plants and 50% of public taps were significantly contamination.

Sharma (1986) studied the drinking water quality of Kathmandu and Pokhara in which significant contamination was observed. Coliform counts of 2400/100 ml and 4800/100 ml was respectively seen in the sampled areas. Tamrakar (2014) revealed that most of the physico-chemical parameters of drinking water in Kathmandu valley felt within the standard limits of NDWQS and WHO. Similarly (Pradhan, 2005) also found the water qualitative in respect to physico-chemical parameters but presence of coliform suggested that water was not suitable to drink. The report by (ADB, 2004) shows that the water supply system of Kathmandu is old and lack of maintenance has led to frequent malfunction. Pathak *et al*. (2013) showed that there was high load of nitrate, chloride and total coliform in shallow sources. Study also showed that coliform contamination to be higher (Aryal *et al*., 2012) than acceptable limit of WHO guidelines.

Pokhrel (2000) analyzed 42 samples of bottled water from 7 companies for Physio-chemical as well as microbiological parameters. He found that the physio-chemical parameters were under the acceptable limit whereas, bacterial count up to 162 was found in Total Plate Count. In addition to this, yeast as well as coliform was also detected. Masaaki and Hiroaki (1998) analyzed the bottled water in Kathmandu valley in July 1997. The conclusion drawn from this study was that water bottles sold in the developing countries were contaminated with bacteria quite frequently. Joshi *et al.* (2009) conducted a study of bottled water in Kathmandu valley. Twenty different brands of mineral water were analyzed for hygienic quality and chemical constituents. In the microbiological analysis, coliforms were detected in 3 samples with fecal coliforms detected in 1 sample and *Salmonella spp* in 2 samples. The conclusion drawn was that the bottled water is contaminated frequently.

Jayana *et al.* (2009) showed that wells and spouts of Madhyapur Thimi were microbially contaminated with 142 bacteria isolation and 64.76% samples crossing WHO guidelines. Bittner *et al.* (2000) carried out a study on the quality of drinking water of Kathmandu. Samples were taken from various sources like well, stream and treatment plants, all of which showed contamination. Hence it was concluded that most drinking water supplies in Kathmandu are microbiologically contaminated. Prasai *et al.* (2007) analyzed a total of 132 water samples collected from various sources. Among the total samples, 49 were from tube wells, 57 from wells, 17 from taps and 9 from stone spouts. The analysis was carried out for various water quality parameters. The results showed that 82.6% of drinking water samples crossed WHO standards. During the study, 238 isolates of enteric bacteria were identified, of which 26.4% were *Escherichia coli*.

Shrestha *et al.* (2014) assessed arsenic contamination in Nawalparasi district which flashed higher arsenic value. Diwakar *et al.* (2008) also confirms the presence of coliform and higher range of physico-chemical matter and high bacterial contamination in taps and well water. Bisankha *et al.* (2012) reported that 56.1% water samples crossed WHO permissible limits. The fecal contamination rates in Sankhuwasabha, Rasuwa and Dolpa districts were 81.8%, 75% and 65% respectively (Rai *et al.,* 2009). Gewali (2002) revealed that tube well has higher parasitic eggs in comparison to stone tap and well. Acharya (2008) confirms the highest parasitic contamination in well than NWSC tap.

Ribeiro *et al*. (2006), analyzed water quality from various sources in Portugal. The objectives of this study were to analyze the seasonal fluctuations of fungal contamination, and to trace the origin of the contaminating fungal populations with molecular biology techniques in a bottled water company. He analyzed water from water tank, water filter and bottled water twice monthly for fungal growth and found significant fungal contamination. The dominant fungal genera in order of highest numbers isolated were: *Penicillium, Cladosporium* and *Trichoderma* followed by *Aspergillus, Paecilomyces* and others. He also observed that fungal contamination increased during the warmer seasons, especially May and June. Centre for Science and Environment, India (2003) analyzed 26 samples of 13 bottled water brands and raw water samples in Mumbai and found that every samples showed pesticides concentration between 0.0007 to 0.0042 mg/L. The maximum concentration was 40 times higher than European Economic Community standards.

Warner *et al*. (2007) studied drinking water quality in Kathmandu valley. Water was sampled from over 100 sources including municipal taps, dug wells, shallow and deep aquifer tube wells and stone spouts. They found that the most problematic were total coliform and E. coli which was present in94% and 72% of all water samples respectively. Contamination by nitrate, ammonia and heavy metals was more limited. Gyawali (2007) conducted a study on Microbial and chemical quality of water available in Kathmandu with six samples of tap and river from Sundarighat upstream and found that the physico-chemical parameters were below WHO standards except chloride. Also, bacteriological contamination was 900 cfu/100 mL in average. Thakuri (2008) conducted a study on the quality of bottled water in Kathmandu, taking 10 different brands of bottled water available in the valley and found that most of the physico-chemical parameters were under the limit of (WHO, 1994). Microbial analysis showed that most brands had satisfactory quality though few numbers of coliforms were present.

Pandey (2009) analyzed the drinking water quality of Central Development Region, Nepal. He analyzed a total of 243 samples: 130 from ground water source and 113 from springs. 20 of the ground water sample exceeded WHO standards. In addition to this, he concluded that most of the springs and ground water sources were heavily contaminated with fecal coliform bacteria. Ali *et al.* (2013) reported that water samples from Pakistan were highly contaminated.

Antony *et al*. (2012) showed that FC count was 12-180 MPN/100 ml while *E.coli* was 6-161/100 ml for all sample sites. About 90-95% of the rural and suburban population in the United States use groundwater as their source of drinking water (Prescott *et al*., 2005), while in South Africa approximately 15% of water consumption is from a groundwater source, with the majority of water originating from surface water sources (DWAF, 2002).A low percentage of groundwater sources is thus also utilised in South Africa, due to high levels of nitrates, calcium, magnesium, phosphates and fluorides, which renders the water unfit for human consumption (Kongolo, 2011).A study conducted by Paulse *et al*. (2007) investigated the microbial contamination at sampling sites along the Berg River system near an informal settlement, industrial sites and close to the agricultural areas.

Parihar *et al*. (2014) conducted research in multiple seasons which showed maximum value of total coliform and fecal coliform in post monsoon season. The comparative study for coliform level in tap water of Kashmir and Srinagar showed the highest value for Kashmir (Rehman *et al.,* 2012). The study of tap water is not suitable for public health (Shrivastava *et al*., 2014). Parasites were significantly found in surface water for human consumption in Alava Northern Spain (Carmena *et al.,* 2006). Ball (2006) explained the relationship between drinking water quality and gastrointestinal diseases. Karanis *et al*. (2007) reviewed outbreaks of water borne parasitic protozoan worldwide which reported 325 water related outbreaks.

Kistemann *et al*. (2002) revealed that most of the bacteriological parameters investigated increased considerably in run –off events. Few studies have been conducted on presence of water borne parasites in Malaysia (Ahmad, 1995). Wolfe (2000) reported that 50% of well water is 100% of surface water were microbially contaminated. Levesque *et al*. (2008) showed the high frequency of fecal contamination of household tank water in Bermuda. Tsega *et al*. (2013) in Ethiopia showed high contamination of water sources. Sorlini *et al.* (2013) reported good chemical quality of water with exception of lead contamination. Yasodha *et al.* (2014) showed that drinking water quality is better in pre-monsoon than post-monsoon in hand pumps. The water quality assessment conducted in Iraq showed that the water samples analysed were considered unfit to human consumption and the values of the studied wells belong to high water electrical conductivity and chloride comparable with other parameters (Muhammad *et al.,* 2013) but conversely (Barbooti *et al.,* 2010) showed the good water quality samples.

3. MATERIALS AND METHODS

3.1. MATERIALS

The following materials, chemicals and equipment were used to carry out the study.

1. PVC sampling bottles
2. Data recording sheets
3. Marking pen
4. Tissue paper
5. Dechlorinated water
6. Nesseler tube
7. Conductivity meter
8. Titrating equipment
9. Coliform P-A vials
10. Diary
11. Masking tape
12. Gloves
13. Nephalometer
14. pH meter
15. Spectrophotometer
16. Essential Chemicals

3.2. METHODS

3.2.1. STUDY AREA AND SAMPLING SITES

The study was performed in Kupondole of Lalitpur district. Kupondole is a small residential area located in Patan, Nepal. It is situated right between the cities of Patan and Kathmandu, a bit closer to the capital city center. The latitude of Kupondole, Patan, Nepal is 27.686382and the longitude is 85.315399. Kupondole is located at the gps coordinates of 27° 41' 10.9752" N and 85° 18' 55.4364" E.

Ten sampling sites (Hanumansthan, Kandevtasthan, Sarwanga area, Bigmart area, Summit area, Campion area, Kupondole height, Nagarjuna area, Nightingale area and Rupak area) of Kupondole were selected for the study. For the qualitative analysis of water, 100 samples were randomly collected from ten sites of Kupondole.

Fig 1: Google map of the study area, Kupondole

3.2.2. SAMPLE COLLECTION, LABELLING AND TRANSPORTATION

Total of 100 samples of drinking water were collected randomly from ten different sites of Kupondole. Out of collected 100 samples, 41 were from pipeline supply, 21 were from well, 17 were from tanker, 14 from tube well and 7 were from boring. Samples were collected carefully in PVC sampling sterile bottles and Coliform P-A vials. The handling of sample was paid due attention to prevent any form of contamination. Sources of sample were coded as 'P' for pipeline, 'W' for well, 'T' for tanker, 'TW' for tube well and 'B' for boring. The details of sample collection is shown in table 2.

After the collection of sample in sterile bottles and vials, each of them was labelled immediately. The labelling included

- Identification tag
- Origin (place and source) of sample collection
- Date and time of sample collection

As soon as the labelling was finished, the samples were transported to KUKL Water/Waste-Water Quality Assurance Division, Mahankalchaur, Kathmandu at earliest time possible for analysis of physico-chemical parameters.

Similarly, for bacteriological analysis, water samples were transported to the working place to test for presence or absence of coliform using coliform P-A vials.

Table 2. Location and source of sample collection in Kupondole

S.No.	Location	Sources of sample					Total
		Pipeline (P)	Well (W)	Tanker (T)	Tubewell (TW)	Boring (B)	
1	Hanumansthan	5	2	×	2	1	**10**
2	Kandevtasthan	×	2	4	×	×	**6**
3	Sarwanga Area	4	3	1	×	1	**9**
4	Bigmart Area	7	2	×	×	1	**10**
5	Summit Area	×	1	6	3	×	**10**
6	Campion Area	3	2	2	×	2	**9**
7	Kupondole Height	3	3	2	1	×	**9**
8	Nagarjuna Area	5	2	×	2	1	**10**
9	Nightingale Area	10	1	1	2	1	**15**
10	Rupak Area	4	3	1	4	×	**12**
Total		**41**	**21**	**17**	**14**	**7**	**100**

3.2.3. ANALYSIS OF WATER SAMPLES

3.2.3.1. Analysis of physico-chemical parameters of water samples

"Standard Methods for the examination of water and wastewater", (APHA, 1998) was followed to analyze most of the physico-chemical (temperature, turbidity, pH, electrical conductivity, total hardness, arsenic, iron and chloride) parameters of water. The testing methods are summarized in the table 3.

Table 3. Testing equipment and methods of physico-chemical parameters

S. No.	Parameters	Equipment/Methods
1	Temperature	Electrode thermometer/Scientific method
2	Turbidity	Nephalometer/Turbidity method
3	pH	pH meter/Potentiometer method
4	Electrical Conductivity	Conductivitymeter/Potentiometer method
5	Total Hardness	Titrating equipment/EDTA titration method
6	Arsenic	Spectrophotometer/Arsine generator method
7	Iron	Spectrophotometer/Phenanthroline method
8	Chloride	Titrating equipment/Argentometric method

Source: APHA

3.2.3.2. Analysis of microbial variables of water sample

Microbial analysis was carried out using Coliform Presence-Absence (P-A) test vials marketed by Water Engineering and Training Centre Pvt. Ltd. The vial was taken to the source of water and non-turbulent running water (100 ml) was poured into the vial. Later the samples were left at normal room temperature for 72 hour and result was analysed in respect to table 4.

Table 4. Analysis of coliform range

S. No.	Colour change (Clear to black) in time	Analysis of range
1	24 hours	> 100/100 ml
2	48 hours	10-100/100 ml
3	72 hours	< 100/100 ml

Source: WETC

3.2.4 DATA PRESENTATION AND ANALYSIS

All the physico-chemical and bacteriological data and results are presented with the help of appropriate figures, graphs, charts, tables and explanation. Also the coliform data are analysed using Chi-square test.

Photographs of the source of sample collection

Photo 1. Boring of Hanumansthan **Photo 2. Pipeline of Bigmart Area**

Photo 3. Well of Nagarjuna Area **Photo 3. Tubewell of Rupak Area**

4. RESULTS

The collected samples were analysed for physico-chemical and bacteriological parameter to assess the quality of drinking water. The mean of data for each physico-chemical and parameter of each source was analysed, calculated and tabulated. Also the data were compared with WHO and NDWQS guidelines.

Table 5. Mean value of physico-chemical parameters of each source

Sources / Parameters	Pipeline (P). N=41			Well (W)=21			Tanker (T). N=17			Tube well (TW). N=14			Boring (B). N=07		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Temperature	24	26.5	25.86	25	27	26.15	24	26.5	25.7	25.3	27.4	26.7	25.2	27.5	26.5
Turbidity	5	7.2	6.44	2.6	4.1	3.33	3	5.2	3.87	2.13	3.67	2.99	2	3.1	2.42
pH	6	8	6.97	6.6	8.2	7.26	6.5	8.3	7.25	6.3	7.9	7.33	6.8	8	7.23
E.C.	171	453	309.3	120	420	302.9	138	334	225.3	310	680	425.2	240	370	321.6
Total Hardness	46	80	68.21	58	122	73	52	86	72.6	83	120	98	52	96	70.6
Arsenic	0.0001	0.0003	0.00013	0.0001	0.0003	0.00015	0	0	0	0.0001	0.0004	0.0003	0	0	0
Iron	1.2	2.4	1.39	1.4	4.9	1.70	1.5	6.8	1.67	1.1	7.2	1.39	1.6	5.1	1.3
Chloride	12.8	43.5	29.60	3	28.7	11.57	20.8	31.7	23.4	0.2	1.1	0.44	12.8	29.7	19.40

4.1. Physico-chemical parameters in different sources.

Temperature

Temperature of fresh water varies from 0ºC to 35ºC depending on the source, depth and season. The temperature of water affects some physical characteristics of water like density, viscosity, conductance, salinity, solubility, etc. Also, the biological characteristics of water varies with temperature. The table shows that the tube well water had maximum temperature of 26.7 °C whereas the well and tanker had minimum temperature of 25.7 °C.

Turbidity

Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality. The table shows high turbidity of 6.44 NTU for pipeline water whereas low turbidity of 2.42 NTU for boring water. All the values were within permissible limit.

pH

pH is the negative logarithm of hydrogen ion concentration. It is used to express the intensity of acidic or alkaline condition of a solution. pH of pure water is 7. pH is an extremely important variable because it is the controlling factor determining the solubility of most metals and also because most micro-organisms can survive within a narrow range of pH. Though values of pH obtained were within the WHO standards of 6.5-8.5 but high pH of 7.33 was obtained for tube well water whereas low pH of 6.97 was seen for pipeline supply. Values were within permissible limit.

Electrical Conductivity

Electrical conductivity is the measure of the capacity of water to conduct electric current. High values of conductance indicate high dissolved gases and other chemicals in the water. There is no minimum guideline value for conductivity; however, values above 400us/cm may affect the chemical quality of drinking water. The table shows high conductivity of 425.2 µs/cm in tube well water whereas low conductivity of 225.3 µs/cm in tanker water. Values were within permissible limit.

Total Hardness

Hardness is imparted to the water mainly by calcium and magnesium ions. Hard water is generally undesirable because it forms precipitate with soap, produces scales in boilers on heating and has high boiling point due to which it is unsuitable for cooking. The table shows minimum value of total hardness 68.21mg/L for pipeline supply while the maximum values was 98 mg/L for tube well water. The WHO standard for hardness is 200mg/L. Thus all the values were within acceptable limits.

Arsenic

Arsenic contamination of groundwater is a form of groundwater pollution which is often due to naturally occurring high concentrations of arsenic in deeper levels of groundwater. It is a high-profile problem due to the use of deep tube well for water supply causing serious arsenic poisoning to large numbers of people. The table shows maximum value of arsenic 0.0003 for tube well water while no arsenic was seen in tanker and boring water. But these were within permissible limit of WHO and NDWQS.

Iron

Iron has got a little concern as health hazard, but it still is considered as a nuisance in excessive quantities. High iron content produces bitter and astringent taste. The WHO has set the permissible limit of iron to 0.3 mg/L. The table shows the maximum value of iron content 1.70mg/L for well water while minimum value of 1.3mg/L for boring water which were above the acceptable limits.

Chloride

Chloride is present in appreciable amounts in all natural water. Concentration varies from few milligrams to several thousand milligrams per liter. High concentration of Chloride results in corrosively and impaired taste. The permissible limit of chloride according to WHO is 250 mg/L. Drinking water is often chlorinated for disinfection. The table has higher chloride value of 29.60 mg/L for pipeline supply while lower value of 0.44 mg/L for tube well water. These values were within the permissible limit.

4.2. Bacteriological (Coliform) presence in different sources

After the analysis and correlation of water samples with respect to table 4 for coliform presence in different sources, the result was tabulated as follows

Table 6. Coliform positive in sources

S. No.	Source	No. of samples	Coliform		
			+ve	-ve	+ve %
1	Pipeline (P)	41	38	03	92.68
2	Well (W)	21	21	0	100
3	Tanker (T)	17	17	0	100
4	Tube well (TW)	14	14	0	100
5	Boring (B)	07	01	06	14.28
Total		**100**	**91**	**09**	**91**

Coliform presence (Source wise)

Coliform bacteria is an indicator of pollution in water. The overall coliform contamination was seen 91%. The table shows that well, tube well and tanker water had maximum 100% coliform presence while boring water had minimum 14.28% coliform presence. The chi-square analysis for presence of coliform in sources was found to be highly significant (p<0.05).

Photograph of Coliform presence and absence

Photo 5. Coliform +ve samples

Photo 6. Coliform –ve samples

Table 7. Coliform positive rate location wise in Kupondole

S. No.	Locations	Sources	No. of samples	Coliform			
				+ve	-ve	+ve %s	Whole +ve percent
1	Hanumansthan N=10	Pipeline (P)	5	4	1	80	90
		Well (W)	2	2	0	100	
		Tanker (T)	X	X	X	X	
		Tube well (TW)	2	2	0	100	
		Boring (B)	1	1	0	100	
2	Kandevtasthan N=6	Pipeline (P)	X	X	X	X	100
		Well (W)	2	2	0	100	
		Tanker (T)	4	4	0	100	
		Tube well (TW)	X	X	X	X	
		Boring (B)	X	X	X	X	
3	Sarwanga Area N=9	Pipeline (P)	4	4	0	100	88.89
		Well (W)	3	3	0	100	
		Tanker (T)	1	1	0	100	
		Tube well (TW)	X	X	X	X	
		Boring (B)	1	X	1	0	
4	Bigmart Area N=10	Pipeline (P)	7	7	0	100	90
		Well (W)	2	2	0	100	
		Tanker (T)	X	X	X	X	
		Tube well (TW)	X	X	X	X	
		Boring (B)	1	X	1	0	
5	Summit Area N=10	Pipeline (P)	X	X	X	X	100
		Well (W)	1	1	0	100	
		Tanker (T)	6	6	0	100	
		Tube well (TW)	3	3	0	100	
		Boring (B)	X	X	X	X	

6	Campion Area N=9	Pipeline (P)	3	3	0	100	77.78
		Well (W)	2	2	0	100	
		Tanker (T)	2	2	0	100	
		Tube well (TW)	X	X	X	X	
		Boring (B)	2	X	2	0	
7	Kupondole Height N=9	Pipeline (P)	3	3	0	100	100
		Well (W)	3	3	0	100	
		Tanker (T)	2	2	0	100	
		Tube well (TW)	1	1	0	100	
		Boring (B)	X	X	X	X	
8	Nagarjuna Area N=10	Pipeline (P)	5	4	1	80	80
		Well (W)	2	2	0	100	
		Tanker (T)	X	X	X	X	
		Tube well (TW)	2	2	0	100	
		Boring (B)	1	X	1	0	
9	Nightingale Area N=15	Pipeline (P)	10	9	1	90	86.67
		Well (W)	1	1	0	100	
		Tanker (T)	1	1	0	100	
		Tube well (TW)	2	2	0	100	
		Boring (B)	1	X	1	0	
10	Rupak Area N=12	Pipeline (P)	4	4	0	100	100
		Well (W)	3	3	0	100	
		Tanker (T)	1	1	0	100	
		Tube well (TW)	4	4	0	100	
		Boring (B)	X	X	X	X	
Total			**100**	**91**	**9**	**91**	**91**

The above table shows that the overall coliform contamination was 91%. Further, the location wise contamination was seen in 100% of samples of Kandevtasthan, Summit Area, Kupondole height and Rupak area. More precisely, it was found that all the sources were contaminated. Similarly, Campion Area, Nagarjuna Area, Nightingale Area, Bigmart Area and Hanumansthan showed that the 77.78%, 80%, 86.67%, 90% and 90% of samples sources were contaminated with coliform reapectively. More precisely, it was found that none out of two boring of Campion area was contaminated, one out of five pipeline supply and none out of one boring of Nagarjuna area was contaminated, one out of ten pipeline supply and none out of one boring of Nightingale area was contaminated, none out of one boring of Bigmart area was contaminated and one out of five pipeline supply of Hanumansthan was contaminated respectively.

Coliform presence (Location wise)

The graph below shows the higher presence in Kandevtasthan, Summit Area, Kupondole height and Rupak Area while lower presence was seen in Campion Area.

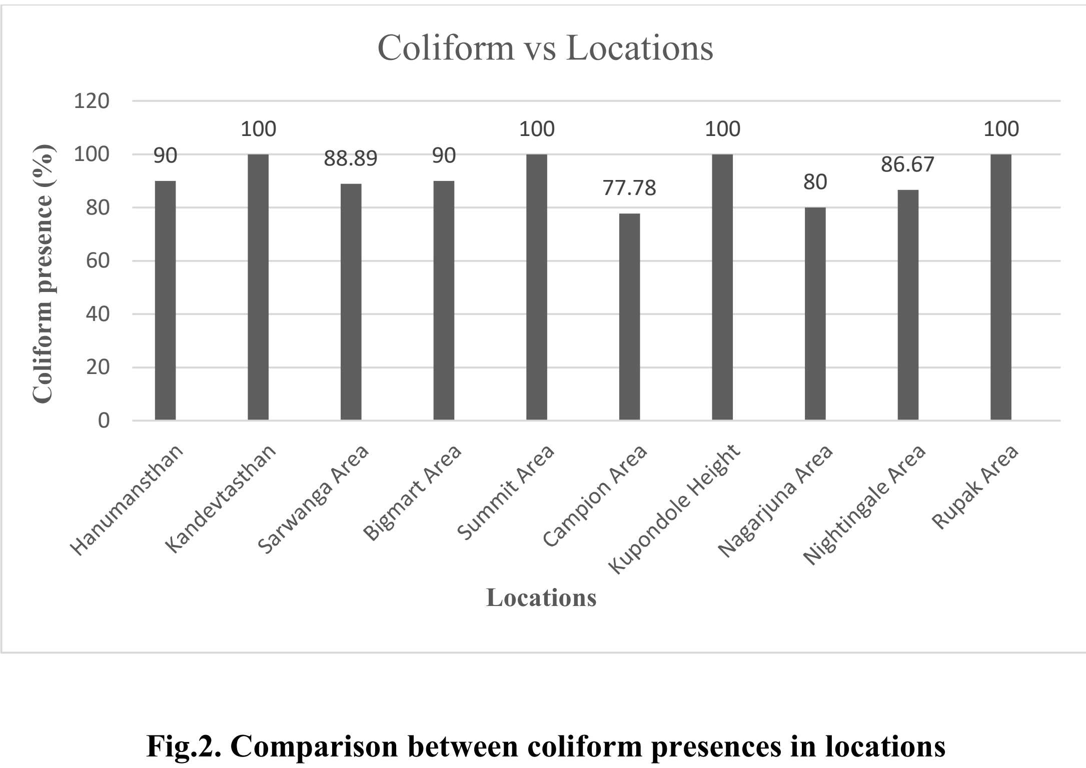

Fig.2. Comparison between coliform presences in locations

5. DISCUSSION

Based on the results, the following physico-chemical and bacteriological discussions can be made.

The temperature is very important factor for chemical and biological growth of an organism. In this study the temperature range was found to be less varied from 25.7 °C – 26.7 °C. Tanwar *et al*. (2014) also revealed less variation in water temperature for different sources of water with range of 25.31 °C – 26.97 °C.

The measurement of turbidity is a key test of water quality. In this study, high turbidity of 6.44 NTU was observed for pipeline water whereas low turbidity of 2.42 NTU for boring water which were above the permissible limit of WHO. Similar studies showed that the value of turbidity were above the WHO guidelines value (Tamrakar 2014, Pant 2011, Jayana *et al*., 2009, Diwakar *et al*., 2008)

pH is an extremely important variable because most micro-organisms can survive within a narrow range of pH. pH is also an important factor in water treatment. Though values of pH obtained were within the WHO standards of 6.5-8.5 but high pH of 7.33 was obtained for tube well water whereas low pH of 6.97 was seen for pipeline supply. Yasodha *et al*. 2014, Gautam *et al*. 2012 also reported that the pH lied within WHO guidelines

Electrical conductivity is the measure of the capacity of water to conduct electric current. In this study, high conductance of 425.2 µs/cm was seen in tube well water whereas low conductance of 225.3 µs/cm in tanker water. The study by Tamrakar (2014) showed the conductivity within the NDWQS while other reported values beyond WHO and NDWQS (Pant 2011, Jayana *et al*., 2009 and Diwakar *et al*., 2008)

Hardness is imparted to the water mainly by calcium and magnesium ions. Hard water is generally undesirable. In this study the minimum value of total hardness 68.21 mg/L was seen for pipeline supply while the maximum values 98 mg/L was for tube well water. The WHO standard for hardness is 200mg/L. Thus all the values were within acceptable limits. Similar results were recorded by Aryal *et al*. (2012) and Diwakar *et al.* (2008) from Arthunge VDC of Myagdi and Bhaktapur municipality area respectively.

Arsenic contamination of groundwater is a high-profile problem due to the use of deep tube well for water supply causing serious arsenic poisoning to large numbers of people. The study showed maximum value of arsenic 0.0003 for tube well water while minimum value 0 for tanker and boring water. But these were within permissible limit of WHO and NDWQS. Pant (2011), Jayana *et al.* (2009) reported the arsenic content above WHO values but within NDWQS.

Iron has got a little concern as health hazard. The WHO has set the permissible limit of iron to 0.3 mg/L. The study showed the maximum value of iron content 1.70 mg/L for well water while minimum value of 1.3 mg/L for boring water which were above the acceptable limits.. Pant (2011), Jayana *et al*. (2009), Diwakar *et al*. (2008) and Khatiwada *et al*. (2002) also reported the iron content above WHO guidelines.

Chloride is present in appreciable amounts in all natural water. The permissible limit of chloride according to WHO is 250 mg/L. Drinking water is often chlorinated for disinfection. The study showed higher chloride value of 29.60 mg/L for pipeline supply while lower value of 0.44 mg/L for tube well water. These values were within the permissible limit. Aryal *et al*. (2012), Tamrakar (2014) and Pant (2011) also reported the chloride value within the WHO and NDWQS values.

In this study the coliform was detected from 91% of samples. The most affected source were well, tube well and tanker water and the least affected source was boring water. Location wise study revealed that the all the sources (100%) of Kandevtasthan, Summit area, Kupondole height and Rupak area were contaminated with coliform while the 86.67 % sources of Campion area were contaminated. The study showed that the regulatory parameters were excessively contaminated above WHO guidelines. Studies carried out by Shakya *et al*. (2012), Timilsina *et al*. (2012), Pant (2011), Jayana *et al*. (2009) found the coliform contamination to be the key problem in drinking water and also showed coliform contamination above WHO guideline value. The levels of coliform should not exceed the permissible value of less than one cell per 100 ml of water set by WHO and NDWQS.

6. CONCLUSION AND RECOMMENDATION

6.1. CONCLUSION

Hence from the above results, it can be concluded that water, although thought to be pure, cannot be trusted. Various physio-chemical parameters like temperature, turbidity, pH, conductivity, total hardness, iron, arsenic, chloride, etc. were analyzed using standard methods of APHA (1998). Similarly, the bacteriological parameters were analysed using coliform P-A vials. Almost of the Physio-chemical parameters like temperature, pH, conductivity, total hardness, arsenic and chloride were within WHO acceptable limits except turbidity (6.44 NTU) and Iron (1.7 mg/L) which crossed the WHO value of 5 NTU and 0.3 mg/L respectively. From the microbiological point of view, 91 out of 100 samples were contaminated with coliform. All the samples collected from well, tube well and tanker were 100% contaminated with coliform while less contamination was seen in boring water, only one out of seven samples was contaminated. These samples crossed the WHO and NDWQS guideline value of 0 cfu per 100 ml. Hence, it can be concluded that from the physio-chemical aspect, the quality of water is good and is within national standard while bacteriologically the water samples are heavily contaminated with coliform bacteria and unsatisfactory for drinking purpose.

6.2. RECOMMENDATIONS

- Almost all the water sources of Kupondole were found to be contaminated with coliform, hence it is recommended to treat water before use.
- Timely sanitation of water resources is recommended to minimize contamination and risk of water borne diseases.
- Regular test of water is highly recommended

7. REFERENCES

Acharya, J., 2008. Assessment of Bacteriological and Helminthological Contamination in Drinking Water Sources of Lalitpur Sub-Metropolitan City. M.Sc Thesis. Central Department of Zoology, Tribhuvan University., Kathmandu, Nepal.

ADB, 2004 Water for All: The Impact of Water on the Poor, Asian Development Bank, Manila.

Ahmad, R.A. 1995. Pathogenic protozoa in Malaysian water resources. Sains Malaysiana **24**: 121-127

Ali, S., Hussain, A., Hussain, A., Ali, A. and Awan, M.S. 2013. Drinking Water Quality Assessment in Some Selected Villages of Nagar Valley Gilgit-Baltistan, Pakistan. Journal of Chemical, Biological and Physical Sciences **3**(1): 567-574.

Antony, R.M. and Renuga, F.B. 2012. Microbiological Analysis of Drinking Water Quality of Ananthanar Channel of Kanyakumari District, Tamil Nadu, India. An Interdisciplinary Journal of Applied Science **7**(2): 42-48.

APHA, 1998. Standard Methods for the Examination of Water and Waste Water. 20th Edition, American Public Health Association, Washington D.C. 1-47 Pp.

Aryal, J., Gautam, B. and Sapkota, N. 2012. Drinking Water Quality Assessment. Journal of Nepal Health Research Council **10**(22): 192-196

Ball, A., 2006. Estimation of the Burden of Water-Borne Disease in New Zealand: Preliminary Report. Estimation of Waterborne Disease in New Zealand.

Barbooti, M.M; Bolzoni, G; Mirza, I.A; Pelosi, M; Barilli, M; Kadhum, R. et. al. 2010. Evaluation of Quality of Drinking water from Baghdad, Iraq. Science World Journal **5**(2): 35-46

Bishankha S., Joshi, T.P., Joshi, D.R. and Bhatta, D.R., 2012. Assessment of Microbial Quality of Chlorinated Drinking tap Water and Susceptibility of Gram Negative Bacterial Isolates towards Chlorine. Nepal Journal of Science and Technology **13**(1): 173-178

Bittner A., Halsey T., Khayyat A., Luu K., Maag B., Sagara J., and Wolfe A., 2000. "Drinking Water Quality and Point – Of – Use Treatment Studies In Nepal"

Carmena, D., Aguinagalde, X., Zigorraga, C., Ferna' Ndez-Crespo, J.C. and Ocio, J.A. 2006. Presence of Gliardia Cysts And Cryptosporidium Oocvsts In Drinking Water Supplies In Northern Spain, Journal Of Applied Microbiology **102**: 619-629.

CBS, 2001. Statistical Year Book of Nepal HMG, Central Bureau of Statistics.

Chapagain, A.K., and Hoekstra, A.Y., 2004. Water Footprints of Nation: Volume I: Main Report, UNESCO- IHE, Institute For Water Education, Value of Water: Research Report Series No. 16, Pp. 75.

Diwakar, J., 2007. "Assessment Of Drinking Water Quality of Bhaktapur Municipality, M.Sc. Thesis, Central Department Of Environment Science, TU.

Diwakar, J., Yami, K. D. and Prasai, T., 2008. Assessment of Drinking Water of Bhaktapur Municipality Area in Pre-Monsoon Season. Scientific World **6**(6): 94-98

DoHS, 1998. Annual Report (1997/98). Kathmandu: DoHS, MoHP, GoN.

DoP, 2002. The Microbiology of Drinking Water, Part 1. Water Quality and Public Health; Department of the Environment

DWAF, 2002. Report of the Department of Water Affairs and Forestry. South Africa.

ENPHO, 1989. "Drinking Water Quality and Sanitation Situation in UNICEF's Project Area.

ENPHO/DISVI, 1990. Water quality testing in Kathmandu. Environment and Public Health Organization and DISVI International Co-operation, Kathmandu

ENPHO/DISVI. 1992. Monitoring of Kathmandu City water supply with reference to chlorination and microbiological quality. Environment and Public Health Organization and DISVI International Co-operation, Kathmandu

Gewali, L., 2002. Bacteriological and Helminthological Assessment of the Drinking Water Quality of Ward- 19, KMC. M. Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Gleick, P.H., 1993. Water and Conflict: Fresh Water Resources and International Security, Vol. 18, No. 1. Oxford University Press, New York.

Global Environmental Facility annual report 2002. A year of renewed commitment to sustaining the earth. Washington, District of Columbia, United States of America

Government of Nepal, National Drinking Water Standards, 2005 And National Drinking Water Quality Standard Implementation Guideline, 2002. Government of Nepal, and Ministry of Physical Planning and Works, Singhadurbar, Kathmandu, Nepal.

Gyawali, R., 2007. "A Study on Microbiological and Chemical Quality of Water of Kathmandu" M.Sc. Thesis, Central Department Of Microbiology, TU.

Hammer, M.J. & Mackichan, A.K., 1981. Hydrology and Quality of Water Resources. John Wiley and Sons, New York.

Jayana, B. L., Prasai, T., Singh, A. and Yami, K. Y., 2009. Assessment of Drinking Water Quality of Madhyapur Thimi and Study of Antibiotic Sensitivity against Bacterial Isolates. Nepal Journal of Science and Technology **10**: 167-172

JICA, 1990. Groundwater quality surveillance in Kathmandu and Lalitpur Municipality areas. JICA expert office at MPPW, Singhdurbar, Kathmandu.

Joshi, D; Khanal, S; Mittle, M; Gupta, M; Maharjan, R. and Shakya, R. 2009. Microbial Quality of Jar Water sold in Kathmandu Valley. Journal of Food Science & Technology, Nepal. 5. 150-152.

Karanis, P., Kourenti, C. and Smith, C., 2007. Waterborne Transmission Of Protozoan Parasites: A Worldwide Review Of Outbreaks And Lessons Learnt. Journal of Water and Health **05**(1): 1-38.

Khadka, M.S., 1993. The groundwater quality situation in alluvial aquifers of the Kathmandu Valley, Nepal, AGSO Journal of Australian Geology and Geophysics 14:207-211.

Kistemann, T., Claben, T., Koch, C., Dangendorf, F., Fischeder, R., Gebel, J. et al. 2002. Microbial Load of Drinking Water Reservoir Tributaries during Extreme Rainfall and Runoff. Applied and Environmental Microbiology **68**(5): 2188- 2197

Kongolo, M. 2011. Water resources management for agricultural growth in drylands in developing countries. African Journal of Business Management. 5(3): 3913-3922.

KUKL, 2018. ADB TA 9171-NEP. Second Kathmandu Valley Water Supply Improvement Project (45339-001). Kathmandu, Nepal.

Madigan, M.T., Martinko, J.M., and Parker, J., 1997. Brock Biology of Microorganisms. International Edition, Eighth Edition.

Masaaki N., And Hiroaki N., 1998, "Quality of the Bottled Water in Nepal", Japanese Journal of Mountain Medicine, Vol. 18, Pp 107-110

Metcalf and Eddy Inc; 2000. Paper Presented At A Seminar On Ground Water And Waste Water. Organized By Melamchi Water Supply Development Board, 14 February 2000, Kathmandu, Nepal.

Muhammad, M; Safdar, S; Asghar, F. and Jamal, F. 2013. Assessment of Drinking water quality and its impact on residentshealth in Bhawalpur city. International journal of Humanities and Social Science **3**(15): 114-118

Muller, M. & Kfir, R., 2003. Management of Water Related Microbial Diseases, Republic Of South Africa.

Olmstead, S., 2003. Water Supply and Poor Communities: What's Price Got to Do with It? Environment. 45. 22-35. 10.1080/00139150309604574.

Pandey B., 2009. “A Case Study of Drinking Water Quality Status in Central Development Region, Nepal”

Pant, B.R. 2011. Ground water quality in the Kathmandu valley of Nepal. Environment Monitoring and Assessment **178**(1-4):477-485

Parihar, S.S., Tomar, R.S., Jyoti, A. Mishra, R.K. and Shrivastava, V. 2014. Assessment of Physico-Chemical & Microbiological Quality of Angoori Barrage Water Bodies at Datiawith Special Reference to Human Health. European Academic Research **2**(3): 4328-4350.

Pathak, D.R., Yatabe, R. and Bhandary, N.P., 2013. Statistical Analysis of Factors Affecting Groundwater Quality in Shallow Aquifer of Kathmandu, Nepal. International Journal of Water Research **1**(1): 12-20

Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E. et.al., 2004. Water Resources, Agriculture and The Environment, Report 04-1, Cornell University, College of Agriculture and Life Sciences

Pokhrel, S.R. 2000. Physio-chemical as well as microbiological parameters of Bottled water of different companies of Nepal.

Pradhan, B., 2005. Water Quality Classification Model in the Hindu-Kush-Himalayan Region: The Bagmati River in Kathmandu Valley, Nepal.

Prasai, T., Lekhak, B., Joshi. D.R., and Baral, M.P. 2007. Microbiological Analysis of Drinking Water of Kathmandu Valley. Nepal Academy of Science and Technology, Kathmandu, Nepal.

Rai, S. K., Ono, K., Yanagida, J-1., Kurokawa, M. And Rai, C. K. 2009. Status of Drinking Water Contamination in Mountain Region, Nepal. Nepal Medical College Journal **11**(4): 281 -283.

Ribeiro, A., Machado, A.P., Kozakiewicz, Z., Ryan, M., Luke, B., Buddie A.G. et.al., 2006). "Fungi in Bottled Water, A case Study of a Production Plant."

Shakya, P; Joshi, T.P; Joshi, D.R. and Bhatta, D.R. 2012. Evaluation of Physico-chemical and microbiological parameters of drinking water supplied from distribution systems of Kathmandu. Nepal Journal of Science and Technology **13**(2):179-184

Sharma, A.P. 1978. The quality of Drinking water in Kathmandu, Journal institutes. 1: 15-22.

Sharma, A.P. 1986. Study of some chemicals and bacteriological aspect of drinking water in Kathmandu, a report submitted to national committee for man and biosphere, Kathmandu. pp: 15-22.

Shiklomanov, I. 1993. World Water Resources. Oxford University Press, New York

Shmueli, Deborah, F. (May 1999). "Water Quality in International River Basins". Political Geography. 18 (4): 437–476. Doi: 10.1016/S0962-6298(98)00106-1. Pdf.

Shrestha, R. R., Sharma, S., 1995. Bacteriological Quality of Drinking Water In Kathmandu City: A Review of ENPHO/DISVI Reports, 1988-1992. Environment and Public Health Organization, 1995.

Shrestha, R. K., Regmi, D. and Kafle, B. P. 2014. Seasonal Variation of Arsenic Concentration in Ground Water of Nawalparasi District of Nepal. International Journal of Applied Science and Biotechnology **2**(1): 59-63

Shrivastava, D. K., Yadav, S. and Chanddra, T. P. 2014. Evaluation of Physico-Chemical Quality of Drinking Water in Bilaspur District of Chhattisgarh State. International Journal of Science and Research **3**(6): 1267_1271

Sorlini, S; Palazzini, D; Sieliechi, J.M. and Ngassoum, M.B. 2013. Assessment of physico-chemical drinking water quality in the Logone valley (Chad-Cameroon) Sustainability **5**(7): 3060-3076

Tamrakar, C.S. 2014, Evaluation of Physico-Chemical Characteristics of Drinking Water Supply In Kathmandu, Nepal. Research Journal of Chemical Sciences **4**(4): 33-36

Tanwar, S. and Tyor, A.K. 2014. Assessment of Physico-Chemical Characteristics of Recreational Lake Tilyor, Rohtak (Haryana) India. International Journal of Pure and Applied Bio-Science. **2**(2): 204-212.

Thakuri, B.M., (2008), "Analysis Of Bottled Water Available In Kathmandu Valley",M.Sc. Thesis, Central Department Of Environment Science, TU.

The World's Water, "The Biennial Report on Fresh Water Resources: 2004-2005", Island Press

Timilshina, M., Dahal, I., and Thapa, B. 2012. Microbial Assessment of Bottled Drinking Water of Kathmandu. International Journal of Infection and Microbiology. **1**(2): 84-86.

Tsega, N; Sahile, S; Kibret, M. and Abera, B. 2013. Bacteriological and Physico-chemical quality of drinking water sources in a rural community of Ethiopia. African Health Sciences. **13**(4): 1156-1161.

UNEP. 2001. State of the Environment Nepal**.** United Nations Environment Programs (UNEP), In Collaboration with Mope/HMGN; SACEP, ICIMOD and NORAD.

United Nations (2003), "Water For People, Water For Life: A Joint Report By The 23 UN Agencies Concerned With Fresh Water, The UN World Water Development Report.

Warner, N. R; Levy, J; Harpp, K. and Farruggia, F. 2007. Drinking water quality in Nepal's Kathmandu Valley: a survey and assessment of selected controlling site characteristics

WHO, 1993. Guidelines for Drinking Water Quality, Volume I, II and III. World Health Organizations, Geneva.

WHO, 1996. Guidelines for Drinking Water Quality 2nd Edition. Volume II, Health Criteria and Other Supporting Information. World Health Organizations, Geneva.

WHO/UNICEF, 2000. Global Water Supply and Sanitation Assessment Report. World Health Organization, Geneva; and the Editorial and Publications Section, UNICEF, New York.

WHO/UNICEF, 2004. Meeting the MDG Drinking-Water and Sanitation Target. World Health Organization, Geneva; and the Editorial and Publications Section, UNICEF, New York.

WHO, 2002. Managing Water in the Home: Accelerated Health Gains from Improved Water Supply. World Health Organizations, Geneva.

WHO, 2017. World Health Statistics 2017: Monitoring health for the SDGs. World Health Organizations, Geneva.

WHO, 2017. Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum. World Health Organisation, Geneva.

Wikipedia.org. Water. Wikipedia, the Free Encyclopedia. July 19, 2019, 09:08 UTC. Available at: https://en.wikipedia.org/w/index.php?title=Water&oldid=906932657. Accessed July 15, 2019.

Wolfe, A.N.C. 2000. Microbial Contamination in the Kathmandu Valley Drinking Water Supply and Bagmati River.

Yashoda, T., Byragi, R.T. and Ramana, C.V. 2014. Pre- and Post-Monsoon Variation in Physico-Chemical Characteristics in Groundwater Quality of Mindi Industrial Area, Visakhapatnam, India. International Journal of Environmental Sciences **4**(5): 746-753.