Assessment of Drinking Water Quality at Myagdi District, Western Nepal

Western Regional Research Grant

Final Report

Submitted by:

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Ms. Bina Gautam

Submitted to:

Nepal Health Research Council

Ram Shah Path, Kathmandu, Nepal

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Mr. Jagannath Aryal, Principal Investigator;

Mr. Nawraj Sapkota, and Ms. Bina Gautam, Co-Investigators

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Acronyms

ADB:	Asian Development bank
APHA:	American Public Health Association
CBS:	Central Buerau of Statistics
CFU:	Colony Forming Units
DoHS:	Department of Health Services
DWSC:	District Water Supply Committee
ENPHO:	Environment and Public Health Organization
E. coli:	*Escherichia coli*
GoN:	Government of Nepal
ICIMOD:	International Center for Integrated Mountain Development
MF:	Membrane Filteration
mg/l :	milligram per liter
MPN:	Most probable Numbers
NRDC:	Natural Resource Defense Council
NDWQS:	National Drinking Water Quality Standards
pH:	Percentage of Hydrogen ions
VDC:	Village Development Committee
WHO:	World Health Organization

Executive Summary

In Nepal drinking water quality is appeared as a great public health concern because is major risk factor for high incidence of diarrheal diseases in Nepal. Water pollution is important and serious issue due to haphazard urbanization and industrialization. The principal reasons of the chemical and bacteriological pollution of drinking water are due to inadequate sanitation, dumping of wastes, poor drainage system and irregular supply of drinking water in the pipeline. Besides that the contamination may be either due to the failure of the disinfections of the raw water at the treatment plant or because of the infiltration of contaminated water (sewage) through cross connection and leakage points. All natural water sources, such as wells, stone spouts and ponds are neither treated nor protected properly. The quality of water has deteriorated due to poor management and no monitoring of water quality. The Government of Nepal gazette the National Drinking Water Quality Standards (NDWQS) in 2005 (2062 B.S) as an effort to take first step towards assuring drinking water quality. The NDWQS requires municipalities to meet the national standards within five years after gazeting. Rural communities have been given a further five years before they have to meet the standards.

The primary goal of this research is to analyze the drinking water quality parameters physico-chemical & microbiological in order to ensure that the water is safe for drinking. The greatest problem continues to be the microbial contamination of drinking water supplies. It is a tragedy that infants and young children are the innocent victims of the failure to make safe drinking water and basic sanitation services. The major challenge is to access whether the water from different existing sources is safe for drinking or not. The assessment of drinking water scientifically is mandatory to detect whether water is safe for drinking or not.

In the present study, a total of 84 water samples were collected from 11 sources, 5 reservoirs and 68 taps water were collected from 9 different wards of Arthunge, VDC and tested physio-chemical and microbiological parameters. The values for majority of the physico-chemical parameters for tested water samples from sources, reservoirs and taps were found to lie within the NDWQS-2062.

The physical and chemical analysis performed on water samples indicates clearly that water does not have any significant effect on physico-chemical characteristics of water except pH, because all parameters remains nearly constant over the experimental period. After testing the physico-chemical parameters of water were satisfactory. Most of the parameters checked were found in

safe limit except pH and Arsenic. The water samples 54 % have found Arsenic concentration exceeded the permissible level given by WHO (0.01 mg/L), but according to NDWQS-2062 all water samples were near constant with permissible level (0.05 mg/L). The statistical analysis through paired t-test revealed that physic-chemical parameters of drinking water for Tap water samples in winter (January, 2010) and summer (June, 2010) was not differ significantly at 5% level of significance.

Microbial analysis performed on water sample was not safe for drinking purpose. There were a number of coliform present in most of samples but there was absence of *E. coli*. While most of the tested waters were found to be higher number of coliform organism especially in tap water which was not safe for drinking. The microbiological contamination was not great in source and reservoirs were unlikely to represent a public health concern. But in tap water it was found that about 71% of water samples found very high risk due to present of coliform organism. All of samples water tested complied fully with NDWQS-2062. The presence of coliform bacteria in the tap water may be due to contamination in pipelining system, back siphoning, and discontinuity in water supply pattern. Also carelessness may be the reasons for contaminated with coliform. There should be regular monitoring of bacteriological quality of water in order to ensure safe drinking water. Diarrheal diseases may be outcome due to unsafe drinking water. Ministry of Health and Population should develop effective strategy to undertake public health concern ensuring better water quality.

CHAPTER -I

Introduction

1.1 Background

Water, the most vital resource for all life on this planet, may be adversely affected qualitatively and quantitatively by different human activities. Clean and safe water is an absolute need for health and productive life. Water has a profound influence on human health and quality of the water supplied is important in determining the health of individuals and whole communities. Safe drinking water is a major concern with reference to public health importance as health and well being of the human race is closely tied up with the quality of water used (Sharma et al., 2005).

Today most of the surface and ground water receive millions of liters of sewage, domestic waste, industrial and agricultural effluents containing substances varying in characteristics from simple nutrients to highly toxic substances. Changes in water quality are reflected in its physical, chemical and biological conditions; and these in turn are influenced by physical and anthropogenic activities (ADB/ICIMOD, 2006).

Supply of safe drinking water is now becoming a global concern since there are still more than one billion people who lack access to clean drinking water and more than a two third of world population do not have access to proper sanitation. The WHO estimates that 1.15 billion population in developing world lack access to improved water supplies (WHO, 2007). The lack of proper purification and sanitation of drinking water in the developing countries leads to the scarcity of safe drinking water among one third of the total population along with the increased prevalence of water borne diseases, diarrhea being the major cause for death, mostly among the children under the age of five years (WHO, 2007). There is a vital connection between water and health. Water, though is an absolute necessity for life, can also be a carrier of many water borne diseases such as typhoid, cholera, hepatitis, dysentery and other diarrheal related diseases. It has been estimated that 4% of the global burden of disease is attributed to unsafe water supply (WHO, 2007). According to the WHO, diarrheal disease accounts for an estimated 4.1% of the total daily global burden of disease. It has also been estimated that approximately 4 billion cases of diarrhea each year cause 2.2 million deaths, mostly among children under the age of five which is equivalent to one child dying in every 15 seconds. Water, sanitation and hygiene interventions reduce diarrheal disease on average by between one-quarter and one –third (WHO, 2007).

Diarrheal diseases are still reconized as a major problem of Neplease children, being recorded as the second most prevalent diagnosis in out-patience services. Today 72% of the nationwide disease burden is related to poor quality of drinking water and around 75 children die each day from diarrhoea alone (Sherpa, 2003). The annual report from department of Health revealed that national incidence of diarrhea per 1000 under 5 children has been increasing. In 063/064 the new cases were 185 whereas in 064/065 the new cases were 378 (DoHS, 064/065). The total case of diarrohea in western region in 063/064 was 101,595 while in 064/065 there were 203,847 cases. Myagdi district is affected by water borne diseases where the incidence rate of diarrhea per 1000 in 064/065 is 660 which is the highest prevalence rate in western region whereas the western region has prevalence rate of 277 per 1000 in 064/065 (DoHS, 064/065). It is believed that poor quality of water i.e, microbiological pollution directly related to public health impact. The microbiological quality of water can be accessed through the analysis of coliform group of organisms which are also called indicator organism of water quality. If there is presence of only one coliform organism (that is expressed as MPN/100 ml or CFU/100 ml), the water is contaminated and suspected to be contained other pathogenic organisms also.

The chemical parameter of drinking water owes significant relation with the public health also. Some chemicals, notably iron, ammonia, nitrates and arsenic have adverse health impacts. The present study intends to assess the water quality parameters of drinking water supplied from different sources in the rural area of Nepal and to compare with National Drinking Water Quality Standards 2062. Therefore, this study has been designed with the aim to analyze the situation of physio-chemical and microbiological quality of drinking water supplied from different sources in Myagdi district.

1.2 Water Quality parameters

The water pollution is assessed on the basis of certain parameters:

i. Physical, used to ascertain Temperature, turbidity, colour, conductivity, suspended, dissolve and total solids.

ii. Chemical, used to ascertain inorganic matter such as acidity, alkalinity, salinity including several insoluble inorganic materials, soluble salts and organic matters.

iii. Microbiological, used to ascertain bacteria and pathogenic organisms.

1.2.1 Physico-chemical parameters

The ordinary consumer judges the water quality by its physical characteristics (Park, 2005). The chemical parameter is used to ascertain the presence of inorganic matter, soluble salts of organic matter in water. It can be argued that chemical standards for drinking water are of secondary consideration in a supply subject to severe bacterial contamination. The problems associated with chemical constituents of drinking water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure; of particular concern are contaminants that have cumulative toxic properties, such as heavy metals, and substances that are carcinogenic (WHO, 1994).

Temperature

Temperature is one of the important parameter of water and is bacically important for its effects on the chemistry and biological reactions in the organisms in the water. It is important in the determination of various parameters such as pH, conductivity, saturation level of gases and alkalinity etc. A rise in temperature of the water leads to the speeding of chemical reactions, enhanced growth of microorganism, reduction in solubility of gases and amplify tastes and odour (Trevedy and Goel, 1986). The temperature range of $7^{o}C$ – $11^{o}C$ has pleasant taste and more palatable than warm water (WHO, 1994).

pH

pH is the measure of intensity of acidity or alkalinity (APHA, 1998). The pH value of drinking water from any sources should be within the range of 6.5- 85 (Trivedy and Goel, 1986). pH less than 7 may cause corrosion and encrustation in the distribution system where as the disinfection with chlorine is less effective is pH of water exceeds 8.0 (WHO, 1993). The pH of water affects treatment processes, coagulation and disinfection with chlorine-based chemicals. Change in the pH of source water should be investigated as it is a relatively stable parameter over the short term and any unusual change may reflect a major event (Payment et.al., 2003).

Electrical Conductivity

Conductivity is the measure of dissolved solids. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate and metal anion or cations (Trivedy and Goel, 1986). The contamination with wastewater also may increases the conductivity of the water so the abrupt change in the conductivity is the indicator of water pollution. Conductivity is strongly dependent on temperature and therefore is reported normally at $25^{o}C$.

Hardness

Hardness is the property of water, which prevents the lather formation with soap and increase the boiling point of water. Calcium and magnesium are the principal minerals contributing to total hardness, magnesium to a lesser extent. It is usually expressed as the equivalent quality of calcium carbonate (WHO, 2004).

Alkalinity

The alkalinity of water is the measure of its capacity to neutralize strong acids, characterized by the presence of all hydroxyl ions capable of combining with the hydrogen ion. Bicarbonate and Carbonate are the major contributors to alkalinity. The relationship of pH, calcium and alkalinity determines whether water is corrosive or whether it will deposit calcium carbonate (Mathur, 2005).

Chloride

It is a major mineral constituent, generally found in all types of water. Chloride in water is mostly in the form of sodium, potassioum and calcium salts. In natural and unpolluted water, it is present in very low concentration and higher concentration of chloride gives an undesirable taste to water (KDHE, 2008). The suggested limit for chloride is 250 mg/l and the increase of chloride indicates the industrial domestic wastewater pollution. High chloride concentrations are corrosive to metals in the distribution system, particularly in waters of low alkalinity (Trivedy and Goel, 1986).

Ammonia

Surface water showing a sudden increase in ammonia content may indicate sewage pollution (Trivedy and Goel, 1986). Sewage contains large amount of ammonia formed by bacterial decay of nitrogenous organic wastes. Ground water often contains some ammonia due to natural degradation processes from reduction of nitrates by bacteria. Ammonia can occur naturally in water supplies, while some water treatment plants add ammonia to react with chlorine to form combined chlorine residual to control formation of trihaloethanes. Ammonia will increase the chlorine demand of raw water in the chlorination process of disinfection. Its presence is not proof of contamination but may provide the supporting evidence of pollution (KDHE, 2008).

Iron

Iron is objectionable because of the bad taste associated with the water, the staining of laundered clothes, and the probable deposition of the elements in the distribution system. They have no significance physiologically but iron promotes undesirable bacterial growth ("Iron bacteria") in water and distribution system, resulting in the development of a slimy coating on the pipes. The suggested limits for iron are 0.3 mg/l (DWSS, 2006). In drinking water supplies the ferrous salt of iron being unstable are precipitated as ferric hydroxide when oxidized where as ground water may contain iron (II) several concentration without turbidity but when pumped directly from a well, turbidity and colour may develop in piped system at iron levels above 0.05 – 1 mg/l (WHO,1993).

Arsenic (As)

Arsenic is a metalloid that found naturally in rocks, soil, natural water and organisms. It is introduced into the drinking water supply mainly through dissolution of naturally occurring minerals and ores. Anthropogenic sources of arsenic include pesticides, chemical fertilizers and industrial discharges. In Nepal high concentrations of arsenic have been found in the Terai regions. The simplest and most immediately achievable option of water in the rural sector of Nepal is digging out tube-wells. The Arsenic problem is complex, while the solution elusive. The underground distribution of Arsenic highly variable within small areas. Generally Arsenic is mostly found in shallow aquifers, those at depth less than 150m. Nonetheless deep aquifers are also occasionally found to be as invisible and do not affect the taste and odor of the water. Even the symptoms/signs and other recognizable symptoms are visible only after several years of water consumption. Arsenic in drinking water can be a significant cause of health effects in some regions. The provisional guideline value is 0.01 mg/l (WHO Standard value). The NDWQS-2005 suggested the guideline value of 0.05 mg/l.

1.2.2 Microbiological Testing of drinking water

The main purpose of microbiological testing of drinking water is the detection of recent and potentially dangerous faecal pollution. Contamination of drinking water by human and animal excreta, sewage is dangerous if there are carriers of infectious enteric diseases which may be waterborne among contributing population. Disease causing organisms may be divided into virus, bacteria, protozoa, helminthes etc. Coliform organisms have long been recognized as a suitable microbial indicator of drinking water quality largely because they are easy to detect and enumerate in water. The term coliform organisms refers to Gram-negative, rod-shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth inhibiting properties and able to ferment lactose at 35-37°C with the production of acid, gas and aldehyde within 24-48 hours. They are also oxidase-negative and non-spore forming, and they display-galactosidase activity. Coliform bacteria belong to the genera *Escherichia*, *Citrobacter*, *Enterobacter* and *Klebsiella* (WHO, 1991).

E.coli is present in the intestine of warm-blooded animals, including humans. Therefore, the presence of *E.coli* in water samples indicates the presence of faecal matter of the possible presence of pathogenic organisms of human origin. *E.coli* has been used and continues to be considered a good indicator organism for the following reasons:

- *E.coli* is found in large numbers in the faeces of human and warm blooded animal (10^9 per gram in fresh faeces).
- It is easy to detect and responds the same as pathogens to changes in the aquatic environment

Water intended for consumption must be free from agents of waterborne disease. However, it is impracticable to test for every pathogen that might be present in drinking water, since methods are often difficult, expensive and time-consuming. For this reason, in routine testing, microbial indicators of water quality, i.e. the normal intestinal organisms as indicators of faecal pollution are used as their presence shows that pathogens could also be present. In this study, *E. coli* and total coliform were tested as indicators of bacteriological quality. Table 1; noted the chemical contaminants and health concern with excess levels.

TABLE 1: Selected Contaminants of Potential Concern for drinking Water	
Contaminant	Health Concern with Excess Levels
Coliform Bacteria	Broad class of bacteria used as potential indicator of fecal contamination; may be harmless of themselves. Harmful types of coliform bacteria (such as certain fecal coliform bacteria or E. coli) can cause infections with vomiting, diarrhea, or serious illness in children, the elderly, and immunocompromised or other vulnerable people.
Heterotrophic Plate Count (HPC) Bacteria	Potential indicator of overall sanitation in bottling and source water; may be harmless of themselves. In some cases may indicate presence of infectious bacteria; data show sometimes linked to illnesses. Can interfere with detection of coliform bacteria or infectious bacteria. Unregulated by FDA.
Pseudomonas aeruginosa bacteria	Possible indicator of fecal contamination or unsanitary source water or bottling. Can cause opportunistic infections. Unregulated by FDA.
Arsenic	Known human carcinogen. Also can cause skin, nervous, and reproductive or developmental problems.
Nitrate	Causes "blue baby" syndrome in infants, due to interference with blood's ability to take up oxygen. Potential cancer risk.
Trihalomethanes (i.e., chloroform, bromodichloromethane, dibromochloromethane, and bromoform)	Cancer of the bladder, colorectal cancer, possibly pancreatic cancer. Also concerns about possible birth defects and spontaneous abortions.
Phthalate (DEHP)	Cancer; possible endocrine system disrupter. Unregulated by FDA.
Source: www.nrdc.org/water/drinking	

1.3 National Drinking Water Quality Standards 2062

The primary purpose of the Standards for Drinking-water Quality is the protection of public health. Safe drinking-water, as defined by the guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. The Guidelines describe reasonable minimum requirements of safe practice to protect the health of consumers and/or derive numerical “guideline values” for constituents of water or indicators of water quality. In order to define mandatory limits, it is preferable to consider the guidelines in the context of local or national environmental, social, economic and cultural conditions.The National Drinking Water Quality Standards (NDWQS)-2062 recently issued by Government of Nepal (GoN) are given in below Table 2.

Table 2: National Drinking Water Quality Standards-2062

S.N.	Parameter	Unit	Max. Concn Limits
Physical			
1.	Temperature	° C	-
2	pH		6.5-8.5
3.	Electrical conductivity (EC)	µS/cm	1500
Chemical			
4.	Chloride	mg/L	250
5.	Total Alkalinity	mg/L	-
6.	Free CO2	mg/L	-
7.	Hardness	mg/L	500
9.	Iron	mg/L	0.3
10.	Ammonia	mg/L	1.5
11.	Phosphate	mg/L	-
12.	Nitrate	mg/L	50
13	Arsenic	mg/L	0.05
Bacteriological			
14.	Total coliform	cfu/100 mL	0 (In 95% Samples)
15.	*E-Coli*	cfu/100 mL	0
Source: DWSS, 2006			

1.4 Rationale of the Study

The principal reasons of the chemical and bacteriological pollution of drinking water are due to inadequate sanitation, dumping of wastes, poor drainage system and irregular supply of drinking water in the pipeline. Besides that the contamination may be either due to the failure of the disinfections of the raw water at the treatment plant or because of the infiltration of contaminated water (sewage) through cross connection and leakage points. All natural water sources, such as wells, stone spouts and ponds are neither treated nor protected properly. Thus, deteriorating water quality is the major problem and it has created serious threat to human health and environment. The quality of water has deteriorated due to poor management and no monitoring of water quality. The primary goal of this research is to analyze the drinking water quality physico-chemical & microbiological parameters in order to ensure that the water is suitable for drinking. The greatest problem continues to be the microbial contamination of drinking water supplies. It is a tragedy that infants and young children are the innocent victims of the failure to make safe drinking water and basic sanitation services. The major challenge is to access whether the water from different existing sources is safe for drinking or not. The assessment of drinking water scientifically is mandatory to detect whether water is safe for drinking or not. Thus, it is important to determine the current status of drinking water that is supplied through public water supply from different sources. The status of current water quality of different sources will provide guideline regarding the proper drinking water monitoring system. The findings and recommendations made may help to formulate strategy for proper implementation of National Drinking Water Quality Standards 2062. The present study has been designed to overcome the issues related to the drinking water quality at community level.

1.5 Objectives

The general objective of the study was to assess the Existing Drinking Water Quality at Arthunge VDC of Myagdi district, Western Nepal.

The specific objectives were:

1. To identify the existing sources of drinking water
2. To analyze physio-chemical parameters of drinking water i.e. temperature, conductivity, pH, chloride, total hardness, alkalinity, free CO_2, ammonia, nitrate, phosphate and heavy metals: Iron, Arsenic at different levels i.e: sources, reservoir and tap
3. To assess microbiological quality of drinking water at different levels i.e: sources, reservoir and tap

1.6 Limitations

The present study is limited to assessment of drinking water quality parameters of different sources, reservoirs and taps in Arthunge VDC of Myagdi district, western Nepal. The findings provide the water quality data for studied sources and areas only and cannot be generalized accurately the whole rural areas of Nepal. The sampling was carried out from January to June, 2010. Due to remoteness of area adequate sample collection was difficult. All parameters stated in NDWQS-2062 were not analyzed due to applicability as well as remoteness of the study area. The study was conducted on winter season (January, 2010) and summer season (June, 2010). Due to time limitation the study could not carried out throughout the year.

CHAPTER-II

Literature Review

2.1 Study on Physio-chemical parameter of drinking water in Nepal

Several studies on the physio-chemical parameters were carried out in drinking water in several parts of Nepal.

Shrestha (2002) analyzed water samples from various sources and reported the physico-chemical parameters of most of the samples are within the WHO guidelines value except for conductivity (42.10%), turbidity (62.10%), and iron (82.10%).

Gyawali (2007) assessed the water quality of Kathmandu, samples taken from seven different sources. Chemical analysis showed that the pH of all collected samples was found to be within limit of WHO guidelines.

Bajracharya et al., (2007) studied the quality of a total of 114 drinking water of the Kathmandu from different sources. The physic-chemical analysis of the samples showed 14.91%, 24.56% , 26.32%, 31.58% and 22% of water samples exceeding WHO guideline value for pH, conductivity, turbidity, iron and ammonia content respectively.

Diwakar et al., (2008) analyzed the drinking water of Bhaktapur Municipality Area in pre-monsoon season. She analyzed 116 water sample from different sources (public tap, well, tube well and stone spout) and the pH values of all water samples were found to lie within Nepal standard. Similarly 57(49.14%), 9 (7.76%), 56 (48.28%) and 1(0.87%) of water samples were found to exceed Nepal standard value for conductivity, turbidity, iron and chloride content respectively. Hardness content of all water samples were within the standard whereas 6 (5.17%) samples crossed ammonia permissible level. The nitrate and arsenic content of all samples were found within permissible level.

Jayana et al., (2009) assessed the status of drinking water quality of Madhyapur-Thimi. The Physico-chemical analysis of 105 water samples comprising 50 (47.61%) wells, 45 (42.82%) tap water and 10 (9.52%) stone spouts showed that pH (1.9%), conductivity (34.28%) and turbidity (16.19%) of water samples had crossed the permissible guideline values as prescribed by WHO and national standard. All samples contained nitrate values within the WHO permissible value as well as national standard but hardness (2%), chloride (2.85%), iron (26.66%), ammonia (11.42%), and arsenic content (1.90%) crossed the WHO guideline value but none of the water samples crossed the national standard for arsenic.

2.2 Study on Microbial Quality of Drinking Water in Nepal

Studies on microbiological quality of drinking water in Nepal have been carried out by different researchers. Some of the relevant studies are depicted as follows.

Shrestha (2002) analyzed a total of 95 water samples for bacteriological parameters from various sources. The maximum count of coliform was observed from all raw, settled and reservoir water distribution point Balkhu and Kuleshwor. The study also found 85.26 % of the samples to have exceeded WHO guideline value for total coliform.

Similarly, Joshi and Baral (2004) also analyzed 160 samples randomly collected from 86 tube wells and 77 open wells in urban areas and reported that more that 87 % of analyzed ground water samples of tube well and open well was contaminated.

Malla (2006) analyzed the quality of the bottled water sold in the Kathmandu valley. That study included testing of more than 50 bottles of 10 different microbiological qualities within WHO and EPA guidelines for drinking water. Total hardness, TDS, alkalinity and electrical conductivity were found below than the prescribed limits of WHO. The elevated TDS in water may have aesthetic problems or cause nuisance problems. Microbial analysis showed that the bottled water is safe for bacteriological quality. There was absence of E. coli, algae, yeast and mold in the samples of bottle water.

Prasai et al., (2007) conducted a study to evaluate the quality of drinking water of Kathmandu valley. A total of 132 water samples were collected and analyzed microbiologically. Total plate and coliform count revealed that 82.6% and 92.4% of drinking water samples found to cross the WHO guideline value for drinking water. During the study, 238 isolates of enteric bacteria were identified, of which 26.4% were *Escherichia coli*, 25.6% were *Enterobacter spp*, 23% were *Citrobacter spp*, 6.3% were *Pseudomonas aeruginosa*, 5.4% were *Klebsiella spp*, 4.0% were *Shigella spp*, 3.0% were *Salmonella* Typhi, 3.0% were *Proteus vulgaris*, 3.0% were *Serratia spp* and 1.0% were *Vibrio cholera*.

Gyawali (2007) assessed the water quality of Kathmandu, taken from seven different sources. all the water samples showed the growth of coliform bacteria and Salmonella spp. the highest bacterial count was found to be 6.4 x 10^6 cfu/ml in river water and lowest bacterial count was found to be 3.0 x10^3 cfu/ml in kuleshwor tap water. Similarly, the highest coliform count was 1100 cfu/ml and lowest coliform count was found to be 500 cfu/ml in sample taken from Sundarighat tank. Both the study showed that the most water get contaminated during the storage or in the distribution system.

Warner et al., (2007) sampled water from over 100 sources in Kathmandu and examined for contamination from sewage, agriculture, or industry. Total coliform and Escherichia coli bacteria were present in 94 and 72% of all water samples respectively.

Diwakar et al., (2008) analyzed the drinking water of Bhaktapur Municipality Area in pre-monsoon season. The analysis of 116 water sample from different sources revealed the presence of total coliform in 96 (82.76%) of samples. This study has pointed out that the drinking water quality of city water supply has not been improved and traditional sources like stone spouts and tube well water are also not free from contamination. Such circumstances are responsible for spreading water borne outbreaks. The waterborne diseases are closely related with the conditions of living and environmental sanitation in the community. So, it can be effectively controlled by appropriate water management and safe disposal of excreta.

Jayana (2009) assessed a total of 105 drinking water samples from the different sources of Madhyapur Thimi and reported 64.76% of the samples cross the WHO guideline value for total coliform count. *Enterobactor* spp. was the most predominant organism (29.5%) followed by *E. Coli* (36.6%), *Citrobacter* spp. (20.4%), *Proteus vulgaris* (7%), *Klebsiella* spp. (5.6%), *Proteus mirabilis* (3.5%) *Shigella dysentery* (2.8%), *Salmonella* Typhi (2.1%), *Pseudomonas* spp. (2.1%), *Samonella* Paratyphi (1.4%), and *Vibrio cholera* (0.7%).

CHAPTER-III

METHODOLOGY

3.1 Study Area

The Myagdi district lies in Dhaulagiri zone of the Western Development Region of Nepal. District headquarter Beni Bazaar is 290 K.M. far from Kathmandu and 90 km from Pokhara to the west. Parbat and Kaski (in the east), Baglung (south), Rukum (west) and Dolpa and Mustang (north) are neighboring districts of Myagdi. It is located $83^{0}08'$ to $83^{0}53'$east longitude and $28^{0}20'$ to $28^{0}47'$ north altitude. It is stated 782 m. to 8167 m. height (Dhaulagiri-I) from sea level. It covered 2297.06sq.k.m; out of that, the geographical pattern is structured by 8 percent plain valley, 56 percent high hill and 36 percent Himalayan Mountain. The total land used pattern is 15 percent land arable with 5 percent grassland, 40 percent forest 45 percent non-arable land.

Arthunge is a village development committee in Myagdi District in the Dhaulagiri Zone of western-central Nepal. The study area is selected as Arthunge VDC, the south-eastern part of the district. The total population of the VDC is 7400 and households of 1806 (CBS, 2001).

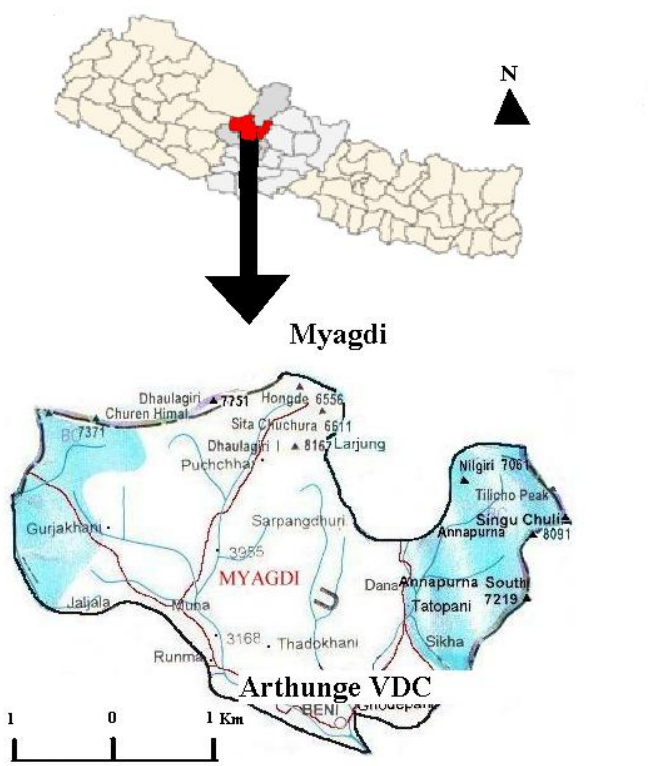


Figure 1: Geographical Map of Myagdi District

3.2 Study design

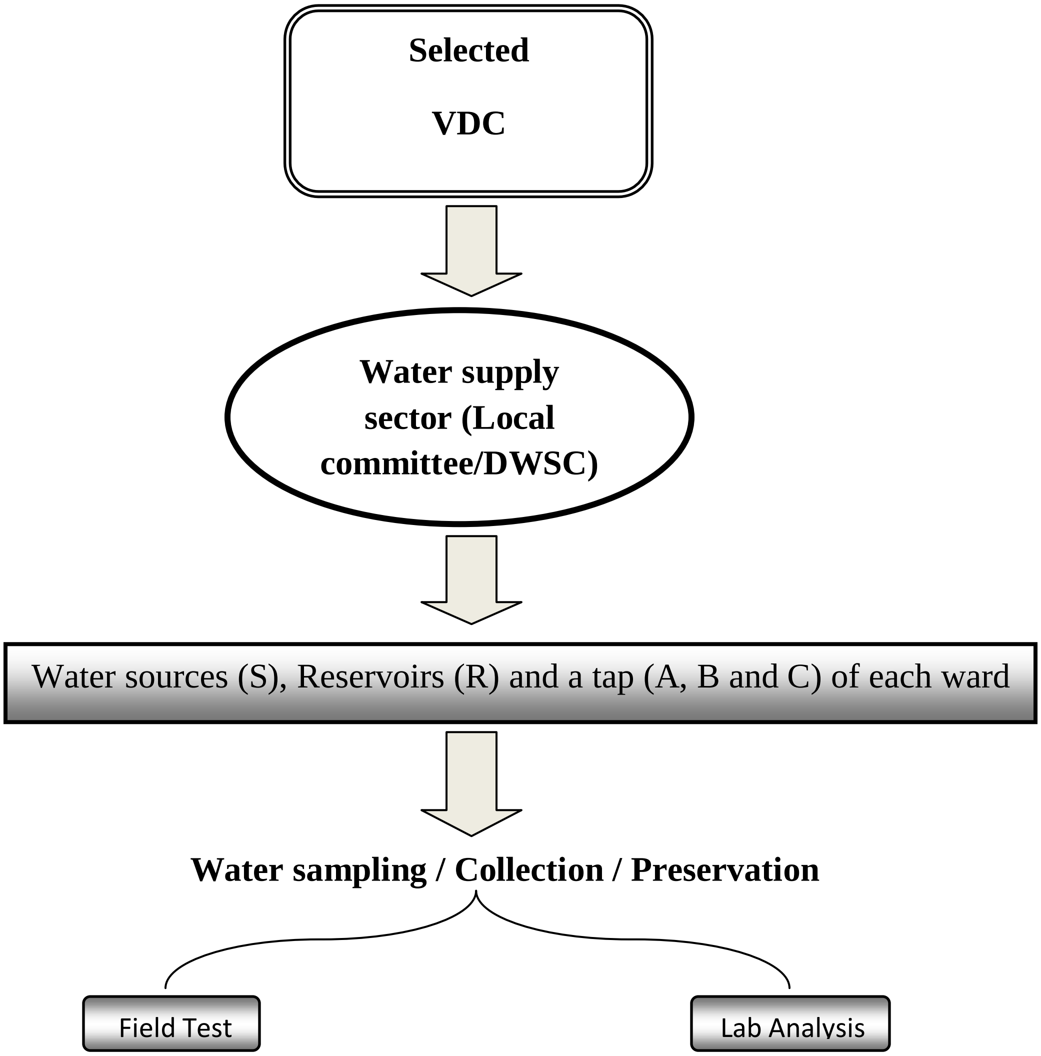


Figure 2: Schematic Diagram of the Study Design

3.3 Methods of sample collection, preservation and analysis

First of all, water management system, water supply system, pipeline and collection reservoirs for this VDC were identified through questionnaire on local level and district water supply management office. The selection of the sampling sites and the samples to be considered in this study was based on the following factors: the availability of data, the number of water quality parameter reported on previous similar study, the length and continuity of water quality records and the importance of potential water supply source. Based on all these consideration, a selection of 84 samples distributed along 11 Sources sample (S), 5 Reservoirs sample (R) and 68 collection samples (T) from the tap water was collected for this study. Water samples were collected from all sources, reservoirs and tap water from each ward. Tap water samples were randomly collected from each wards households having water supply. The sampling was done within two seasons as summer and winter seasons in 2010.

Water samples for field and laboratory testing were collected in separate bottles, as prescribed by APHA 1998. Water samples from the sampling sites were collected in two bottles and a sterilized poly-reagent plastic bottle. (I) 1000 ml, collection bottle for field test where, pH, temperature, Electric conductivity, chloride, alkalinity, Total hardness and free CO_2; were analyzed. (II) 1000 ml precleaned collection bottle for laboratory analysis as ammonia, nitrate, phosphate, iron, and Arsenic, the samples for metal testing were immediately acidified by adding conc H_2SO_4 and HNO_3 to maintain pH level less than 2; (III) 125 ml, polyreagent sterilized plastic bottle for microbiological analysis. Water samples for testing were carried out, as mentioned by American Public Health standard methods. Water samples for Microbiological analysis were transported to the Mount Annapurna Microbiological Research Laboratory in Pokhara within 6 hours and tested The samples for physicochemical testing were transported to the CDES research Lab in Kirtipur at earliest possible time.

Figure 3: Different sources of water

Water sampling and testing were done following the APHA prescribed standard methods. These methods are reliable and believed to the best for the assessment of water quality and water pollution. Our testing methods are summer summarized below in table 3; and described in greater details in the annexes:

Table 3: Methods and instruments used for analyzing physicochemical parameters

S.N.	Parameters	Methods	Instruments
Physical parameters			
1.	Temperature (°C)		Thermometer
2.	Electrical conductivity (EC; µS/cm)	Potentiometer method	Conductivity meter
Chemical Parameters			
1.	pH	Potentiometer method	pH meter
2.	Chloride	Argentometric method	Burette, pipette
4.	Alkalinity	Titrimetric method	Burette, pipette
5.	Hardness	EDTA method	Burette, pipette
6.	Calcium hardness	EDTA method	Burette, pipette
7.	Magnesium hardness	EDTA method	Burette, pipette,
8.	Free CO_2	Titrimetric method	Burette, pipette,
9.	Orthophosphate (PO_4-P)	Ammonium molybdate	Spectrophotometer
10.	Nitrate-nitrogen (NO_3-N)	Phenol disulfonic	Spectrophotometer
11.	Total iron	Phenanthroline	Spectrophotometer
12.	Arsenic	Arsine generator	Spectrophotometer
13.	Ammonia	Colormetric method	Spectrophotometer
Bacteriological			
14.	Total Coliform	Membrane Filtration	Millipore, USA
15	E-Coli	Membrane Filtration	Millipore, USA
			Source: APHA, 1998

3.4 Data Processing and Analysis

3.4.1 Data Editing

Data were edited as soon as possible to detect errors, mission and to make sure that the data were accurate, uniform and well arranged.

3.4.2 Coding

Information was coded so that they were easily classified and tabulated.

3.4.3 Classification and Tabulation

All the data were classified according to the need of the objectives and tabulation was done for summarizing the data and displaying statistically.

3.4.4 Data Analysis

Data were analyzed by means of table and diagrams and percentage rate. Statistical analysis was carried out using SPSS 11.5.

Figure 4: Laboratory analysis for microbiological study

CHAPTER-IV

RESULTS

4.1 Existing Sources of Drinking Water

The table 4 below shows the environmental condition of overall sources of drinking water at Arthunge VDC of Myagdi district. The sampling station is also indicated.

Table: 4: Sampling location of sources of drinking water in Arthunge VDC

S.N	Category	Sampling code	Location	Remarks
1	Spring	S_1	Arthunge-5, Khareni	Tank has been constructed to collect water in source, Afforestation area, no human influence
2	Spring	S_2	Arthunge-3, Jamunakharka	Minimum human impact on source,
3	Spring	S_3	Arthunge-3, Jamunakharka	No human impact
4	Spring	S_4	Arthunge-3, Banskhola	No human impact
5	Spring	S_5	Arthunge-3, Jamunakharka	Open well with human impact
6	Spring	S_6	Arthunge-5, Amarai	No human impact
7	Spring	S_7	Arthunge-6, Thakanpokhari	Open well with minimum human impact
8	River water	S_8	Arthunge-7, Kaule	Collection tank, collected from very remote area
9	River water	S_9	Ramchhe VDC, Pumdi	Pumdi river, no human impact
10	Spring	S_{10}	Arthunge-8, Kaphalbot	Open well with minimum human impact
11	Spring	S_{11}	Arthunge-6, Kaphalbot	No human impact

During the field visit, however, it was seen that only wards 1 & 2 of this VDC have adequate water supply regularly and other wards use drinking water direct from sources as pond, river and well. There were more than 3 reservoirs in wards and some individual persons have their own sources of water and they supplied water through pipeline for individual households in Beni Bazar, Arthunge VDC.

4.2 Physio-chemical parameter of water samples

Almost all values of physio-chemical parameters for tested water samples from source, reservoir and taps were found to within the NDWQS-2062. The table-5 shows the result of physico-chemical parameter of drinking water quality at sources of Arthunge VDC, Myagdi district in winter season (January 2010). In regard to physical parameters, all tested source water samples were within NDWQS-2062 except pH. The pH ranges from 7.5 to 9.15. Out of 11 sources 4 exceeded the guideline value of 8.5. The four sources exceeding 8.5 were S3, S4, S5 and S6. Chemically, the values for majority of tested parameters for source samples were found to lie below the maximum level of NDWQS-2062. The value for arsenic were found to be within NDWQS-2062 but exceeded the WHO standards in all sources.

Table: 5: Physio-chemical parameters for drinking water at source (winter, 2010)

S.N	Test Parameters	Units	Range	Mean value	Reference Value (NDWQS-2062)
1	Temperature	0c	9-11.5	10.30	-
2	pH	PH	7.5-9.15	8.35	6.5-8.5
3	Conductivity	µs/cm	74-489	234.45	1500
4	Chloride	mg/l	5.68-28.4	11.50	250
5	Total Hardness	mg/l	12-140	56.73	500
6	Total Alkalinity	mg/l	30-190	113.18	-
7	Free CO2	mg/l	8.8-63.8	32.70	-
8	Ammonia	mg/l	<0.018-0.089	0.033	1.5
9	Arsenic	mg/l	0.017-0.030	0.023	0.05
10	Iron	mg/l	<0.014-0.099	0.033	0.3
11	Phosphate	mg/l	<0.011-0.064	0.051	-
12	Nitrate	mg/l	<0.007-0.088	0.043	50

The table 6 shows the result of physico-chemical parameter of drinking water quality at Reservoir (which are collected from different sources for distribution to pipelines for consumption) of Arthunge VDC, Myagdi district in summer season (June, 2010). In regard to physical parameters, all tested source water samples were within NDWQS-2062 except pH of Reservoir 4 exceeded the guideline value 8.5. Chemically, the values for majority of tested parameters for source samples were found to lie below the maximum level of NDWQS-2062. The value for arsenic were found to be within NDWQS-2062 but exceeded the WHO standards in one Reservoir.

Table 6: Physio-chemical parameters for drinking water at Reservoir (summer season, 2010)

S.N	Test Parameters	Units	Range	Mean value	Reference Value (NDWQS-2062)
1	Temperature	0c	17-21	19.20	-
2	pH	Ph	7.5-8.6	7.90	6.5-8.5
3	Conductivity	µs/cm	185-222	204.40	1500
4	Chloride	mg/l	5.68-8.89	7.33	250
5	Total Hardness	mg/l	44-88	99.00	500
6	Total Alkalinity	mg/l	95-225	145.00	-
7	Free CO2	mg/l	24.6-62.5	43.22	-
8	Ammonia	mg/l	0.020-0.027	0.024	1.5
9	Arsenic	mg/l	0.003-0.016	0.007	0.05
10	Iron	mg/l	0.009-0.011	0.010	0.3
11	Phosphate	mg/l	0.142-0.148	0.145	-
12	Nitrate	mg/l	0.040-0.099	0.064	50

The table 7 shows the result of physico-chemical parameter of drinking water quality of tap water of Arthunge VDC, Myagdi district in winter season, 2010. All tap water samples tested were within permissible value (NDWQS-2062) except pH. The pH ranges from 7.5 to 9.2. out of 23 taps 8 exceeded the guideline value of 8.5. Chemically, the values for majority of tested parameters for source samples were found to lie below the maximum level of NDWQS-2062. The value for arsenic were found to be within NDWQS-2062 but exceeded the WHO standards in all taps.

Table 7: Physio-chemical parameters for drinking water at Tap (winter, 2010)

S.N	Test Parameters	Units	Range	Mean value	Reference Value (NDWQS-2062)
1	Temperature	0c	9-13	10.80	-
2	pH	pH	7-9.2	8.28	6.5-8.5
3	Conductivity	µs/cm	88-489	203.30	1500
4	Chloride	mg/l	5.6-35.5	12.47	250
5	Total Hardness	mg/l	16-144	50.57	500
6	Total Alkalinity	mg/l	43-190	89.33	-
7	Free CO2	mg/l	8.8-68.2	22.78	-
8	Ammonia	mg/l	0.018-0.057	0.028	1.5
9	Arsenic	mg/l	0.019-0.048	0.033	0.05
10	Iron	mg/l	0.013-0.079	0.017	0.3
11	Phosphate	mg/l	0.017-0.074	0.042	-
12	Nitrate	mg/l	0.015-0.050	0.035	50

Table 8: Physio-chemical parameters for drinking water at Tap (summer, 2010)

S.N	Test Parameters	Units	Range	Mean value	Reference Value (NDWQS-2062)
1	Temperature	0c	16-22	18.55	-
2	pH	Ph	7-9.1	7.93	6.5-8.5
3	Conductivity	µs/cm	87-292	158.77	1500
4	Chloride	mg/l	4.26-24.14	10.20	250
5	Total Hardness	mg/l	40-190	72.91	500
6	Total Alkalinity	mg/l	15-160	78.05	-
7	Free CO2	mg/l	8.3-62.8	27.88	-
8	Ammonia	mg/l	0.018-0.032	0.025	1.5
9	Arsenic	mg/l	0.007-0.036	0.019	0.05
10	Iron	mg/l	0.009-0.017	0.011	0.3
11	Phosphate	mg/l	0.131-0.2	0.153	-
12	Nitrate	mg/l	0.001-0.057	0.019	50

The table 8 shows the result of physico-chemical parameter of drinking water quality of tap water of Arthunge VDC, Myagdi district in the summer, 2010. All tap water samples tested were within permissible value (NDWQS-2062) except pH. The pH ranges from 7.5 to 9.2. out of 22 taps 2 exceeded the guideline value of 8.5. Chemically, the values for majority of tested parameters for source samples were found to lie below the maximum level of NDWQS-2062. The value for arsenic were found to be within NDWQS-2062 but exceeded the WHO standards in the majority of the taps (19 out of 22).

4.3 Statistical Analysis

The statistical analysis was carried out for physic-chemical parameters of drinking water for Tap water sample in winter (January, 2010) and summer (June, 2010) through paired t-test. The p-value was 0.675. The result showed that there was not significant difference at 5% level of significance in values of physic-chemical parameters in winter and summer 2010.

4.4 Bacteriological quality of water samples

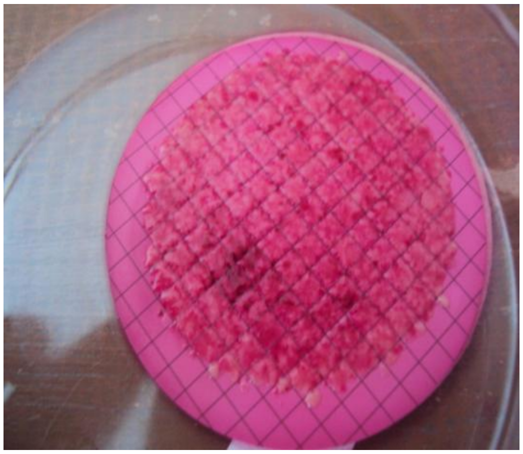
A total of 84 water samples were analyzed for presence of coliform by Membrane filtration technique. Water testing result showed high proportion of water samples (source, reservoir and taps) to be contaminated. Out of 11 sampled source, 6 (55 %) were found to be contaminated with total coliform, while rest 5 (45 %) are free from coliform. Similarly, out of 5 reservoirs, 100% were found to be contaminated with coliform.

Out of 68 tap water samples, 62 (91 %) were contaminated with total coliform rest were free from coliform. Table 9 gives the ranges of total coliform were found during entire study. Water testing result showed out of 84 water samples, 72 (86 %) were found to be contaminated with total coliform, which exceeds the NDWQG standards (0 cfu / 100 ml) and all tested samples were free from *E.coli* in source, reservoir and taps.

All the water samples were free from *E.coli*, which indicates that the water sample was within the NDWQG permissible level (0 cfu / 100 ml).

Table 9: Range of Total coliform and *Ecoli* (cfu/100ml)

Sample	Range (cfu/ml)
Total Coliform	
Source	0-332
Reservoir	105-215
Tap	7- 1365
E.Coli	
Source	Nil
Reservoir	Nil
Tap	Nil



(a)

(b)

Figure 5: Culture of bacteria (a) present of coliform (b) absent of coliform

Figure 6: shows the comparative percentage of contaminated samples taken from source, reservoir and taps. Figure 4 shows the percentage of total coliform contamination for all 84 samples, the contaminated samples are also categorized according to the risk grade.

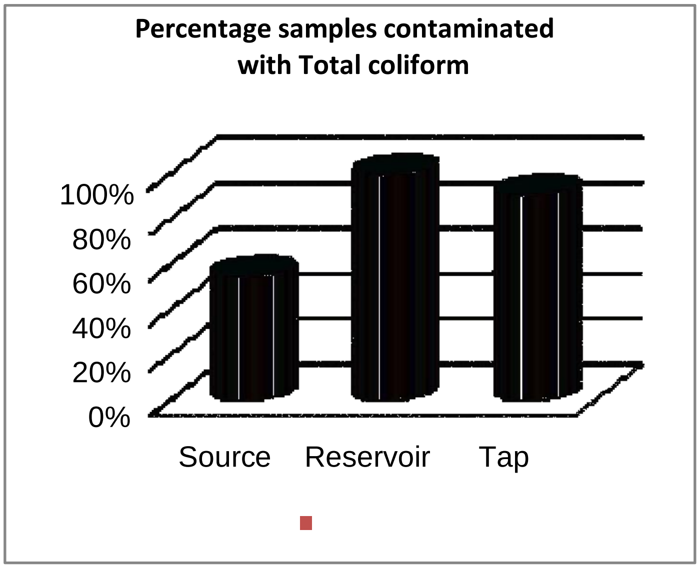


Figure 6: Percentage of Total coliform for source, reservoirs and tap samples.

Table 10: Total coliform risk for source, reservoir and tap water samples

Total coliform	Risk Grade	Source(n=11)	Reservoir(n=5)	Tap(n=68)
cfu/100mL			(%)	
0	A (No risk)	55	0	9
1-10	B (Low risk)	36	60	3
11-100	C (High risk)	9	20	17
101->1000	D(Very high risk)	0	20	71

Table 10 showed the risk grades for source, reservoir and tap samples individually. The aforementioned data describes there was high risk in reservoir and taps. This may be due to contamination of water in supply system and collection system.

CHAPTER-V

DISCUSSION AND CONCLUSION

5.1 Discussion

Based on available data and testing, most source of water is of good quality, and contamination posing immediate risks to healthy people is rare. However, blanket reassurances from the drinking water supply committee that water is totally safe and pure are false. The testing was performed to find out the quality of the water supplied in Arthunge VDC using different samples such as source, reservoir and tap water. Study has been carried out on 84 samples from 9 wards of VDC.

The survey result indicate that: Physio-chemical analysis should not be necessary in future unless contamination is suspected. The samples which had a pH outside the advised range may has effect on the water system in such a way that pH less than 7.0 may cause corrosion and a pH more than 8.0 can make disinfection with chlorination less effective.

Table 5, 6, 7 and Table 8 summarizes the result of physical and chemical analysis performed on water samples indicates clearly that water does not have any significant effect on physico-chemical characteristics of water except pH, because all parameters remains nearly constant over the experimental period. After testing the physico-chemical parameters of water were satisfactory. Most of the parameters checked were found in safe limit except pH and Arsenic. The water samples 54 % have found Arsenic concentration exceeded the permissible level given by WHO (0.01 mg/L), but according to NDWQS standards all water samples were near constant with permissible level (0.05 mg/L). The statistical analysis through paired t-test revealed that physic-chemical parameters of drinking water for Tap water samples in winter (January, 2010) and summer (June, 2010) was not differ significantly at 5% level of significance.

Microbial analysis performed on water sample is not safe for bacteriological quality. There are number of coliform present in most of samples but there was absence of E-coli. While most of the tested waters were found to be higher number of coliform bacteria especially in tap water which is not to say pure for safe to drink. .The exceedences were not great in source and reservoirs were unlikely to represent a public health concern. But in tap water it was found that about 71% (Table 10) of water samples found very high risk due to present of coliform bacteria. All of samples water tested complied fully with NDWQS, 2062 microbiological parameters. The presence of coliform bacteria in the tap water may be due to contamination in pipelining system, back siphoning, and discontinuity in water supply pattern. Also carelessness may be the reasons for contaminated with coliform. If quality of water is not improved it may serious health hazard for consumers that exceed the maximum permissible value of levels of coliform organisms. The amendments to the NDWQG mean that these results are not a significant Public Health Concern.

Comparing the data for drinking water quality with those for source reservoir and tap water is not straightforward. Thus, direct comparison of tap water quality versus source water quality is not possible based on comparable databases. During the sample collection, some observations are also made. The water supplied by local committee has been treated or disinfected by chlorination; the provision for use of disinfectants was present in the entire reservoir except in the individual's reservoir. There are lots of individual reservoir, water from such reservoir also mixed with water supplied by local committee without treating. This may increase the risk of transmitting water of unacceptable quality to the public.

(a) **(b)**

Figure 7: Water collection on reservoir (a) individual source (b) local committee source

5.2 Conclusion and Recommendations

Many people use of tap water as their primary source of drinking water. Some of these people are compromised and use treated water at the recommendation of public health officials or health care providers, who suggest that direct use of tap water, may be too risky. In some cases, officials also may urge the general public to use bottled water during a tap water contamination crisis.

The findings of this study shows coliform contamination to be the major problem with drinking water. Microbiological quality is also not so bad, source and reservoir water quality shows there is no high risk of coliform, proper management and use of treatment system (i.e. chlorination) can minimize such risk in near future.

For the reasons just noted, it would generally be better to upgrade and improve tap water quality than to have a part of society shift to bottled water. Those who dislike the taste and smell of their tap water may want to consider placing tap water in a glass or ceramic pitcher, with the top loose to allow the chlorine to dissipate overnight. Change the habit can make the people healthy.

Based on the available data, findings of study and existing condition of source, reservation, collection and supply system, following recommendation are made:

- ✓ Physico-chemical and Microbiological analysis of drinking water should be performed on regular basis.
- ✓ Regular monitoring of drinking water reservation and supply schemes must be performed and necessary maintenance should be undertaken for quality control.
- ✓ Prior to water distribution, chlorination is to be performed regularly to maintain the recommended level of residual chlorine for drinking water.

- ✓ Regular and necessary maintenance of water supply system for quality control should be implemented to ensure public health safety.
- ✓ Public awareness programs should be effectively conducted for improving sanitation condition of rural parts of Nepal
- ✓ Ministry of Health and population should develop strategy for implementation of NDWQS-2062 through periodic surveillance of water quality in all municipalities as well as VDCs.
- ✓ Analysis of toxic heavy metals should be done sufficiently to support a human health risk assessment for these compounds.
- ✓ Further detailed study is recommended to know the status of arsenic in drinking water at rural parts of Nepal.

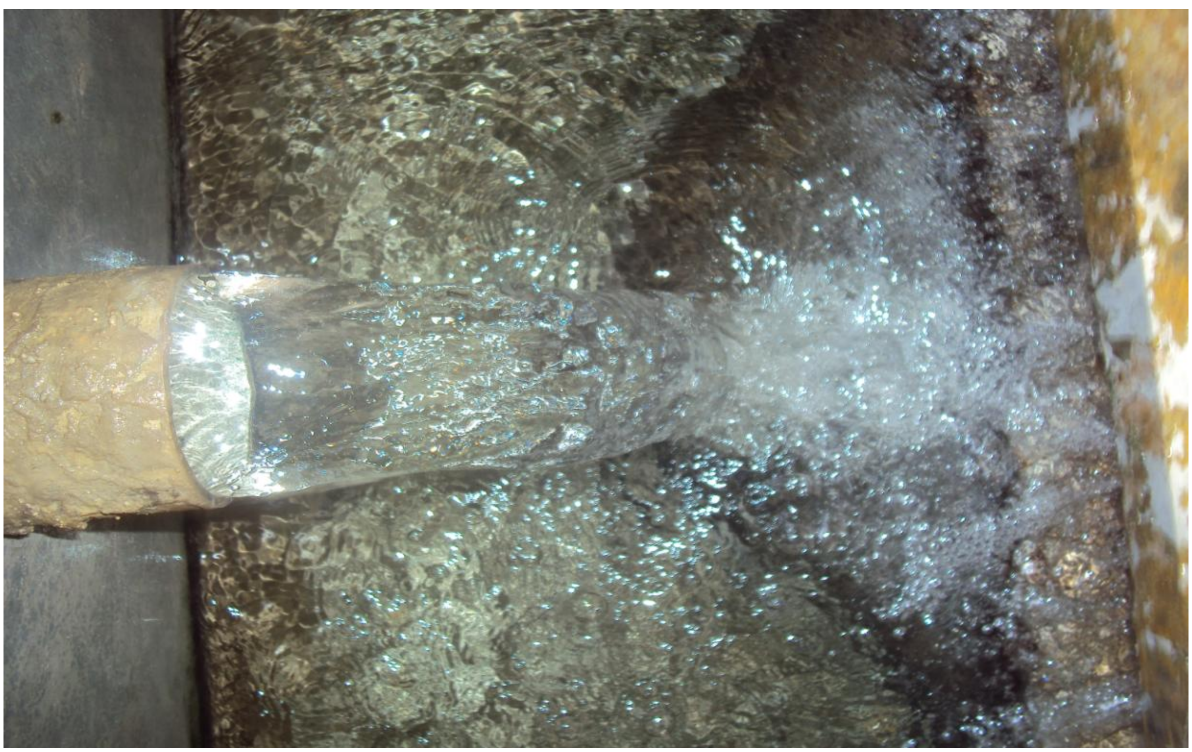


Figure 8: Collection reservoir at Arthunge-1

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