DRINKING WATER SUPPLY SYSTEM IN KATHMANDU VALLEY

Pratima Tamrakar
pratima.tamrakar@sac.tu.edu.np
Sanothimi Campus, Bhaktapur

Abstract
This study designed to analyze physical, chemical and microbiological parameters of drinking water quality and its management by the city water supply system in the Kathmandu Valley. The study covers 18 core areas including 32 samples sites. Altogether 325 samples collected from intake, reservoirs, treatment plants and deep wells to their connectivity as well as alternative sources such as shallow wells, tube wells, processed water and stone spouts of Sundarijal water supply system. Primary information collected through In-depth interview with 155 households (hhs), 15 focus group discussions, interview with 20 water suppliers (government and private sector) and 30 school teachers and students of linking with water supply system within the study areas. The study analyzed 7 physical, 16 chemical and 2 microbiological parameters (Total coliform (TC) and Fecal coliform (FC) following the standard methods (APHA 2000). The findings have elaborated the water quality in the source is acceptable and it is deteriorate the quality linking with its supply chains and connectivity, which is severely affected by the scaled, rusted, leakage, old pipelines and intermittence of water supply. Most of the sampling sites were microbiologically, contaminated (TC 6->180MPN/100mL and FC 1-7MPN/100mL). The processed water contains lower level of essential minerals because of reverse osmosis treatments. The fluoride (0.8-2mg/L), manganese (0.1-0.5mg/L), ammonia (52-70mg/L), iron 5mg/L, color (20-25^{o}Hazen), pH (6) and turbidity (32-40 NTU) in deep wells, its supplies, well, tube wells were found beyond the value of tolerance level recommended by NDWQS and WHO guidelines. About 98%hhs used traditional methods for water management; indicates poor handling practices. Hence water quality management is a big challenge in Kathmandu Valley in terms of adequate safe water and requires regular surveillances and monitoring system for improvement.

Key words: *Water Quality Management, Kathmandu Valley, Microbiological Parameters, Big Challenge.*

INTRODUCTION

Every human beings need safe drinking water and needs at least two liters of pure and safe drinking water for healthy survival as per WHO standard ((WHO, Guidelines for Drinking Water Quality.3rd Edition vol.1,, 2016). Constitution of Nepal, 2015 explicitly mentioned in subsection 4 under section 35 that every citizen has right to access safe drinking water and sanitation. Safe drinking water supply to each and every household is accountable to the Government, hence SDG has elaborated specific goal no. 6 for the clean water and sanitation. Safe water is already a limiting resource in many part of the world (Bindu & Selvemohan, 2009) and becoming even more limiting due to increased population, urbanization, industrialization and climate change. Deterioration of drinking water quality arises from introduction of physical, chemical and biological compounds into water supply system through leaks and cross connections. World Health Organization (WHO) estimated, 80% of all sickness, diseases in the World is caused by inadequate sanitation, polluted water or unavailability of water (WHO, 1997). Water carries many diseases such as diarrhea, dysentery, typhoid, cholera, hepatitis, jaundice, respiratory illness, Poliomyelitis and gastroenteritis etc (Casey, 2009).Water borne diseases result human morbidity and mortality. The major problem of drinking water in Kathmandu valley are inadequate supply against huge demand and poor maintenance and repair of water resource to supply pipelines (Bhattarai, 2010) Water quality in stay to address high demand and there is no monitoring mechanism to penalize the low quality of water supply, which has directly impacted to the consumer's health (Sharestha, Joshi, & Pune, 2010). Under developed country like Nepal has severe problem in access of safe drinking water and adequate sanitation services (WHO, 2012). However the Government of Nepal has set target to cover 90% of the population with the regular supply of safe drinking water, 99% basic water supply coverage, 90% population use safe drinking water Turbidity 5%NTU by 2030 AD under the SDG-6 (SDG, 2016)).

Study Area

Kathmandu valley is situated in the elevation of 1,300–1,400 m asl with warm climate. It has population of 1.44 million consist of hh in 2020 and rapid increasing day by day i.e.1.55 million hh in 2023. (9). Kathmandu Upatyaka Khanepani Limited (KUKL) is the only one government owned supplier in Kathmandu valley. Its production is 154mld in wet season and 102mld in dry season and demand is 472mld. KUKL is now expecting a change in this situation with availability of the additional 170 MLD water from Melamchi since December 2022. (KUKL, 2022). Hence water users opted for other alternate sources of water supply and compromise on available standard. Community water supply system and private vendors fulfill the alternate water demand of consumers but their priority is to address quantity of water not quality. There is no government institution to monitor social responsibility on water quality.

Thus the study was focused on KUKL water quality management system and community, private sector water supply system. The study is designed to analyze physical, chemical, microbiological quality of the drinking water sources and suppliers from source to end users. The research areas were from source of Sundarijal to Mahankalchor, Kapan, Chabahil, Gaurighat, Mitrapark, Sinamangal, Anamnagar, New Road, Kamalachi, Bhotahiti, Sankhapark, Sukedhara, Dhumbarahi, Boudha, Gaushala, Baneshwor and Ghattekulo drinking water supply points. Altogether 32 sample stations were selected from research areas in a ratio of 1 sample per 5000 populations. Total of 320 samples were collected from Sundarijal intake, reservoirs, treatment plants, deep wells, supplied tap stand of house connections, processed waters, stone spouts, community shallow well, and private tube wells during summer seasons only because of low discharges and unavailability to reach at water sources in winter seasons. The study also covered the knowledge and skill of water suppliers and water users on water quality management. The study also analyzed the school curriculum on water quality and pollution as well as knowledge and skill of teacher and students.

METHODOLOGY

The study adopted different methods such as review of literatures, selection of research areas, sampling stations, water quality parameters, water sampling, laboratory analysis, compared with referral cases etc.

Two samples were collected from each sampling sites for physic-chemical analysis and bacteriological detection. Water samples were collected in 1L polyethylene (pet) bottles for physical and chemical analysis. The temperature, appearance, taste and odor, pH and total chlorine were detected immediately in sampling sites. For bacteriological analysis, sterilized pet bottles of 0.5L capacity were used and addition of 2 drops $Na_2S_2O_3$ for preservation of bacteria at every sample. Total coliform and fecal coliform were examined in laboratory by using standard method of most probability of number (MPN). Rest of 18 parameters were analyzed in laboratory by following procedures of standard methods of Apha. Awwa. Wpcf, 20th edition (2000) within 12 hours of sample collection (Table 1).

Table 1 : Parameters tested and methods of analysis

For water distribution system sampling, only unrusted direct service pipeline water supply taps were selected. The sample did not cover leakage in between spindle and gland as well as the pipe linked with storage tank or reservoir and upper tanks. Also, water was collected from taps after fully opened for 5 minutes to get truly representative samples of source and distribution system. Same procedure was followed to collect ground water sample from deep wells (<30meter depth), shallow well (3 to 11meter depth) and tube wells (1 to 30meter depth), the pipelines of deep wells, shallow well and tube wells were discharged the water flow fully for 15 minutes to sample true representative of source and avoid the outside contaminations.

Almost 155 selected households within research areas for in-depth interview and 15 focus group discussion with water managers, consumers were conducted to get information about their

Physical Parameters	**Methods of Analysis**
Temperature	Thermometer (Line Seiki TC-1100)
Color	Disc comparator (Lovibond Nesslersis 2250)
Turbidity	Nephelometer (Elico, CL 52 India)
Taste and odor	Testing and Smell
pH	105 pH probe meter
Electrical conductivity	Conductometer (CL157,ELICO)
Chemical Parameters	
Total Ammonia, Iron, Manganese	Calorimetric
Chloride, Akalinity, Total Hardness, Calcium hardness, Magnesium, Calcium, Magnesium,	Titrimetric
Total chlorine, Aluminum	Kit Method (HACH, USA)
Fluoride	SPADNS Spectrophotometric
Sodium, Potassium	Flame Emission Photometric
Microbiological Parameters	
Total coliform, Fecal coliform	Multiple-tube fermentation technique

knowledge on water quality and practices of safe water handling along with purification methods. Similarly, 20 water suppliers (government, community and private) were interviewed and 30 schools (community and private) were conducted reviewed course curriculum and interviewed teachers (20 Science and 20 Environment, Population and Health teachers) and students (30*20) of same schools. Observation was made on the water quality management in the school and practical use of drinking water by the students and teachers. Enough time was spent to observe the water quality management practices in households and schools.

RESULT AND DISCUSSION

Water Quality Analysis

The statistical data of chemical water quality is presented in table 2.

The study revealed the value of alkalinity from 4-220mg/L and mean value identified in the phases as 79.88mg/L (Table 2). The value was within the standard limit of NDWQS and WHO

Variables	**Units**	**Average Value Of All Sampling Stations In two Phases**						**WHO**	**NDWQS**
		Mean	**Med**	**Min**	**Max**	**STD**	**CV**		
Alkalinity	Mg/L	79.88	33	4	220	78.01	97.73		
Total hardness	Mg/L	78.57	40	4	300	84.97	108.10	500	500
Calcium hardness	Mg/L	53.66	24.25	2	224	62.51	166.45	75	200
Magnesium hardness	Mg/L	24.87	14.75	2	80	24.40	97.75	50	
Calcium ion	Mg/L	21.48	9.70	0.80	96	25.01	116.36	75	200
Magnesium ion	Mg/L	6.03	3.57	0.48	22.8	5.92	97.96	50	
Iron	Mg/L	0.92	0.15	0.01	5	1.31	144.48	0.3	0.3(3)
Manganese	Mg/L	0.08	0.015	0.00	0.5	0.12	146.08	0.1	0.2
Total ammonia	Mg/L	9	0.19	0.02	65	16.34	181.8	1.5	1.5
Sodium	Mg/L	12.95	2	1	61	17.87	138.17	200	
Potassium	Mg/L	4.6	0.25	0.00	40	8.9	194	12	
Fluoride	Mg/L	0.2	0.00	0.00	2	0.57	282.77	1.5*	0.5(1.5)*
Arsenic	Mg/L	0.00	0.00	0.00	0.01	0.0	219.6	0.05	0.01
Aluminum	Mg/L	0.13	0.00	0.00	1.00	0.26	189.24	0.2	0.2
Total Chloride	Mg/L	19.27	7.68	1.90	130	29.59	152.38	250	250
Total Chlorine	Mg/L	0.08	0.00	0.00	1.20	0.16	247.70	0.2	0.2

NOTE: WHO-Limitation values of drinking water quality parameters set by World Health Organization health based guidelines. *- Maximum limit for water quality parameters.
NDWQS- Nepal Drinking Water Quality Standard set by government of Nepal in 2005

recommendations. In this research Sinamangal deep well and Ramhiti deep well and their supplies to house connections had maximum alkalinity value of 206-220mg/L respectively which is lower compared with Pant, 2010 found the value of alkalinity 258-366mg/L in shallow well, tube well and deep tube well of Kathmandu valley. The presence of carbonates, bicarbonate and hydroxide in the water contributed to increase the alkalinity of water (Clifford, 2014) found 450mg/L concentration of alkalinity in drinking water of Aligarh city of India, 120-720 mg/L in the ground water of Narwana city of India by Deshwal, et al., 2016 which are higher than present research.

Table 2: Summary of Statistical Data Of Chemical Parameters

The total hardness, calcium hardness, magnesium hardness were found higher concentration in deep tube wells, shallow tube wells, wells and stone spouts. However the mean values of hardness were maintained the recommended limit of WHO guidelines. But the maximum hardness 300mg/L (total hardness), 240mg/L (calcium), 60mg/L (magnesium) were found in Kapan tube well which crossed the threshold limit of WHO and NDWQS health based guidelines due to presence of higher concentration of organic and inorganic salts in water which is the runoff infiltration, percolation of pesticides used in agricultural land and industrial effluent (Ainsworth,

1990) (Aid, Drinking water quality in rural India: Issues and approaches. , 2016) (Aremu, 2011). Recommendation made for maximum and minimum levels (75-200mg/L) of calcium hardness in drinking water by BIS, 2012 was maintained by Sundarijal surface water supply system. Similarly, the average value of iron and manganese of all sites were detected as 0.92mg/L and 0.08mg/L respectively which could be adjusted within the recommended value of WHO and NDWQS guidelines. Although the most of deep wells, tube wells had higher concentration of iron and manganese. But the maximum value of iron (5mg/L) and manganese (0.5mg/L) were found in Sinamangal deep well and shallow well of Kapan Faika because of higher concentration of reduced iron in deep aquifers (Pant, 2010). And the values were above the threshold level of health based recommendation of WHO and NDWQS guidance. However most of the deep well, shallow wells and tube wells were observed to be rusted pipe fittings and red brown precipitation of ferrous oxide. Ingestion of iron in amount (>0.5g) causes saver toxicity in human physiology system leading to liver, heart and lungs ((Gurzau, Neagu, & Guauz, 2003). The study found maximum concentration of ammonia 40-65mg/L got in Ramhiti deep well and its supplies had crossed the limit (1.5mg/L) of WHO and NDWQS. Ammonia can be present in high levels in wells because of underlying geochemistry (peat and lignite) (APHA, 2000). However higher concentration of ammonia occurred in water is the indication of recent pollution by sewage, fertilization, and agricultural or industrial effluent containing nitrogen, free ammonia or ammonium salts infiltrations, percolation from surface to ground valley (Aid, Drinking water quality in rural India: Issues and approaches, 2016). The mean value of ammonia of all the sampling sites was found 9mg/L, minimum 0.02mg/L and maximum 65mg/L. Sodium is essential element for human body but its large concentration may lead cardiac difficulties and proper quantity (20mg/L advisory limit for sodium in drinking water in reference to U.S. Environmental Protection Agency (APHA, 2000), 200mg/L recommended by WHO health based guidelines) prevents many fatal diseases like kidney damages, hypertension, headache etc. The present study revealed maximum content of sodium in Sinamangal well water (65mg/L) and minimum in Sundarijal source and its supply system. The average concentration of sodium in all sites was 12.95mg/L which is below the recommended standard limit of WHO and US Environmental Protection. Similar studies made by Meriede et al, 2016, 28.54 to 34.19mg/L sodium concentration in drinking water of Wondo Genete Campus, Ethiopia and Deswal, et al., 2016 18.1 to 395.7mg/L quantity of sodium in drinking water of Narwana City, India

The total potassium amount in human body lies between 110 and 140gm. It is a vital for human. And functions like heart protection, regulation of blood pressure, protein, dissolution, muscle contraction, nerve stimulus etc. Potassium deficiency is rare but may lead to depression, muscle weakness and heart rhythm disorder etc. In reference to WHO Standard the potassium concentration in the water is limited to 12mg/L. The mean value of potassium in all the station was 4.6mg/L which was below compared with the value 23.7mg/L, 24.2mg/L potassium found by Edimeh et al, 2011 and Aremu et.al.,2011 respectively.

The fluoride was found excessive 0.8 -2mg/L in deep wells of Sinamangal and Ramhiti and their supplies to house connections and average value 0.20mg/L of all sites was tolerable concentration compared with the WHO and NDWQS guidelines. Fluoride (F) is essential to reduce dental decay, but excess fluoride in drinking water could cause fluorosis which is found many part of Terai belt of Nepal. Deshwal, et.al., 2016 reported range of fluoride quantity 5.5mg/L in the ground water of Narwana City, India which much higher than current study. Pant, 2010 investigated Fluoride (F) 0.43 mg/L, 0.27 mg/L, 0.74 mg/L in shallow well, tube well and deep well respectively in Kathmandu which is similar to the study.

The arsenic and chloride content in all stations were not violated and within the standard limit of WHO and NDWQS. Similar values 3.7mg/L of Chlorides were reported by Meride et.al., 2016. And higher concentration of chloride 580mg/L was found in ground water of Narwana city by Deshwal and found 665mg/L in Aligarh city, India by Ahmad et.al, 2014 which are much higher than current study.

The content of chlorine 0 - 1.2mg/L and aluminum 0-1mg/L were found in treatment plants and their supplies to house connections. That was the residual element of bleaching powder and alum used in the treatment plant. The maximum chlorine and aluminum were detected in clear water of Mahankalchor Treatment Plant which was higher than the standard limit (0.2mg/L) of NDWQS and WHO guidelines. For effective distribution WHO remarks, residual chlorine should be ≥5mg/L after supply at least 30minutes contact at <8.0 (Hanson A. J., 2014).

Physical Parameters

As table 3 depicted, the water was detected as temperature pH, electrical conductivity, turbidity and color, appearance, taste and odor as physical parameters. The average temperature was 22.7^0C in all sampling sites whereas recommended ranges of temperature are 15-25^0C by European Economic Community and Canadian drinking water guidelines (National water quality management, 1996) and also WHO standard limit is 30^0C for portable drinking water. Thus the temperature of present study was palatable and normal to use for drinking water. Almost similar temperature 28-29^0C and 28^0C were reported by Meride et al., 2016 and Ezeribe et al., 2012 respectively.

Table 2: Summary Of Statistical Data Of Physical Parameters

Variables	Unit	Average Statistical Data Of All Sampling Sites						WHO	NDWQS
		Mean	Med	Min	Max	STD	CV		
Temperature	^{0}C	22.7	22.5	18	26	1.8	7.77	30	
pH		6.82	7.0	6.0	7.6	0.8	11.92	6.5 - 8.5*	
EC	µS/cm	220.87	103.45	12	860	227.14	102.75		1500
Turbidity	NTU	9.9	4.5	1	50	12.48	125.26	5(10*)	5
Color	^{o}Hazen	5.51	2	1	25	6.47	116.97	5(15*)	15

NOTE: WHO-Limitation values of drinking water quality parameters set by World Health Organization health based guidelines. *- Maximum limit for water quality parameters.
NDWQS- Nepal Drinking Water Quality Standard set by government of Nepal in 2005

Though the pH values were less than the threshold level of WHO and NDWQS guidelines in Shankha park deep well along with it supplies to Sukedhara, private well, tube well and stone spouts. The mean value of pH in all sampling sites had met the limit (6.5 - 8.5*) pH set by WHO and NDWQS guidelines. Similar maximum pH level 8.02 was found by Aducable (2021) in drinking water of Adis Kidame Town of northeast Ethiopia.

Electrical Conductivity (EC) is the ability of water to conduct an electrical current and the dissolved ions are the conductors. The major positive charged ions are sodium (Na+), calcium (Ca+2), potassium (K+), magnesium (Mg+2) etc. The dissolved and negative charged ions are chloride (Cl-), sulphate (SO4-), Carbonate (CO3-), bicarbonate (HCO3-), Nitrates (NO3-), phosphate (PO4-), etc (Shakya, 2000). These are source of turbidity and also responsible to bring high EC level (150-860 µS/cm) in shallow well, tube wells, deep well and stone spouts in the present study. The mean value of EC was revealed 220.87µS/cm which is lesser than Nepalese standard (1500 µS/cm) for conductivity. And the EC standard for surface water used for potable abstraction is 400µS/cm which is also maintained by average value of present study (APHA, 2000).

The study analyzed the average value of turbidity 9.9NTU in all the stations which is slightly higher than the lower limit of NDWQS and threshold (5NTU) of WHO guidelines. The color of deep wells, tube wells and well were investigated higher value up to 25ºHazen and clear to hazy state and rest of the sampling stations were normal color. The sample water of Sundarijal source, treatment plants, their house connections, processed water and stone spouts were appeared clear and had no odor found.

Table 3: Summary of statistical data of microbiological parameters

Variables	Unit	Average value of all stations of two phases						WHO	NDWQS
		Mean	Med	Min	Max	STD	CV		
Total coliform	MPN/100ml	37.59	5.5	5	>180	66.85	177.8	0	0
Fecal Coliform	MPN/100ml	1	0	0	7	1.65	292.95	0	0

NOTE: WHO-Limitation values of drinking water quality parameters set by World Health Organization health based guidelines. NDWQS- Nepal Drinking Water Quality Standard set by government of Nepal in 2005

According to bacteriological classification of WHO guidelines (Table 5) 30% sampling station of clear water of Treatment plants, Anamnagar, Kamalachi house connections and raw water of deep wells were found to be safe. And 18.5% sites had intermediate risk, 8.5% sites had high risk (>100coliform/100ml). The maximum fecal coliform was recorded 7MPN/100mL in Sukedhara stone spout and deep well supplies to Sukedhara. This is due to intermingled of waste pipe into distributing channel of pipeline system and also very old, breakage, leakage and scaled pipelines. Similar studies conducted by Baye et.al 2020, and reported 94.16% coliform, 82.5% fecal coliform in the drinking water of public tap of Wageda town, Ethupia.

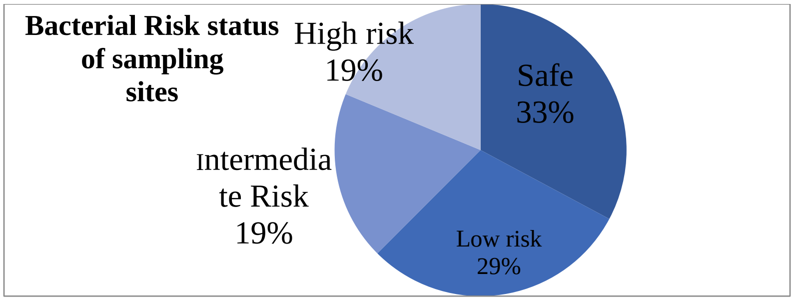

Figure 1: Bacterial Classification of Sampling Stations as per WHO standard.

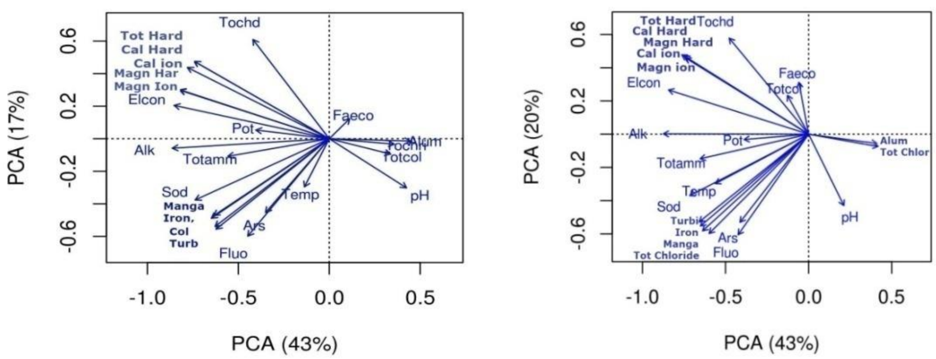

Figure 2: Principal component analysis of water quality variables during 2019, 2020

The figure 2 of principle components analysis determined variation of all measured water quality variables 43% by first axis and 17% by second axis in first phase and 45% in first phase, 20% by second axis in second phase. Fecal coliform was strongly significant ($p \leq 0.05$) and negatively correlated with alkalinity, ammonia, sodium, iron, manganese, turbidity, color, fluoride, arsenic and temperature. Hence chloride, total hardness, calcium, magnesium, conductivity, potassium were significant and positively correlated with each other. And above variable shows strong negative correlation with pH, aluminum, chlorine. Likewise, temperature, arsenic, fluoride, turbidity, color, manganese, sodium and ammonia showed significant positive correlation among each other.

Water Quality Management

The study revealed that the limited water supply in study area, hence, 94% hhs adopted alternative water sources. About 49% consumers dissatisfied with water supply and received unhygienic and high turbid water. Though 52% consumers didn't know about the water quality and relied upon suppliers for their water quality. Even though there was existence of water borne diseases, 59% respondents were not aware about water borne diseases. The study identified that 25.% suffered from gastroenteritis , 23% dysentery, 22% Direahorea, 11% Eye infection, 8% typhoid, 6% skin infection, 3% Jaundice and 2% cholera. Most of the respondent were using traditional practice of purification of water such as ceramic candle filter (43.1%), boiling,(28.9%) Piyush, sodium hypochlorite (Chlorine tablet) (7.19%), biofilter treatment plant (0.65%), bleaching powder and normal wiping to clean the water storage, disinfection, home purifier with reversed osmosis and UV light (17%). All private and community water suppliers have limited knowledge on water quality and its management. However there was no information on water quality management in school curriculum but 28% private schools had organized the extracurricular activities on water quality and pollution to the students. The water quality could be improved through regular monitoring of drinking water at source, water distribution system, and installment of new pipelines and enhancing public awareness about water quality management and purification techniques at household level.

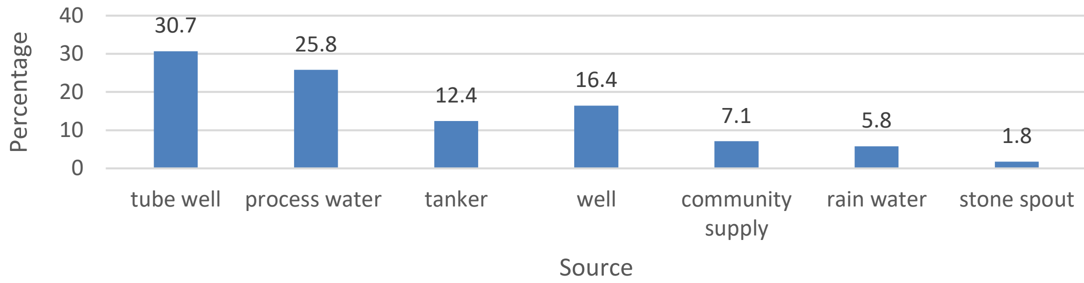

Figure 3 Alternate coping strategy of community

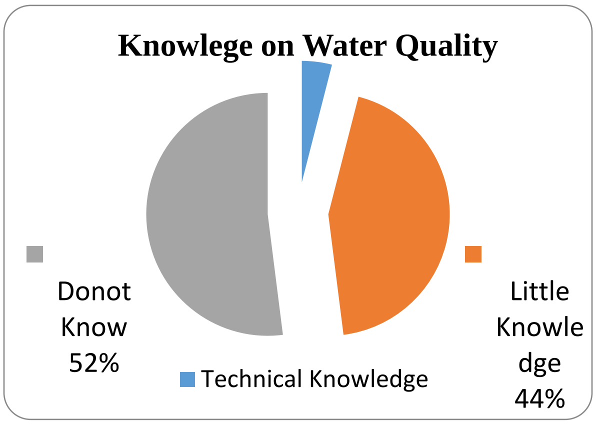

Figure 4 Knowledge on water quality

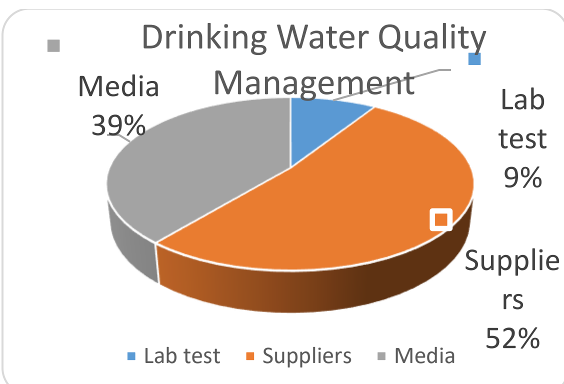

Figure5 Drinking water quality management

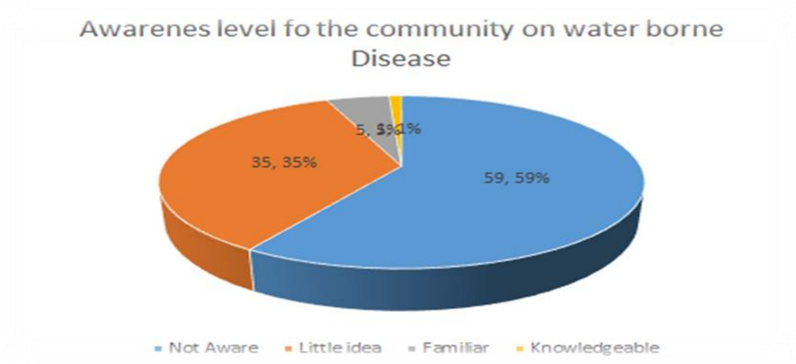

Figure 6: Awareness level of the community on water borne diseases

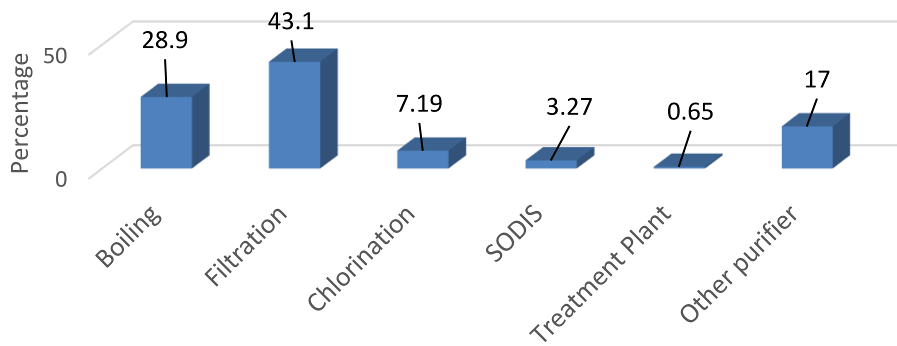

Figure 7: Water purification technique adopted by community

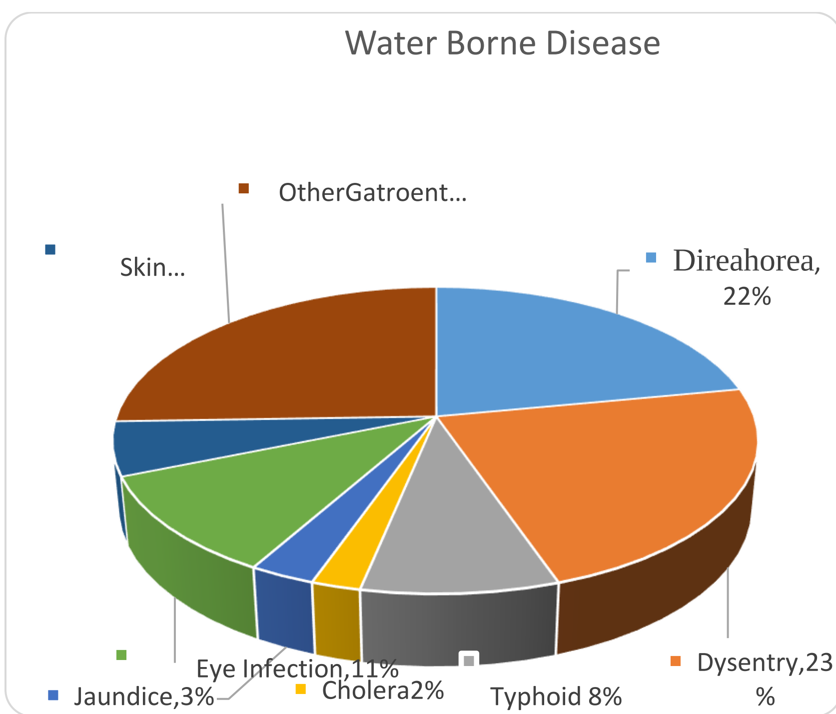

Figure 8: Community suffered with water borne diseases

CONCLUSION

The water quality of surface water source Sundarijal intake and treatment plants was found better than the water quality at end users in household connectivity. There is only one government water supplier and it has acceptable quality in physical and chemical but contaminated by microbiologically in connectivity pipe lines. The water quality of alternative water sources deep wells, shallow wells, tube-wells, and stone spouts were contaminated in physical, chemical and microbiological parameters. The processed water had lack of essential minerals and found coliform 5->180 MPN/100mL. The community, private suppliers and consumers had limited knowledge in water quality and its management. Around 49% people were getting unhygienic water and existence of water borne diseases but 59% people did not know about the water borne diseases. However 43.1% households used the ceramic candle filter and other were still practicing traditional methods of water purification and water treatment techniques due to limited of knowledge of water quality and its management.

There was no course and curriculum on water quality management and pollution in school level education.

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