Potential of Promoting Rainwater as a Source of Safe Water for Consumption in North Central Province of Sri Lanka

G.V. Norica Aiome
Sangeeth Prasad Fernando
P.C.J. De Silva
S.M. A. Samarakoon
H.M.J.K. Herath

Research Report No.: 228 December 2019

Hector Kobbekaduwa Agrarian Research and Training Institute
114, Wijerama Mawatha
Colombo 7
Sri Lanka

First Published: December 2019

Final typesetting and lay-out by: Dilanthi Hewavitharana

ISBN: 978-955-612-256-5

FOREWORD

In North Central Province, have many water quality problems. They are the existing water sources does not have enough water throughout the year, groundwater contamination problems in the area and the kidney disease of unknown etiology.

The past, present and future predictions on rainfall indicate that there is a drastic reduction in rainfall during *Maha* and *Yala* seasons and therefore additional irrigation water must be developed in NCP for drinking purposes. Reductions in rainfall will pose severe threats to safe and clean water for drinking purposes; therefore, to collect rainwater during the rainy season is very important, in NCP with special reference to climate change impacts.

The study surveyed the different health and socio-economic consequences of present water consumption. Such as analysing the quality of the water in the present sources of water consumption, finding the people's opinion on the drinking of rainwater and to find out how the people can be guided and made aware of the rainwater harvesting as a mean of safe water for consumption.

This study reviewed the overall situation of RWT in the study area, identified the constraints, and proposes the remedial measures.

According to the findings, the physical, chemical and biological quality of rainwater, meet the prescribed standards. Harvested rainwater water quality was found to be better than the samples tested from surface water sources, shallow wells and deep wells. In addition, rainwater can use as a reliable water source than the water buying from water sellers.

People who had rainwater tanks can use it for all the purposes during rainy seasons as well as in the dry seasons. There are no health issues recorded on the drinking of rainwater when comparing the health issues between uses and non-rainwater uses. When having a rainwater system, they can achieve many advantages. Rainwater harvesting is a feasible strategy to mitigate the increasing water crisis. In Sri Lanka, it seems that rainwater is the best source of safe water consumption due to reasons such as Good quality and availability. Therefore it requires correct guidance and provisions of the awareness required for the rainwater harvesting as a mean of safe water for consumption in NCP of Sri Lanka.

I congratulate the research team for successfully undertaking this research project, hope the findings and recommendations in the study will be useful, and provided scientifically reliable evidence for policymakers, the international community, academia, and civil society.

W.H. Duminda Priyadarshana
Director/CEO (Acting)

ACKNOWLEDGMENT

First, we pay gratitude to the Director of HARTI Mr. W.H Duminda Priyadarshana, for his constant support in publishing the report. We extend our gratitude to Mr. K.W.E. Karalliyadda and Mr. Keerthi B. Kotagama former Directors of HARTI who provided the required assistance to make this study success.

The special appreciation goes to Mr. R.L.N. Jayatissa, former Additional Director, HARTI for encouraging us to conduct this study and for the comments to improve the research report, and we would like to convey our gratitude to Dr. W.A.R. Wikramasinghe, Additional Director, of HARTI who provided the required assistance to make this study success.

We thankful to the comments received from the external reviewers on the final draft report by Prof. (Mrs.) C.S. De Silva, Senior Professor in Agriculture and Plantation Engineering, Faculty of Engineering, The Open University of Sri Lanka and Dr. (Ms) Thanuja Ariyananda, Chief Executive Officer, Lanka Rain Water Harvesting Forum.

We would like to thank Mrs. D.R. Pradeepa Dematapitiya, Mrs. W.A.A.S. Wijesinhge, and Mrs. G.K.C. Nilusha Statistical Assistants, HARTI for their dedicated service when collecting and analysing data.

We are also thankful to Mr. H.L.L. Salinda, Management Assistant for coordinating support for the field surveys and typesetting support for the report.

We are also thankful to Ms. S.D.N.M. Senadeera, Ms. R.S.K. Muthumali, Ms. W.V.P.D.T. Wijerathna and Ms. R.M.A.V. Wijesinghe, Casual Investigators of this study for their dedication extended during data collection, data tabulation, and data analysis.

We wish to convey our sincere thanks to Mrs. L.A.K.C. Dahanayaka, Senior Assistant Registrar (programme), HARTI for making administrative facilitation throughout the study and the staff of the programme unit and accounts unit. We are also thanking Mr.H.A. Siriwardana for language editing and Mr. S.A.C.U. Senanayake for proofreading the report. Further, extend our appreciation to the staff of the publication and printing unit of HARTI for making the report published.

The research team highly appreciate the household and members of “Govisamithi” who participated in the questionnaire survey and focus group discussions during the field survey. Further, we extend our appreciation to all the Officers, Agriculture instructors, and Agriculture Research and Production Assistants attached to Agrarian Services Centers in Anuradhapura and Polonnaruwa districts for the excellent support given during the field survey. And the staff of the NWSDB Anuradhapura and Polonnaruwa for their great support on water quality analysis.

G.V. Norica Aiome
Sangeeth Prasad Fernando
P.C.J. De SilvaS.M.A. Samarakoon
H.M.J.K. Herath

EXECUTIVE SUMMARY

This study investigates the potential of promoting rainwater as a source of safe potable water in the North Central Province of Sri Lanka. Study area, mainly agricultural marks high incidences of chronic kidney diseases of unknown etiology (CKDu), alleged to have been caused by unsafe drinking water.

Study location is the North Central Province (NCP) of Sri Lanka, namely Anuradhapura and Polonnaruwa Districts. Madawachchiya and Kabithigollawa were selected from Anuradhapura District, Madirigiriya, and Dimbulagala from the Polonnaruwa District as the sampling Divisional Secretariat (DS) areas. Sample covered all the selected GN divisions in relevant DSs**.** Both primary and secondary sources were used for data collection. Primary data was collected mainly through a structured questionnaire administered on a sample of 300 households. The questionnaire survey focused on general socio-economic status of households, water sources used for domestic purposes, water related issues, and the impact of the drought on livelihood activities**.** The quality of drinking water was tested using 100 water samples**.** Quality parameters, such as important chemical, physical and biological parameters of drinking water from all sources in the entire sampling area including rainwater tanks and water from RO plants and wewa were tested**.**

People who had rainwater tanks used it for all purposes both in the rainy seasons and the dry seasons. There are no health issues recorded about the drinking of rainwater when compared to the health issues between the users and non-rainwater users. A rainwater system, offers many advantages. Rainwater harvesting is a feasible strategy to mitigate the increasing water crisis. The past, present and future predictions on rainfall indicate that there is a drastic reduction in rainfall during the *Maha* and the *Yala* seasons and therefore additional irrigation water must be developed in the NCP. Reductions in rainfall will pose severe threats to safe and clean water for drinking purposes; therefore, to collect rainwater during the rainy season is very important, in the NCP with special reference to climate change impacts.

Drinking rainwater is not preferred by some, mainly due to misunderstanding and misinformation about the quality of the rainwater. In Sri Lanka, rainwater is concided the best source of safe water for consumption due to reasons such as free availability. According to the results, harvested rainwater water quality was found to be better than the samples tested from well water. Rainwater was found to have been not biologically contaminated to the extent of more than 90 percent and 10% biological contaminated, due to the bad maintainers of their tank and mixed rainwater in the tank with surface water, when the tank getting empty. People try to use it as a storage tank. Chemical and physical parameters in rainwater tanks were within the safe range for drinking purposes, under the maximum tolerant level according to the standards (SLS 614:2013) (UDC 663.6).

Water quality parameters of filter water from water sellers, in Kabithigollewa and Madawachchiya DS divisions, observed that nearly 10% of the water samples collected from water sellers were not in the safe range. People of the area, have to spend money to buy water. Due to this problem, there should be a proper procedure to control the water standards for the water sellers by issuing a license system and renewing system, with the help of NWSDB.

The main reason for not using the existing tanks was the operational and maintenance problems, which they have to face. It is observed 70% is operational and maintenance problems. This highlighted the training and awareness requirement for rainwater tank use.

When taking these into account rainwater harvesting is undoubtedly the most rational, cost-effective, socially acceptable and ecologically sustainable method of providing clean drinking water to widely scattered rural households in the CKDu affected dry zone. As reliable water source rainwater, harvesting is the best solution to water shortage in Sri Lanka.

Recommendations are mainly based on the findings in this study. According to the research findings, in Sri Lanka, the past, present and future predictions on rainfall indicate that there will be drastic reductions in rainfall during the *Maha* and the *Yala* seasons and cannot receive the rainfall at the monsoon period. Therefore, additional irrigation water must be developed in the NCP**.** Reductions in rainfall will pose severe threats to safe and clean water for drinking purposes; therefore, to collect rainwater during the rainy season is very important, and recommended as a reliable water source for NCP with special reference to climate change impacts, and include social benefits by having an RWH system.

According to the survey, the physical and chemical quality of rainwater, meet the prescribed standards. Harvested rainwater quality was found to be better than the samples tested from well water. According to the findings, there is a relationship between the source of water drinking and the CKDu. Due to that good quality water help to control the CKDu. Water obtained from rainwater are in good quality and low cost and considered suitable and reliable water source for consumption for CKDu patients.

Main reason for not using rainwater tanks was operational and maintenance problems, Awareness programmes on maintenance and operation of the system should be a mandatory requirement for all rainwater-harvesting programs to ensure collection of good quality water. Further recommended the training requirement for RWT uses.

Schoolchildren should be educated about rainwater harvesting. By including more details about rainwater harvesting methods and rainwater harvesting as a climate change adaptation method for Sri Lanka in to the new school curriculum.

In terms of the National Policy on Rainwater Harvesting in Sri Lanka, we strongly recommended the need for implementing the rainwater policy. This comprehensive policy should be implemented in addition, identified the requirement of a weather indicator, according to the agro-ecological zones.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ADB	Asian Development Bank
ARPA	Agriculture Research and Production Assistant
ASC	Agrarian Services Center
^{0}C	Celsius
Ca^{2+}	Calcium Iron
$CaCO_3$	Calcium Carbonate
Cd	Cadmium
CKDu	Chronic Kidney Disease of Unknown Etiology
CO_2	Carbon Dioxide
CI	Chloride
CWSSP	Community Water Supply and Sanitation Project
DCS	Department of Census and Statistics
DS	Divisional Secretariat
F	Fluoride
GIS	Geographic Information System
GND	Grama Niladhari Division
DSD	Divisional Secretariat Division
E-Coli	Escherichia Coli
HadCM3	Hadley Centre Coupled Model, Version 3 General Circulation Model
HARTI	Hector Kobbekaduwa Agrarian Research and Training Institute
HCO_3	Bicarbonate
HH	Household
K^+	Potassium Iron
LRWHF	Lanka Rainwater Harvesting Forum
MOH	Medical Officer of Health
MRL	Maximum Residues Limits
Na^+	Sodium Iron
NCP	North Central Province
NCPI	National Consumer Price Index
NGOs	Non-Governmental Organization
NO_3	Nitrate Iron
NTU	National Turbidity Unit
NWSDB	National Water Supply and Drainage Board
PE tank	Polyethylene Water Tanks
Ph	The pH is equal to $-\log_{10} c$, where c is the hydrogen ion concentration in moles per litre
RO	Reverse Osmosis Plants
RWH	Rainwater Harvesting
RWT	Rainwater Tank
SLS	Sri Lanka Standard
TDS	Total Desolved Solid
TH	Total Hardness
WHO	World Health Organiza

CHAPTER ONE

Introduction

1.1 Background of the Study

Water, the most essential element for the survival of life is considered the nature's precious gift to living beings. Nevertheless, mainly as a result of the continued disastrous acts by the modern man has degenerated the whole environment, huge damage has occurred to the quality and the availability of the water resource on earth. This exhibits the shortage of consumable water has seriously affected a large segment of the world population.

In Sri Lanka, a significant segment of the population suffers from the absence of good quality water. On one hand, this is due to the natural phenomenon like high mineral content of the groundwater and on the other hand, the contamination with the dangerous and poisonous substances released by human activities mainly including the mal agricultural practices. Many in the dry zones of the country find it difficult to access the water in years which longer dry seasons are experienced.

Chronic Kidney Disease of Unknown etiology (CKDu) which is the most threatening non communicable disease in agricultural districts, particularly in the North Central Province of the country has experienced is also suspected due to the consumption of water contaminated with harmful substances from agrochemicals. Both ground and surface water in the North Central Province of the country and in the other main agricultural districts are reported to be affected with agrochemicals and possessed heavy metals, which are very harmful to health. Sources of groundwater in their large numbers in the CKDu affected areas, as a result, have been condemned for consumption. This situation has embarrassed both the people in these areas and the authorities concerned. While it is impossible to supply as understandable to those entire required quality pipe born drinking water in the short run without a high financial cost in terms of capital and maintenance expenses. It is also a huge liability on the government, and other hand access to safe drinking water is also no way an issue can be delayed without a solution. When concerning the severity and the adverse repercussions that may follow, are taken into account.

As a result, it can be found that various suggestions and strategies are being presented and implemented to provide people with safe drinking water in particular areas including North Central Province. However, rainwater harvesting for drinking purpose which is a long introduced strategy for easy access to safe quality water seems irrespective of its many advantages have not been very much popular and spread broadly in use. This seems to be due to the misconceptions still prevailing over rainwater consumption. This situation has originated from a lack of awareness although the rainwater harvesting has by now emerged as an important theme in the International Sustainable Development Goals as well.

Sri Lanka has used rainwater for both domestic and agricultural use for many centuries. The famous proclamation by King Parakramabahu the Great (1153-1186 AD) could be considered as one of the earliest policy statements, on water resources development and management in Sri Lanka, which highlights rainwater harvesting. “Let not allow, a drop of water falling as rain flow into the sea without being used for the benefit of mankind”. This shows the wisdom and commitment of ancient kings and people to conserve and efficiently manage water resources. Initiated by the government of Sri Lanka in recent years we have seen a revival of attempts on promoting rainwater harvesting systems and research has been done to look for ways and means of improving the technology.

Rainwater is one of the purest sources of water available, as it does not come into contact with many of the pollutants often discharged into local surface water. It comes free and can be used to provide potable (drinkable) water and non-potable water, if collected properly.

However irrespective of the advantages of harvesting rainwater for consumption, all the efforts taken by various segments of the society including the government, NGOs, academics and other experts.

1.2 Research Problem

As mentioned above even though there is a paucity or absence of safe drinking water in certain parts of the country including the study area, the North Central Province, drinking of rainwater has not been adequately adopted or made a viable measure to counter the unsavoury situation despite some efforts taken by the government, NGOs, academics and freelance experts over the years. As a result, this severe issue of the absence of access for safe drinking water in particular areas has continued to persist. Consequently, this study looks into the problem of as to how the harvesting of rainwater can be promoted as a source of safe water for consumption in the North Central Province in Sri Lanka.

1.3 Importance of the Study

Water scarcity is a crucial problem; we have to face in the future. The increasing population and the development activities like rapid urbanization, industrialization and agricultural activities create heavy pressure on the available water resources.

In our study area, North Central Province, the main drinking water source is open dug wells. According to the data reported in the Annual Health Bulletin 2015 Ministry of Health, in this area the water quality for drinking purposes is not up to the accepted standard level. According to the data reported in the Annual Health Bulletin 2015 Ministry of Health, there are lots of factors which affect the quality of water. The geological formation of the area is one of the main affecting factors for the water quality of the study area. This has been attributed much to the health issues faced by the people in the area.

The Annual Health Bulletin 2015, Ministry of Health identifies following as the possible factors for the emergence of the CKDu. Agro-chemicals, hard water (Calcium Chloride, Fluoride), alcohol addiction, average water consumption, salinity level in dry zone water, bio-remediate plant consumption, algae effect (toxic compounds), soil type, source of drinking water (tank, agro well, canal), food habit/food source, beverages, job factors, farming types (tenure, owner), aluminum utensils and mal-nutrition (Jayasinghe, 2011**).**

In the study area, Chronic Kidney Disease (CKDu) is a major health problem. North Central province is the worst affected, and has been categorized as a CKDu endemic area (Wanigasuriya, 2012).

Around 50% of the CKDu patients have died within the first year of diagnosis and more than 90% had died within a period of seven years since diagnosis. Only a few have survived more than five years after diagnosis. The duration that a person survives after being diagnosed of CKDu depends on how early the disease is identified and on how well the treatment is received and quality of life is maintained, as drinking good quality drinking water (Jayasinghe, 2011**).** According to the data reported in the Annual Health Bulletin 2015, Ministry of Health, quality of the drinking water directly affects the long life span of the patients and prevention of the disease**.** Due to these matters, drinking of good quality water is a must. The best solution to several facets of the problem of safe drinking water in the NCP is the harvesting of rainwater (Ariyananda, 2000).

Rainwater harvesting can well safeguard safe water availability at home. Rainwater is one of the purest sources of water available as it does not come into contact with many of the pollutants often discharged into local surface waters. It comes free and can be used to supply potable (drinkable) water and non-potable water. If collected properly, it can be used for all domestic purposes including drinking. Rainwater from well-managed roof catchment sources is generally safe to drink without treatment. Except in heavily urbanized and industrialized areas, atmospheric rainwater is pure.
National Water Supply and Drainage Board (NWSDB) has commenced a programme of supplying treated water from their main treatment plant to surrounding rural areas using bowsers for some time now.

RO (Reverse Osmosis) plants are also being introduced and located in highly affected areas. The NWSDB and some other institutions initiated, a large number of small RO plants since 2013. At present almost 400 RO, systems are in operation. These plants typically treat locally available surface (tank) water and the treated water (RO permeate) is distributed to surrounding area either by trucks, or directly at the production plants. The drinking water problem of these rural communities is the collection and storage of RO plant water.

Presidential task force for control of kidney disease collaborated with the Sri Lanka Navy and constructed RO plants and mobile RO plants for several CKDu affected villages. Currently, there are 400 RO plants have been established in the affected areas sponsored by the government and non-governmental organizations. Due to the lack of technical knowledge to maintain RO plant, many RO plants are not functioning well. (Article by the Sri Lanka Navy captain M.C.P.Dissanayake in the book published by the president secretariat for the presidential task force for control of Kidney Disease in 2017).

All rainwater harvesting tanks have satisfied the WHO recommendation on turbidity for drinking water, overall 40% of the tested rainwater tanks records No *E-coli*, which is the WHO, recommended value for drinking water. In more than 55% of the rainwater tanks the E. coli levels are less than 10 in 100 ml of water, WHO low-risk value (Ariyananda, 2003). Having a simple charcoal and gravel filter and first flush systems reduce the contamination levels in the tanks markedly (Ariyabandu, 1999).

E. coli levels in the tanks receiving rainwater from G. I roof are less than from another roof due to heating of the G. I roof which results in perishing of *E. coli* in the roof (Vasudevan et al., 2001).

Mosquito breeding is reported in some tanks. Experience in Ahaspokuna in Kandy has shown that mosquito breeding could be prevented by raring fish in these tanks. People utilize the RWH system for various purposes, including cooking and drinking. (Kandasamy & Nilmini, 2014).

The best practical and the best solution for the drinking water problem of these rural communities is collection and storage of rainwater. But the majority of the people with no or less access to safe water still have some reservations over using rainwater for consumption. (HARTI survey, data 2018). This is due to misunderstanding and misinformation about the quality of the rainwater. In Sri Lanka, it seems that rainwater is the best source of safe water consumption due to reasons such as availability. Therefore it requires the correct guidance and provisions of the awareness required for the rainwater harvesting as a mean of safe water consumption. It is estimated that a household consisting of 5 persons, would require approximately 20 liters of water per day for drinking and cooking purposes (4 liters/person/day). A 5000-liter capacity plastic storage tank complete with gutter and downpipe will cost around Rs. 65,000 which can provide households with independent access to potable water at an affordable price (25 cents/liter) at their doorstep. When taking these into account rainwater harvesting is undoubtedly the most rational, cost-effective, socially acceptable and ecologically sustainable method of providing clean drinking water to widely scattered rural households in the CKDu affected dry zone in particular.

Rainwater is also listed as an adaptation method in the National Adaptation Plan for the Climate Change Impacts in Sri Lanka report 2016 – 2025. Global warming, driven by the rising of greenhouse gas especially CO_2 in the earth's atmosphere, could cause many changes to ecosystems of the world. One of the most important changes in climate changes and is a long-term shift or alteration in the climate. (De Silva et al., 2007).

The average annual temperature for 2050 using General Circulation Model (HadCM3) is predicted to increase by 1.6°C (A2 scenario) and 1.2°C (B2 scenario). According to the findings, rainwater harvesting as an adaptation measure for the Impact of Climate Change on Water Recourses in Dry Zone and Central Hills of Sri Lanka (De Silva, C.S., 2014).

Rainwater harvesting should be re-encouraged and should be facilitated as a short-term measure for CKDu affected areas in Sri Lanka. (De Silva, C.J., 2014). As a result of CKDu, easy access to better quality water has become a huge burden to the people in affected areas.

1.4 Objectives

1.4.1 Main Objective

Looking into the potentials of promoting rainwater as a source of safe water for consumption in the North Central Province.

1.4.2 Specific Objectives of the Study

- To study the people's opinion on the drinking of rainwater.
- To look into the use of rainwater tanks in the sample area.
- Analysing the quality of existing water sources and the quality of harvested rainwater from respective samples from the study area (If it is not possible to get secondary data)
- To look into the ways of guiding and making people aware of the rainwater consumption
- To provide scientifically reliable evidence for policymakers to promote rainwater as a way out to the safe water issue in the North Central Province.

1.5 Expected Outcomes

It expects to promote rainwater harvesting for safe water consumption in North Central Province. The study examines different health and socio-economic consequences of the present water consumption sources such as analysing the quality of the water in present sources of water consumption, finding the people's opinion on drinking of rainwater and to find out how the people can be guided and made aware of the rainwater harvesting as a means of safe water for consumption.

CHAPTER TWO

Review of Literature

2.1 Present Drinking Water Sources and the Climate of the NCP

North Central Province (NCP) comprising the two districts, Polonnaruwa and Anuradhapura. It is the largest province in Sri Lanka. It falls under the low country dry zone of Sri Lanka, covering 16% of the country's total land area (7,128km2). The majority of the NCP population is engaged in agriculture and related occupations (92% farmers) (Jayasekara et al., 2015).

The NCP is well known as the breadbasket of the country as it produces the largest portion of rice. A majority of the farmers in the NCP has been involved in intensive paddy cultivation since ancient times.

The total area of NCP is estimated to be 10,472 km^2; including 9741 km^2 of land and 731 km^2 of inland water bodies (Department of Survey, Sri Lanka, 2016).

In the dry zone, annual temperatures range from 26°C to 34°C. Tanks and irrigation channels typically occur in a closed-cascade system where water is mainly contributed through rainfall and lost through evapotranspiration, surface and underground outflow (Panabokke, 2007). Several main rivers flow through the area, including the Mahaweli River.

Anuradhapura and Polonnaruwa districts are the study area of this research and, they fall under the dry agro-ecological zone of Sri Lanka with an average annual precipitation of 960mm. Most of the precipitation is carried by the Northeast monsoonal rains and the second inter-monsoon, which falls in the months from October to March.

Throughout the dry period lasting around for eight months, farmers depend on surface water, which includes more than 3000 medium and large-scale irrigation tanks in NCP (Karunaratne, 1983). NCP has hard rock or crystalline basement complex of rocks, which are well known for their very limited shallow groundwater aquifers (Panabokke, 2003). Groundwater is the main drinking water resource and more than 85% of the drinking water requirements for the rural communities, which are obtained from shallow and deep wells. The shallow groundwater sources are known to benefit by seepage from small tank cascade systems located upstream (Panabokke, 2003).

The ancient tank systems in districts have historically been used for irrigation and drinking water supply. But since the 1980's the irrigation has extended by the rapid increase of groundwater wells. Most people in the "endemic" area use drinking water from different sources, they are surface water (found in tanks, reservoirs, irrigation canals, rivers, and streams), shallow dug wells in the shallow regolith aquifer, deep tube wells that may reach the deeper "fracture zone" aquifers; and water-bearing quartzite strata that give rose to nature springs (Panabokke, 2007).

Pipe-borne drinking water is available to only 16% of the total population. The rest of the drinking water requirements of NCP are met by spring wells and shallow wells. NWSDB has constructed water supply schemes in NCP, in 2014 and 2015.The government started to providing drinking water from RO plants as a part of the remediation strategy. Private water sellers are also involved in water selling business. Water sellers in these districts; use to collect RO plant water and filtered water. They use lorries, tractors and land masters to sell water, to the villagers doorstep. Government and private institutes have provided sizeable number of rainwater tanks to meet the water scarcity in some districts.

Sri Lanka Navy also provide RO plant water, free of charge. Presidential task force on chronic kidney disease prevention too is engaged in providing RO plants for CKDu affected areas.

2.2 Climate Change Consequence in NCP

Rainfall analysis of past to present decade, the Meteorological Department data for Polonnaruwa from 1951 to 2010 presented that the rainfall during the Maha season (second inter-monsoon and northeast monsoon) had reduced by 230 mm over a period of 55 years at the rate of 4 mm/year. The population and the demand for water have increased over the period. Likewise, the rainfall during Yala season (first inter-monsoon and southwest monsoon) also has been decreased according to the Meteorological Department data. There was a reduction of 150 mm of rainfall over a period of 55 years. (De Silva, C.S., 2013).

Similarly, in Anuradhapura according to the Meteorological Department data, the rainfall decreased during the Maha and the Yala seasons approximately at the rate of 2mm/year. The reduction in the volume of water in the area of the NCP (2 mm x 7,128km2) had a significant effect on agricultural activities over the past and recent decades. It was reported that in July and September 2012 (Bandara, 2012), drought conditions continued with the lowest rainfall received in May and June, which had devastating effects on domestic, agriculture and hydropower generation. The low rainfall resulted in a drastic drop in water levels in hydro catchments and reservoirs, with severe disruption to hydropower generation, domestic water supply, and agriculture. Anuradhapura and Polonnaruwa districts were the worst affected by the drought. (De Silva, C.S., 2013).

According to the research findings of De Silva, C.S. (2013) predictions for rainfall in 2050 rainfall predicted by HadCM3 for Polonnaruwa there is a drastic decrease in rainfall during the months of January, February and March and a slight decrease in April, September and December compared to the baseline (1961-1990). A drastic decrease in the Northeast monsoon rains in January and February is foreseen and it is predicted to decrease by 37% in 2050 compared to the baseline. This decrease will affect the Maha season rains badly on which farmers heavily depend for their paddy cultivation. Accordingly, the Maha season rains (October – February) are predicted to decrease by 12% in 2050 compared to the baseline. Further, the first inter-monsoon (March- April) is predicted to decrease by 84% in 2050 compared to the baseline (1961-1990). This decrease will definitely affect the rains in the Yala season too. According to the HadCM3 prediction, there will be a 10% decrease compared to the baseline during Yala season (March –September) rainfall in 2050.

According to the HadCM3 prediction, in Anuradhapura also, there will be a drastic decrease in rainfall during January, February, and March. There will be a slight decrease in rainfall during April, September, and December too. Therefore, there will be a 3% and 8% decrease in the Yala and the Maha seasons respectively (De Silva, C.S., 2013).

According to the conclusions and recommendations of De Silva, C.S. (2013) project, the past, present and future predictions on rainfall specify that there will be a drastic reduction in rainfall during the Maha and the Yala seasons and therefore additional irrigation water must be recognized. Reductions in rainfall will pose severe pressures on safe and clean water for drinking purposes; therefore, treated water supply is mandatory for domestic purposes. The government development programmes should be attentive on developing water resources in NCP with special reference to climate change effects. (De Silva, C.S., 2013).

2.3 Water Quality Problems in the Study Area

2.3.1 CKDu Problem in the Study Area

Chronic kidney disease of unknown etiology (CKDu) is a serious public health problem in Sri Lanka. There are many water quality problems in these districts, In the absence of safe drinking water. Dental fluorosis and kidney disease are frequently observed in many parts of the dry zone of Sri Lanka, mainly in the North Central Province of Sri Lanka.

Chronic kidney disease of unknown etiology (CKDu) has been reported from 10 districts in the country. According to the Health Ministry, the number of CKDu patients in 2010 was 29,336. By 2014, this number increased to around 40,000. The present data is not available but according to the MOH office reports, nearly 60,000 people have been affected by CKDu (HARTI survey, data 2018). North Central Province (NCP) reports the highest number of CKDu patients and mortality rates due to CKDu. Anuradhapura District reports the highest number and Polonnaruwa District reports the second-highest number of CKD patients (Poulter & Mendis, 2009).

Quality of the water is a factor for chronic kidney disease in the area. Jayasekara et al. (2015) found a much lower CKDu prevalence amongst communities using water from natural springs (1.5%) compared to those consuming water from wells (7.7%) in the high-prevalence areas in North Central Province. Siriwhardana et al. (2015) found that people using only well water have a higher CKDu prevalence compared to people consuming water from multiple sources.

Based on our interviews it is perceived that the farmers do not take sufficient amounts of water for drinking, when they are working in their field, due to their idea about the unsafe water quality of their water source, which is near the field. In addition, to their poor habit of not drinking enough water, when they are thirsty, due to the unavailability of safe drinking water at their field. This unhealthy habit can lead to repeated dehydration. We personally also experienced that the climate is very hot, requiring a high water intake to maintain vigor. A doctor of the Renal Care Centre of Polonnaruwa said that patients first undergo several acute cycles previously entering the chronic phase of CKDu. This acute phase is sometimes associated with dehydration and develops mainly in the hot/ dry May-August period.

According to some research findings, heat stress in NCP was identified. In Sri Lanka, a tropical country located close to the equator, occupational heat stress is most common in the North Central Province (NCP), where temperature and other environmental factors are thermally stressful (Tawatsupa, Lim & Kjellstrom, 2012; Siriwardhana et al., 2015). High temperatures are typical and range, on average, between 33.3 °C and 34.7 °C (Department of Meteorology, Sri Lanka, 2016).

The etiology of the disease is unclear, but researchers have proposed that "heat stress nephropathy may represent one of the first epidemics due to global warming" (Glaser et al., 2016). Chronic dehydration and inadequate water consumption may increase the risk of kidney damage. For example, risk factors for CKDu identified in a case-control study included daily exposure to heat (> 6 h) and low intake of water (<3 l) (Siriwardhana et al., 2015).

Wimalawanse (2014) also noted the renal stone formation characterized ailment. Chronic kidney disease was observed significantly high in some areas of Polonnaruwa and Anuradhapura Districts. Geochemically, the groundwater in these areas is generally of the Na/K type with the Cl- salt type predominating possible due to the increasing drought conditions and salt built up. The total dissolved solids and the electrical conductivity are also correspondingly high. This is a unique feature of the dry zone in a large number of areas. Previous studies have shown that even in low doses of F (7.5mg) over long periods of time (example 100 days) can make morphological changes in kidneys (Manocha et al., 1975).

Another cause of CKD explained by Chandrajith et al. (2011) is a Na/Ca ratio in drinking water with high levels of Fluoride.

Several studies have been conducted by a number of Sri Lankan scientists as reported by Noble et al. (2014). Results of these studies indicate that CKDu is likely to be multi-factorial and attributed to a combination of chemicals or toxins in water, among these toxic compounds are aluminum and fluoride (Ileperuma, 2011) Cadmium (Bandara et al*.,* 2008), toxins released by Blue-Green Algae (Dissanayaka, 2005), some pesticides

(World Health Organization, 2013) and many other factors. A study conducted in six CKDu affected areas in Anuradhapura, Polonnaruwa and Kurunegala districts indicates that severity of CKDu is reduced by consuming water from Reverse Osmosis (RO) plants. Heavy metal pollution is a recent concern for CKD in Sri Lanka and Arsenic and Cadmium are mainly suspected as heavy metal pollutants (Johnson et al., 2012) suspected to be originating from agrochemicals (Wijewardena, 2012). Research by Bandara et al. (2008) had shown Cd concentrations between 0.03 to 0.06 mg/L in dissolved form and 1.78 to 2.45 mg/Kg in sediments in certain irrigation tanks of NCP. Since then Chandrajith et al. (2011) have shown that there is hardly any Cd in drinking water sources in NCP.

In the past, several researchers have attempted to explain the etiology of CKDu. Herath et al. (2005) reported that high fluoride content in drinking water may be the cause of CKDu; nevertheless, they have not been able to explain the reasons for the absence of CKDu in places where drinking water contains extremely high content of fluoride. The high content of fluoride in groundwater, contamination of the water supply with artificial fertilizers used for paddy cultivation, use of aluminum utensils instead of clay pots for cooking and toxin released from Blue-Green Algae are some of the suspected reasons for these crises (Jayasumana et al., 2013).

A relationship between fluoride and aluminum utensil usage has also been established by Herath et al. (2005) concluding aluminum and fluoride in combination could be another factor to cause CKD in areas with high Fluoride in groundwater. They have concluded that aluminum leaching is higher when aluminum pots are used for cooking using an acidic ingredient.

National statistics indicate high mortality associated with kidney disease. WHO data for 2012 suggest kidney disease is the seventh most common cause of death in Sri Lanka and may be increasing (WHO, 2012).

2.3.2 Drinking Water Quality Problems in the Study Area

Rain is the key source of water in various parts of the world. For drinking purposes, water is obtained frequently from wells, reservoirs, rivers, and lakes. These water sources in various parts of the world are contaminated with many cations or anions. Among the cations regularly found in toxic levels in water are Arsenic, and Cadmium. Nitrates and Fluorides are among the common anions found at toxic levels in water sometimes these levels will increase the drinking water standard. These toxic substances are involved in contaminating groundwater bodies (Weeraratna & Ariyananda, 2009).

The pH of groundwater in the dry zone in Sri Lanka ranges from Neutral to Alkaline. Geochemically water from the dry zone is abundant in HCO_3^-, Cl, Ca^{2+} and/or Na^+. This is in line with other studies in the area (e.g. hardness in general between 250 and 500 mg/L $CaCO_3$ according to Dissanayake and Weerasooriya (1986), Iron and Manganese are mainly found in the deep aquifer owing to reduced conditions.

According to the literature, K+ is often used as an indicator of flushing out of NPK-fertilizer. Chandrajith et al. (2011) reported high K+ values up to 60.3 mg/L but without access to the raw data it is not possible to rule out other sources (e.g. by checking Na/K ratios).

When considering about fluoride (F), Chandrajith et al. (2012) who found that almost 50% of wells in the dry zone had F- concentrations greater than 1 mg/L, with peaks up to 13 mg/L. It is not entirely clear whether the deep aquifer has higher F concentrations compared to shallow. In a study in Udawalawe region, Hoek, W.V.D et al. (2003), Chandrajith et al. (2012) found lowest F- concentrations in surface water (median 0.22 mg/L), 0,48 mg/L in shallow wells and 0,8 mg/L in tube wells. Rajasooriyar et al. (2013) found similar F- concentrations in both shallow and tube wells in the same district (average 1.0 mg/L) as did Young et al. (2011) in the North Central Province. These results are in line with leaching experiments conducted by Hallet et al. (2015) on rock samples from Southern India and Sri Lanka, which indicate a greater potential from the regolith compared to bedrock.

Studies on Fluoride in groundwater in NCP carried out by Dissanayake (1991) and Young et al. (2010) show that the condition has not changed even after about two decades with Fluoride above 4 mg/L in groundwater. It was found that high Fluoride areas lie within low plains. It might be due to the contact time through the geological, material was longer in the plains and there exists slow groundwater movement related to highlands (Dharmagunawardhane & Disanayake, 1993). Fluoride concentration fluctuating from 6-8 mg/liter in drinking water has been reported in some parts of the Dry Zone of Sri Lanka. (Padmasiri & Wickramasingha, 2004), Ileperum, Dharmagunawardena and Herath (2004), reported that water in dug wells in some parts of Anuradhapura District has a Fluoride content of 1.0-4.0 ppm. It is exceeding the safe limit, according to the WHO standards.

Heavy use of pesticide also a factor for water contamination in the area. But pesticides despite apparent high dosages and intensive use of pesticides, hardly any information is available on ambient concentrations in the ground and surface water in literature or with the NWSDB. The study by Jayasumana et al (2015) who measured Glyphosate in abandoned wells (median 3.2 µg/L) and the serving wells (from 0.6 to 3.2 µg/L).

Cadmium has been reported to be present in high concentrations in water in five reservoirs in the North Central Province, located in the dry zone of Sri Lanka.

Measurements of NWSDB showed a complete absence of Coliform Bacteria in tube wells of Anuradhapura and Polonnaruwa, indicating that deep groundwater is microbiologically safe and wells are generally in a sound technical status (i.e. absence of short circuit flow due to leaky casings). Shallow wells and surface water show considerable Coliforms Bacteria (including Escherichia Coli) Rajasooriyar et al. (2013) found microbiological contamination of both wells close to irrigation canals and wells at a larger distance. This recommends that both infiltration of surface water and sewage and other waste disposal as a likely source of pollution (Bandara et al., 2008).

2.4 Rainwater Harvesting and the Current Situation in the Study Area

Surface water and water from the aquifer is under burden due to urbanization, deforestation, and pollution. To meet the rising demand for water supplies, different types of water sources need to be developed. Rainwater harvesting is a good option for rainwater collection. Rainwater harvesting (RWH) is gradually becoming an important part of the sustainable water management technique (Ward et al., 2012).
Rainwater is the main source of water in Sri Lanka. Sri Lanka gets an annual average rainfall of 2000 mm, fluctuating from 900 mm to 6000 mm in different regions. However, from that an average 40% of this water is used and the balance goes to the sea as run-off.

The whole amount of rainwater received by the island is around 100 billion cubic meters, and around 40% of it runs-off. Around 35% of the run-off is used for irrigation and generation of hydro-power and the balance is about 65% of the run-off escapes to the sea. Thus, nearly 26 billion cubic meters of water is wasted.

Our famous proclamation by King Parakramabahu the Great (1153-1186 AD), “let not even a small quantity of water obtained by rain, go to the sea without benefiting man”. Sri Lanka has an extensive history of rainwater collecting, in rural villages; many people for many years have informally collected rainwater from the roofs of their homes for storage in containers. The practice of harvesting rainwater is a longstanding tradition adopted in many parts of the world and it has been practiced in Sri Lanka for many centuries; a good example is the sophisticated rain water-cum-reservoir systems in the 5th century Sigiriya Fortress Complex.These provides the ample evidence of rainwater collection in Sri Lanka.

Large scale household rural rainwater harvesting (RWH) was introduced to our country from the World Bank Funded Community Water Supply and Sanitation Project (CWSSP) around 1995. After that, the number of other organizations and institutes donated RWT for the households both in the wet and the dry zones.

In 1995, Community Water Supply and Sanitation Project initiated by the government of Sri Lanka with World Bank funds introduced rainwater harvesting as one water supply option in Badulla and Matara. Since then, this technology has been promoted by both the government and the non- government organizations throughout the country (Ariyananda, 2010). Understanding the importance of rainwater harvesting as a solution to overcome the water shortage in the country the government of Sri Lanka passed a national policy on rainwater harvesting in 2005. Legislation, which followed, has made rainwater-harvesting mandatory in the new building above a certain roof size in Urban and Municipality areas since 2009.

This project initiated the emergence of the Lanka Rainwater Harvesting Forum (LRWHF), which is a nongovernmental organization (NGO) actively engaged in promoting rainwater harvesting in the country. Mainly the rainwater policy speaks about rainwater harvesting.

National policy on RWH in Sri Lanka was officially implemented on September 27th of 2005. LRWHF also represented the steering committee for formulating this policy.
The main objective of the National RWH Policy is to ensure that the “City of Tomorrow” applies RWH approximately by the control of water near its source, in its pursuance of becoming a “Green City” in the future.

This policy is implemented by the RWH secretariat of the Ministry of Urban Development and Water Supply and the NWS&DB together with the LRWHF. Presently Almost 42,000 domestic rainwater harvesting units have been constructed under various water supply development programmes in all provinces of Sri Lanka. During the last few decades, 13000 rainwater-harvesting units were constructed in North Central Province (Rainwater Harvesting Forum data, 2018).

In our pre-test of the research, we saw, that women are primarily responsible for water in their households, but decisions to undertake investments, such as installing an RWH system, are typically undertaken by men.

Rainwater is one of the purest sources of water available, in rural areas; it is not contaminated with the pollutants as surface water. It comes free and can be used to supply potable (drinkable) water and non-potable water. If collected in the right way, it can be used for all domestic purposes as well as for drinking purposes.

CHAPTER THREE

Methodology

3.1 Study Location and Sample Selection

This study was launched in North Central Province of Sri Lanka from April 2018 to July 2018. The secondary data sources are the Ministry of Health, Lanka Rainwater Harvesting Forum and the National Water Supply and Drainage Board.

There are many Chronic Kidney Diseases of unknown etiology (CKDu) patients in Madawachchiya DS (Divisional Secretariat) and Kabithigollewa DS in Anuradhapura district and Madirigiriya DS and Dimbulagala DS in Polonnaruwa district. When reviewing the reasons for the above scenario, we realized that the lack of good quality water for drinking is the major problem in those areas. Moreover, experiences of the preliminary visits and the number of rainwater harvesting tanks available in the area were considered to launch in the study in the aforementioned areas.

The sample size of a survey is decided considering the margin of error and confidence level of a certain segment of the population. Depending on the confidence level and the margin of error, the number of households to be taken to the sample is varying. In this study, we contemplated the margin of error and confidence level as 5% and 95% respectively. Then the required number of households surveyed was 300. Multi stage sampling technique was used to derive the study sample.

In the first stage, Madawachchiya DS and Kabithigollewa DS from Anuradhapura district and Madirigiriya DS and Dimbulagala DS from the Polonnaruwa district were selected. Next, the two most affected villages in each of those four DS divisions were to be selected to draw the sample of 300 households which would represent each village in proportionate to the number of households it consists of.

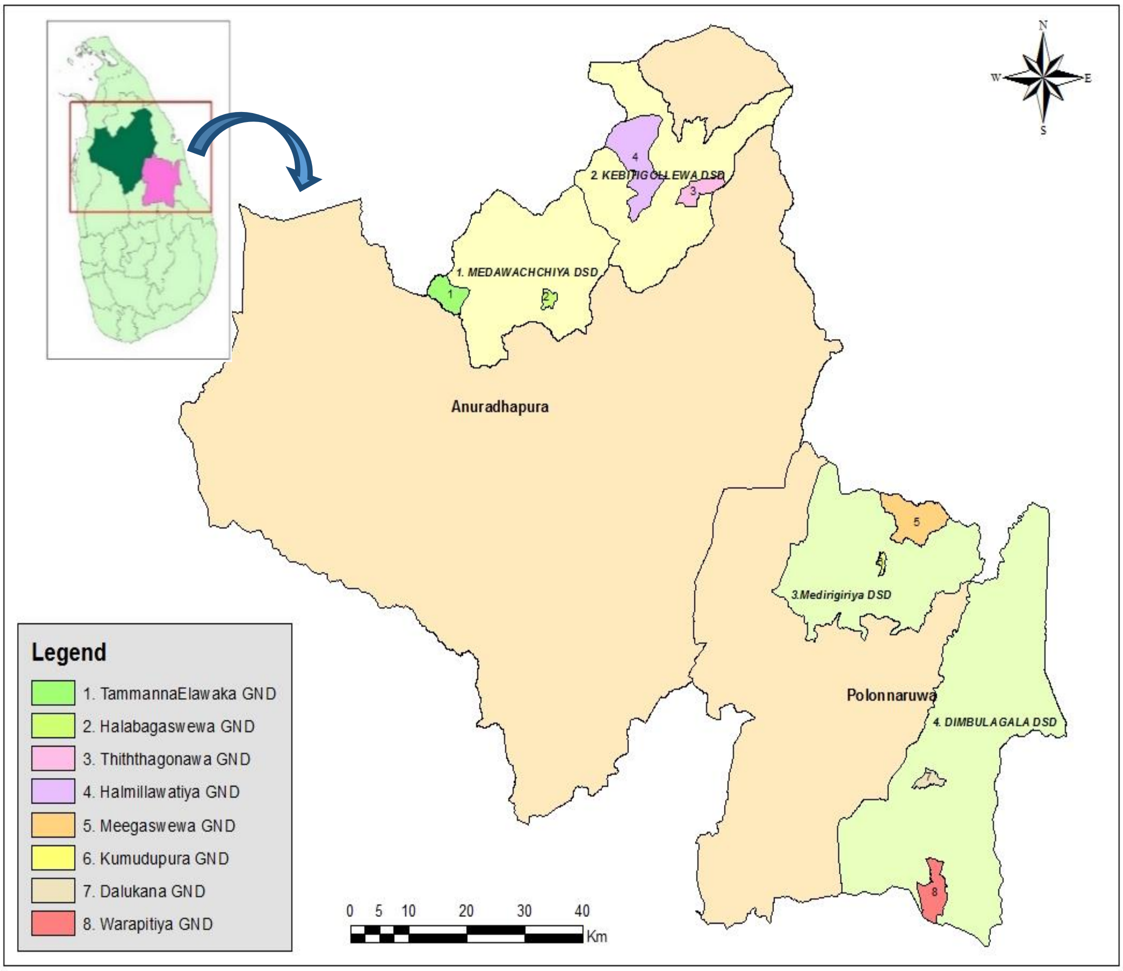
3.2 Methods of Data Collection

Both primary and secondary data was collected in order to achieve the research objectives. A structured questionnaire was administrated to extract the required primary data from a sample of 300 households in the study area in North Central Province. Respondents were from the households in the villages with most CKDu patients living as a result of lack or absence of safe drinking water.

Table 3.1: Distribution of the Selected Sample

District	DS Division	GN Division	Sample Size(proportionate to the population)
Anuradhapura (150)	Kabithigollewa (75)	Yakawewa	25
		Thiththagonnewa	50
	Madawachchiya (75)	Thammennaelawaka	51
		Madawachchiya	24
Polonnaruwa (150)	Madirigiriya (75)	Meegaswewa	28
		Kumudupura	47
	Dimbulagala (75)	Dalukane	53
		Kajuwatta(Warapitiya)	22

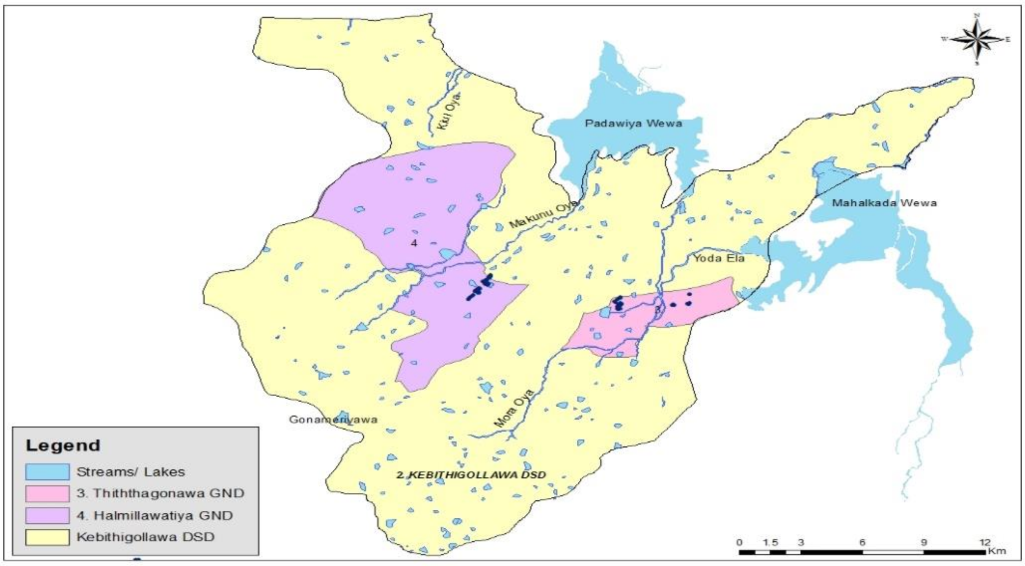
Source: HARTI survey data, 2018

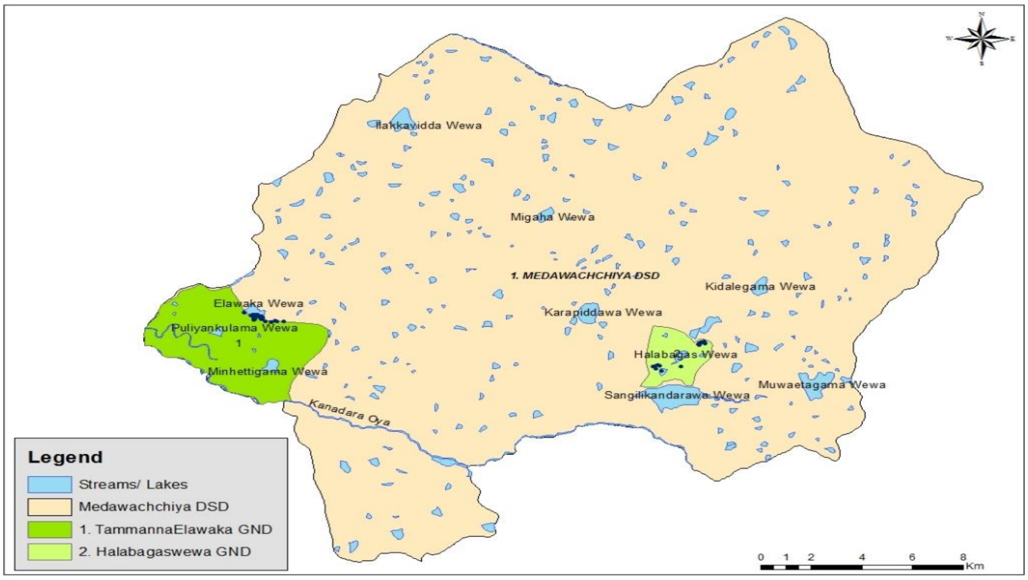


Source: HARTI survey data, 2018

Figure 3.1: Map of the Study Area

3.2.1 Location of the RWH Tanks in Different GND's Locations of the RWH Tanks in the Study Area at Anuradhapura District (Kabithigollewa and Madawachchiya DS Divisions)

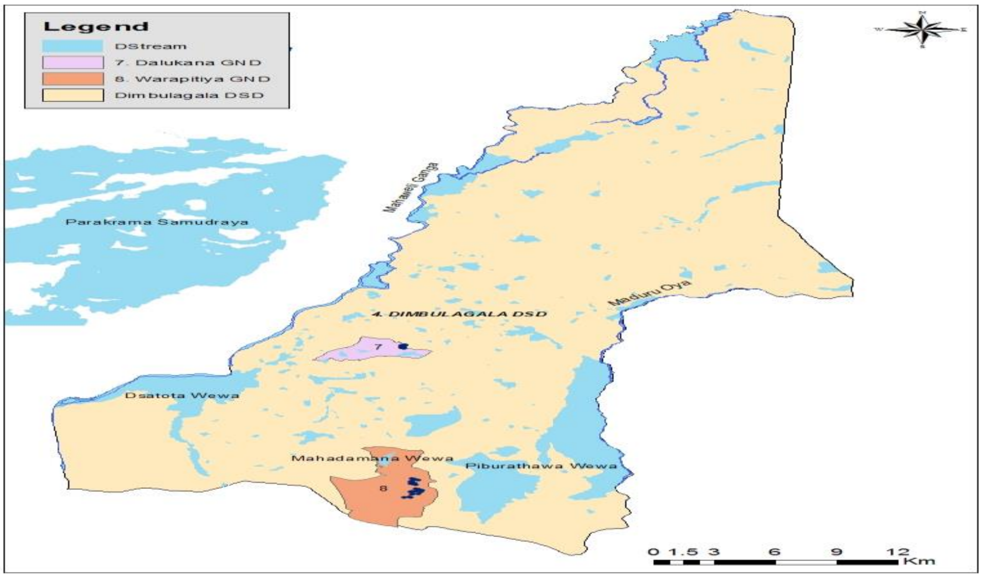


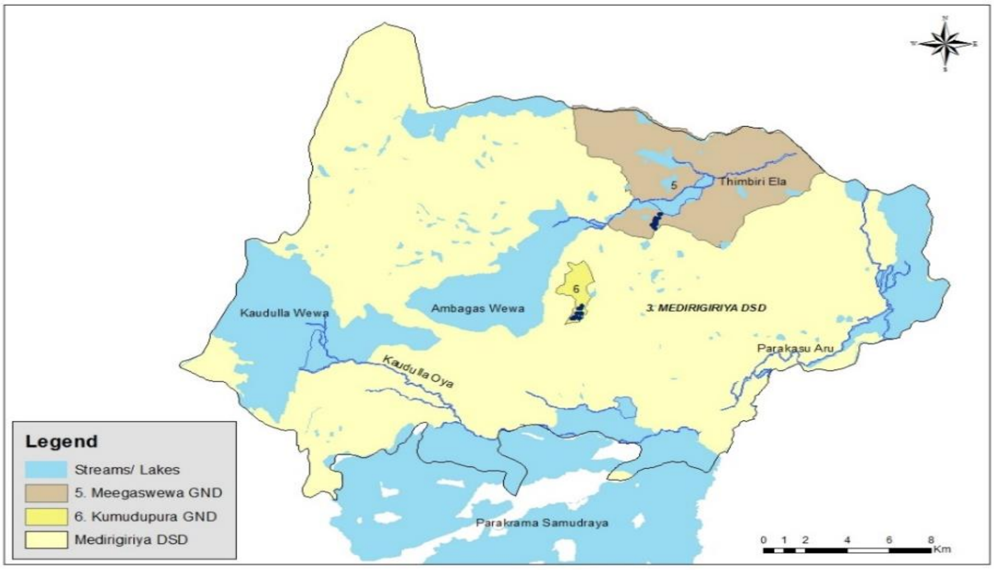


Source: HARTI survey data, 2018

Figure 3.2: Map of Different GND's Location of RWH in Anuradhapura District (Kabithigollewa and Madawachchiya DS Divisions)

3.2.2 Location of the RWH Tanks in Different GND's Location of the Selected RWH Tanks in the Sample Area (dark blue colour) at Polonnaruwa District (Dimbulagala and Madirigiriya DS Divisions)





Source: HARTI survey data, 2018

Figure 3.3: Different GND's Map of Location of the Selected RWH Tanks in the Sample Area (dark blue colour) at Polonnaruwa District (Dimbulagala and Madirigiriya DS Divisions)

3.3 Tools Used in Data Collection

3.3.1 Primary Data Collection

Key informant interviews, focus group discussions, observations and questionnaire surveys were conducted to gather primary data from the stakeholders.

3.3.1.1 Key informant Interviews

Key informant interviews were conducted to the officers of the Agrarian Service Centers, officers of the Lanka rainwater harvesting forum, Officers of the presidential task force on CKDu prevention, Divisional Medical Officers, Officers of the Environmental Authority District Office and the village level, Grama Niladhari and PHI of the relevant area to collect information on the present status of the rainwater tanks, RO plants in the study area and existing issues and performances. This was done with the help of structured and guided schedules.

3.3.1.2 Focus Group Discussions

Focus group discussions were held with the participation of officers of the Lanka rainwater harvesting forum, Officers of the President Task Force on CKDu prevention, Divisional Medical Officers, Officers of Environmental Authority Distract Office and village level officers (Grama Niladhari, PHI of the relevant area and the members of the farmer organizations in the relevant area).

3.3.1.3 Structured Questionnaire Survey

A single visit personal interview using a structured questionnaire was adopted for each and every household in the sample. The questionnaire survey focused on the general socio-economic status of households, water usage for domestic purposes, water sources used, water quality problems and the impact of the drought on livelihood activities.

3.3.1.4 Case Studies

Case studies relevant to analyse specific issues were used to fulfil the objectives of the study.

3.3.2 Secondary Data Collection

Socio-economic and health implications of surface water sources currently use, deep wells, agro wells, and rainwater tanks were identified in the study. Secondary data were collected using relevant maps and the water quality parameters (chemical and physical) of drinking water sources of the relevant areas. Moreover, medical reports with reference to basic demographic factors of the hospital medical records of the

CKDu patients, relevant research reports, journal articles, and government publications, were other sources made use of for secondary data collection.

3.4 GIS Maps

GIS maps were developed about the study area to indicate the spatial distribution of water quality parameters of rainwater tanks and the distribution of water sources, water quality distribution in wells, CKDu distribution and to indicate the sample area. GIS software was used to draw the maps, and to generate the maps to show the spatial distribution of water quality parameters of rainwater tanks.

3.5 Data Analysis

Objective 1: To look into the people's opinion on the drinking of rainwater
Cross-tabulations were applied to find the association of the factors, which cause of opinion on drinking of rainwater. In addition, descriptive statistics such as frequency distribution tables, percentages, graphical representations, and arithmetic mean was used to describe the data.

Objective 2: To look into the use of rainwater tanks in the sample area
Here too cross-tabulations were applied to find the association of the factors, which contribute to the usage of rainwater tanks in the sample area while frequency distribution tables, percentages, graphical representations, and arithmetic mean was used as the descriptive statistics in order to describe the data.

Objective 3: Analysing the quality of existing water sources and the quality of harvested rainwater from respective samples from the study area (If it is not possible to get secondary data)
Water quality testing
Water quality was analysed in stored rainwater tanks, RO plants water and the quality of the main water source of households during the sampling period were analyzed.

Water quality parameters (important chemical, physical and biological parameters) of rainwater tanks (100 water samples), RO plants, filter water, well water, water samples from water sellers of relevant areas were identified using water quality testing. Sampling was done covering all the eight GN divisions (Yakawewa, Thiththagonnewa, Thammennaelawaka, Madawachchiya, Meegaswewa, Kumudupura, Dalukane, and Kajuwatta) in the study area.

Sampling was done using standard water sampling methods. This collected water sample quality was determined at the National Water Supply and Drainage Board labs in Anuradhapura (regional laboratory Anuradhapura) and Polonnaruwa districts (regional laboratory Gallalla) and the Open University of Sri Lanka, Agricultural Engineering lab according to the SLS 614: 2013. This standard was approved by the Sectoral Committee on Agricultural and Food Products and was authorized for adoption and publication as a Sri Lanka Standards Institution on 2013-08-28. Graphical representations, arithmetic means stranded divisions were used to describe the data.

Objective 4: To look into the ways of guiding and making people aware of the rainwater consumption

Once again, cross-tabulations were applied to find the association of the factors, which have the ways of guiding and making people aware of the rainwater consumption. Hence, descriptive statistics such as frequency distribution tables, percentages, graphical representations, and arithmetic mean were used to describe the data.

CHAPTER FOUR

Results and Discussion

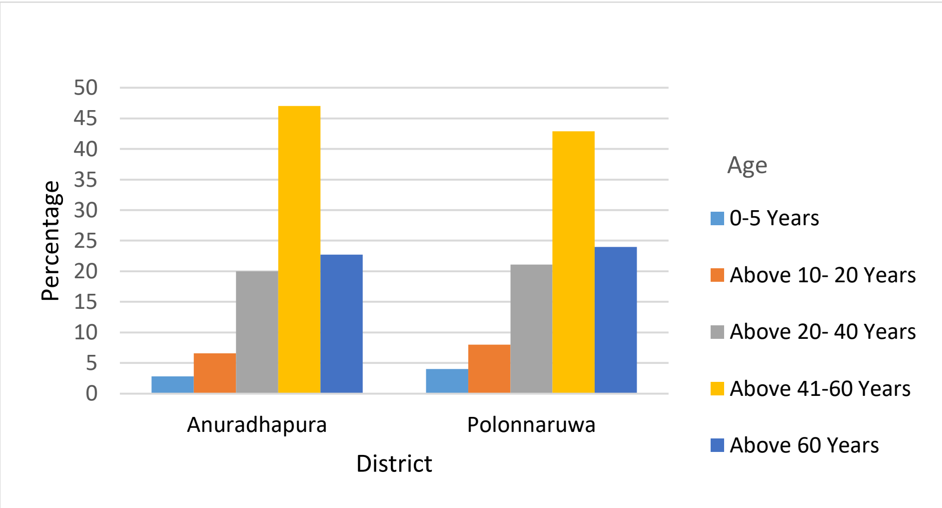
Socio-Demographic Characteristics of the Villagers in the Study Area

4.1 Introduction

This chapter will present an overview of the socio-demographic characteristics and economic level of the family members of the villagers in the study area. Descriptive statistics is used to illustrate the findings.

4.2 Age Distribution of the Study Area

Age distribution of the population is given in figure 4.1, which shows that the age group below 20 years in the population is less than 15% in both districts. Age between 40-60 years represents the major part of the population in both districts. Around 25% belong to the age category of over 60 years in each district. The majority belong to the age category of 41- 60 years accounting for 45% of the sample population. This age group takes the responsibility of fulfilling HH needs.

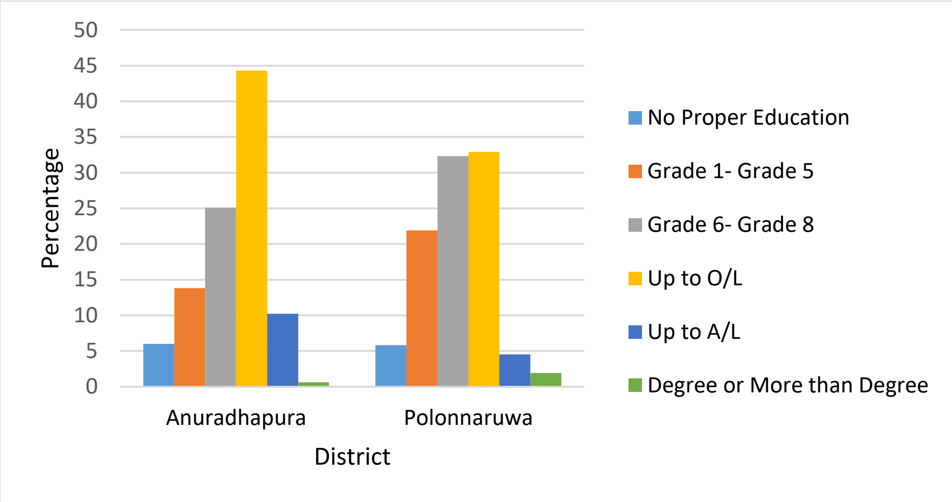


Source: HARTI survey data, 2018

Figure 4.1: Age Distribution of the Study Area

4.3 Educational Level of Household Heads in the Sample Area

The educational levels of the household heads in the sample area are illustrated in Figure 4.2. shows the education level of the household heads. A majority had never received a secondary education. In addition, most of them gains up to O/L. There is a significant correlation between educational level and the number of CKDu patients in the house (correlation coefficient is 0.034 and significant at 0.01 level). According to the results, nearly five percent had not received formal education and 45 percent had studied at least up to GCE O/L, in Anuradhapura District and 33% Polonnaruwa district. The major difference in the level of education, which can be identified across two districts, was, that in Anuradhapura, 32% involve in government jobs comparing with Polonnaruwa (figure 4.3). This is due to, in both districts average of 38 % had studied up to O/L exam. According to the results, in Anuradhapura, 10% studied up to A/L exam and meanwhile 1% were graduated.

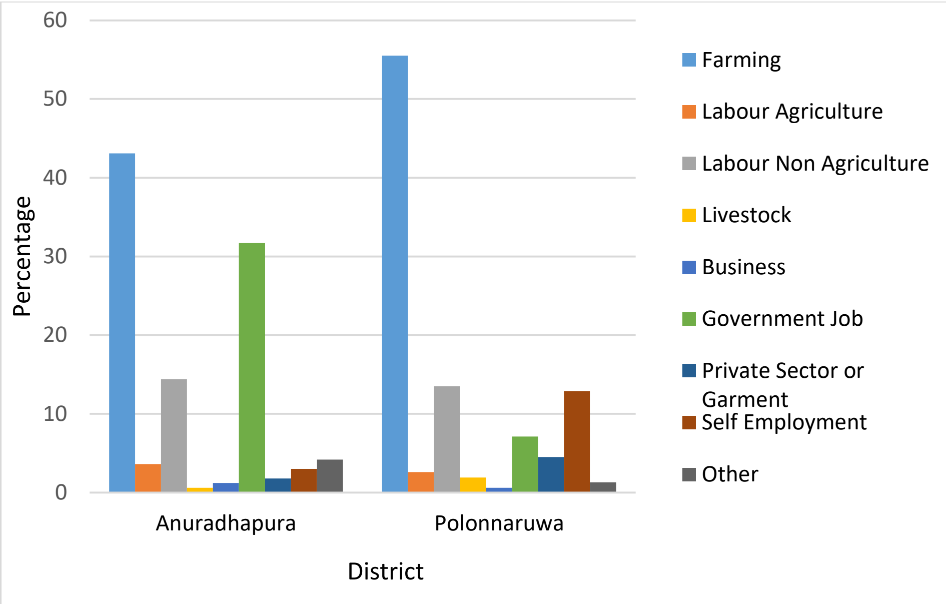


Source: HARTI survey data, 2018

Figure 4.2: Educational Status of the Household Heads

4.4 Employment of Household Heads

Figure 4.3 shows the distribution of primary employment among the households the main employment of the majority of the sample (55%) was engaged in agriculture in Polonnaruwa and 43% in Anuradhapura. Only 13 % were engaged in self- employment in Polonnaruwa and less than 4% in Anuradhapura.The figure 4.3 reveals that 34% of them were state or private sector jobholders in Anuradhapura district and 15% in Polonnaruwa district. The government job holder's percentage was high in the Anuradhapura district. According to figure 4.2, household heads education levels up to O/L and above were significantly high in Anuradhapura comparing to the Polonnaruwa. Significant percentage from Polonnaruwa involved in farming.Others were engaged in casual jobs and overseas employments. Some were unemployed.

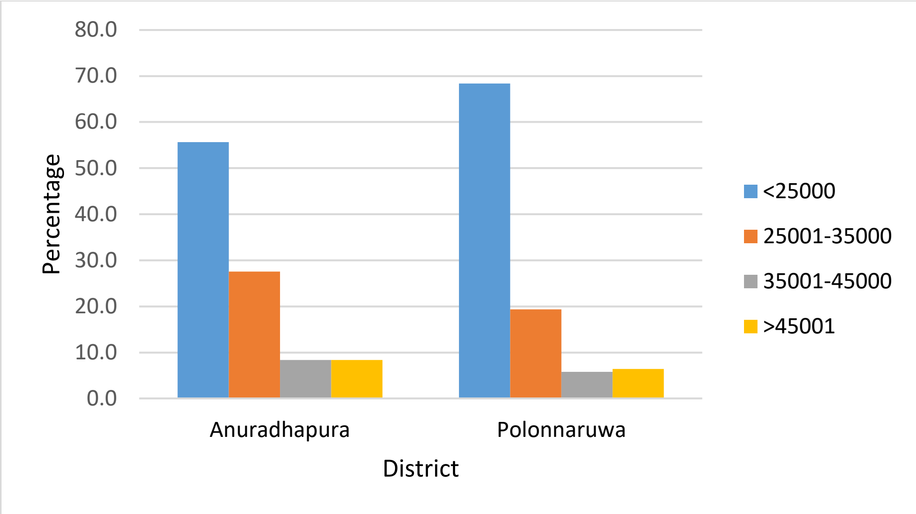


Source: HARTI survey data, 2018

Figure 4.3: Distribution of Primary Employment among Farming Households

4.5 Monthly Expenditure Level of the Households

Household expenditure information was collected through three major sections of the questionnaire survey, I. expenditure on food. II. expenditure on non-food.III.expenditure incurred by boarders and domestic servants. The expenditure is discussed under education, meals, medical savings, cultural and religious activities, social and entertainment, electricity, rent, and for agricultural activities. According to the graph exposes that 56% in Anuradhapura and 68% in Polonnaruwa, spend less than Rs.25000. Monthly expense level of the households' value directly depends on the family size and the income level of the family (correlation coefficient is 0.004 and significant at 0.01 level).



Source: HARTI survey data, 2018

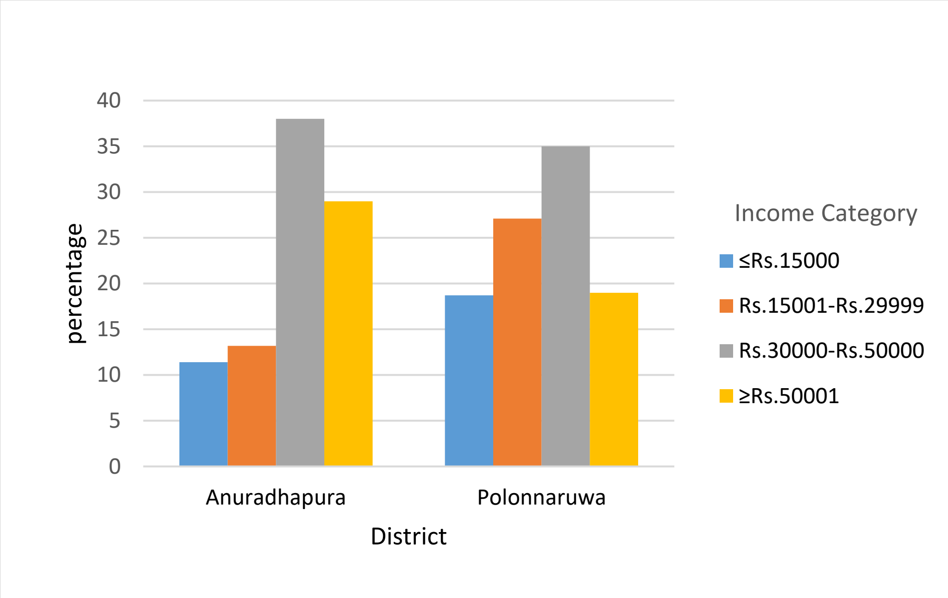
Figure 4.4: Monthly Expense Level of the Households

4.6 Family Monthly Income Level of the Households

Figure 4.5 illustrates the monthly gross income of households in both districts. Accordingly, 36% of households had received a gross monthly income between Rs. 30,000 and 50,000. Only 11% was recorded with a monthly income of fewer than Rs. 15,000 in Anuradhapura and 18% in Polonnaruwa. Indicates 35% of households earned more than Rs. 35,000 per month in both districts

According to the Department of Census and Statistics, the average household income per month was Rs. 62,237 in 2016 in Sri Lanka. The median household income per month in Sri Lanka was reported as Rs. 43,511 in 2016. The real mean household income per month has been reported as Rs. 43,320 based on 2009/10 (adjusted for the inflation of prices using National Consumer Price Index (NCPI)) showing an increase approximately of 15.8 percent from 2012/13 to 2016. The real median household income per month as reported was Rs. 30,285 in 2016.

According to the findings, in Polonnaruwa 54% and in Anuradhapura 66%. These HHs income values were above Rs. 30,000 per month. It is within the national real median household income per month.

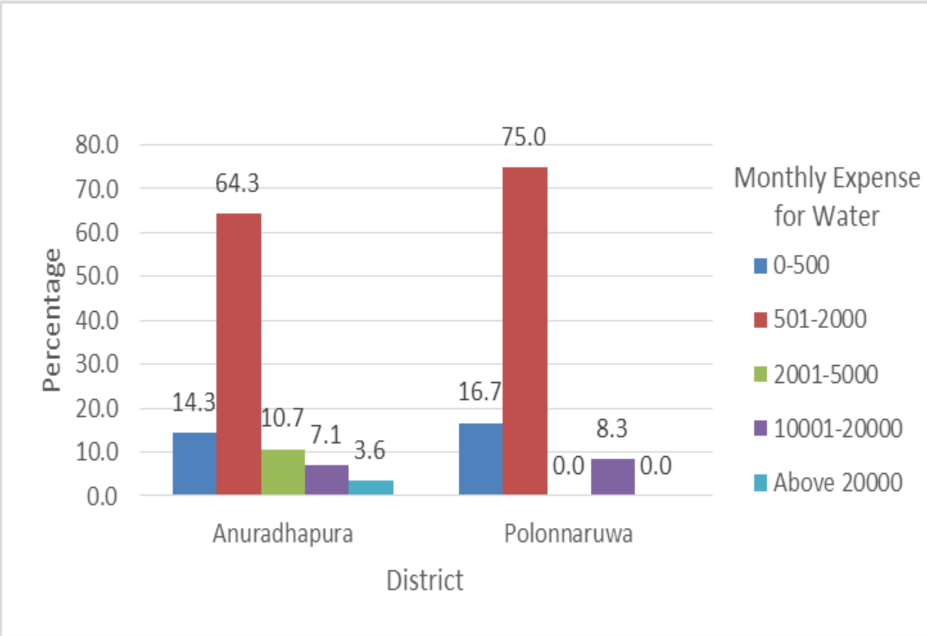


Source: HARTI survey data, 2018

Figure 4.5: District wise Variation of Monthly Household Income

4.7 Monthly Expenditure to Buy Water in the Sample Area

According to the districts and monthly expense cross-tabulation, it was found that 75% of the families in Polonnaruwa district spend up to Rs 500 to Rs 2000 per month, to buy water. The figure 4.5, illustrates that 90% of the total population in Anuradhapura have have an income level of over Rs 15000. When we consider the Rs 15000 as the minimum level of income, they have to spend 13.3% of their earnings to buy water, which is a considerable expense. From the population 8.3% from Polonnaruwa, have to spend Rs 10000 - Rs20000 to buy water. Is a consequences of the lack of total number of rainwater tanks in Polonnaruwa comparing with Anuradhapura District. In Anuradhapura, 64.3% have to spend up to Rs 2000 to buy water.



Source: HARTI survey data, 2018

Figure 4.6: Monthly Expenditure to Buy Water in the Sample Area

CHAPTER FIVE

Results and Discussion

Water Usage in the Area (before and after introducing rainwater tanks) and the Villagers' Perception, Awareness on Rainwater Tanks

5.1 Introduction

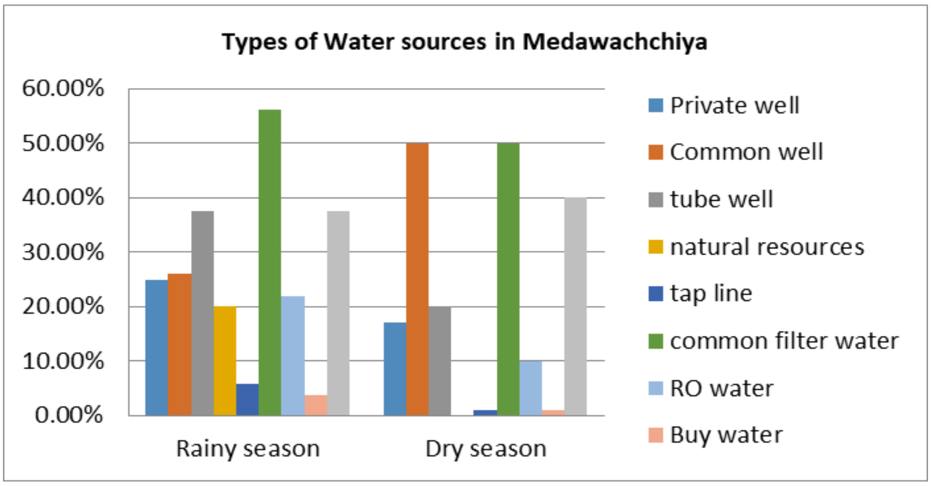
This chapter presents an overview of the water usage in the study area, before introducing rainwater tanks, and the villager's perception, and their awareness of rainwater tanks, and the spread of the unknown kidney problems in the study area**.**

5.2 Usage of Water in the Sample Area before Introducing Rainwater Tanks

People in this area, take drinking water from, shallow and deep dug wells, tube wells, river, reservoir, water sellers and pipe borne water supply systems introduced by the National Water Supply and Drainage Board. The existing water sources, now in use, do not have enough water throughout the year, and sometimes water sources, near the houses are contaminated and cannot be used for potable water. Due to this problem, most of the people depend on common well water. Many people in the sample area are used to drink filtered water and RO plant water. Figure 5.1 indicates the water usage in the study area, before implementing the rainwater tanks.

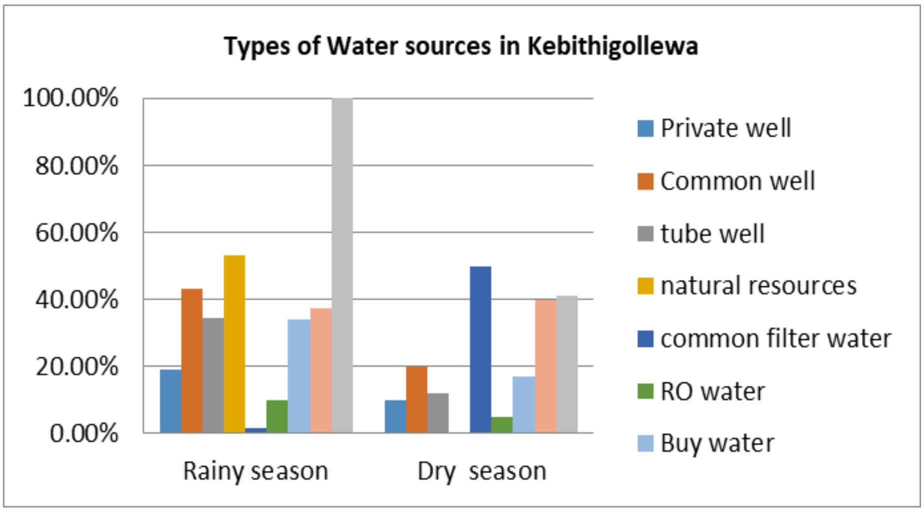
In Anuradhapura district, people in Madawachchiya area during the dry season, More than 50% used to drink water taken from common filters, and 23% used to drink water from common wells during the rainy season(wells identified as the water quality is, within the safe range by NWSDB). Kabithigollewa area 55% used to drink spring water(Gonamadiyawa and Sinhaya water springs) during the rainy season, but during the dry season, they can not get enough water from the springs due to drying of the springs. (figure 5.1). Some people used to buy spring water from water sellers (Authors survey data, 2018). In Kabithigollewa area(Figure 5.2), most of the private wells are identified as contaminated wells, but during the dry season, most of the people used to drink water from their own private well, due to drying of common wells.

When considering Thammennaelawaka in the Madawachchiya DS, In this area the total number of dug wells are fewer, because even after digging for 40 feet. people cannot reach the water table.



Source: HARTI survey data, 2018

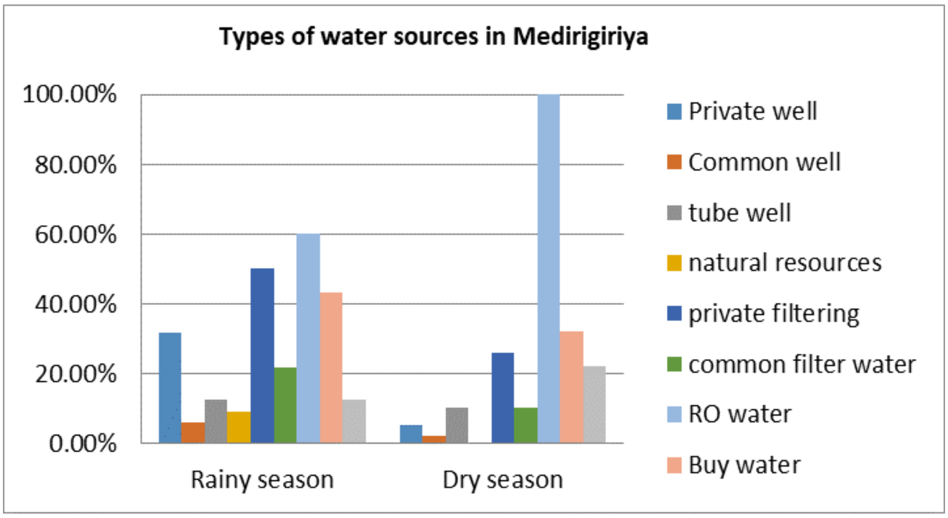
Figure 5.1: Water usage in Madawachchiya DS Division before Implementing Rainwater Tanks (Thammennaelawaka and Halabagaswewa DN Divisions)



Source: HARTI survey data, 2018

Figure 5.2: Water Usage in Kabithigollewa DS Division before Implementing Rainwater Tanks (Yakawewa and Thiththagonnewa DN Divisions)

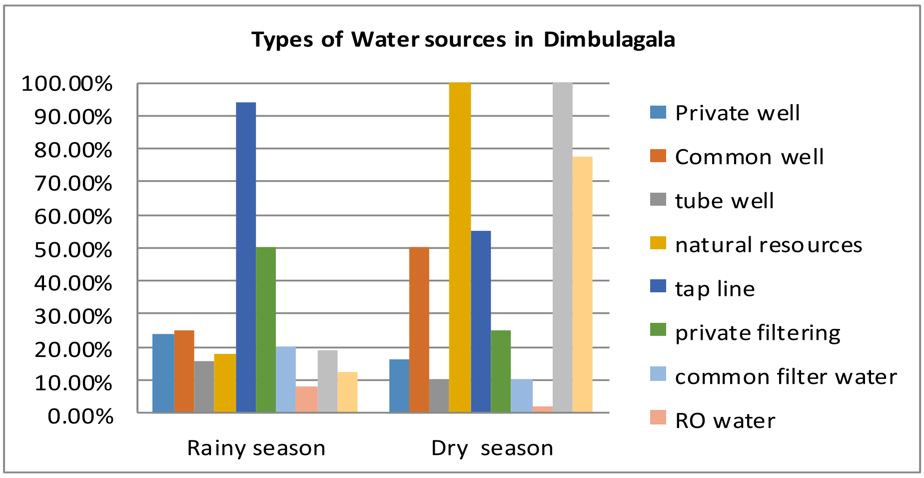
In Polonnaruwa District most of the people in Medirigiriya (Meegaswewa and Kumudupura) area during the dry season, most of them used to drink RO plant water, and 5% use to drink water from common wells during the rainy season. (Figer 5.3) Most of the private wells are identified as contaminated wells but during the dry season, most of the people used to drink water from their private well, due to drying of common wells. Villagers know their privet wells are not suitable for drinking, but they use this water for their drinking purposes, after boiling. During our survey we identified, that during the dry season, a significant number of water sellers do not come to the village.



Source: HARTI survey data, 2018

Figure 5.3: Water Usage in Madirigiriya DS Division before Implementing Rainwater Tanks (Meegaswewa and Kumudupura DN Divisions)

People in Dimbulagala (Dalukane and Warapitiya(Kajuwatta) areas) 93% getting water from the tap line systems (Figure 5.4). But they did not get water regularly throughout the day from the system. From that, 78% of these water users are of the view that the pipe borne water is not up to the stranded level for drinking purposes. Because sometimes they get water in a dark colour. They also buy water from water sellers. In both districts, people have to spend an average of 5% from their earnings to buy water (HARTI survey data, 2018).



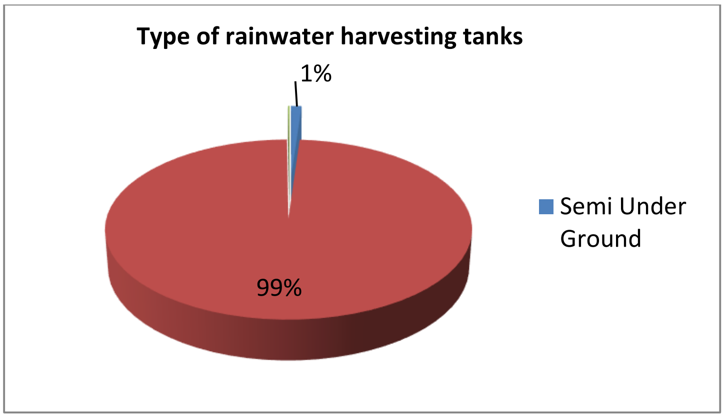
Source: HARTI survey data, 2018

Figure 5.4: Water Usage in Dimbulagale DS Division before Implementing Rainwater Tanks (Dalukane and Warapitiya DN Divisions)

5.3 Existing Situation of the Rainwater Tanks in the Sample Area

5.3.1 Different Types of Rainwater Harvesting Systems Surveyed

Figure 5.5 shows the percentage of different types of RWH systems surveyed**.** Majority (99%) of the tanks were above surface tanks, only 1**%** are semi underground tanks.(located during the survey)**.**



Source :HARTI survey data, 2018

Figure 5.5: Percentage of Different Types of RWH Tanks Surveyed

5.3.2 Availability of the Rainwater Harvesting Tanks in the Study Area

According to the findings, in Polonnaruwa district, nearly 37% of the respondents have a rainwater tank (HH level). The correspondent figure for Anuradhapura district 63% of them have a rainwater tank, this is due to the highest number of total RWT in Anuradhapura (5236) comparing to the Polonnaruwa (3506). According to the findings, about 70% of the RWT systems in the study locations have been constructed under a fully subsidized approach, and 25% is partial subsidized approach as they have to contribute to the labour cost. Most of the fully subsidized approach was implemented in 10-15 years' period from 2018.

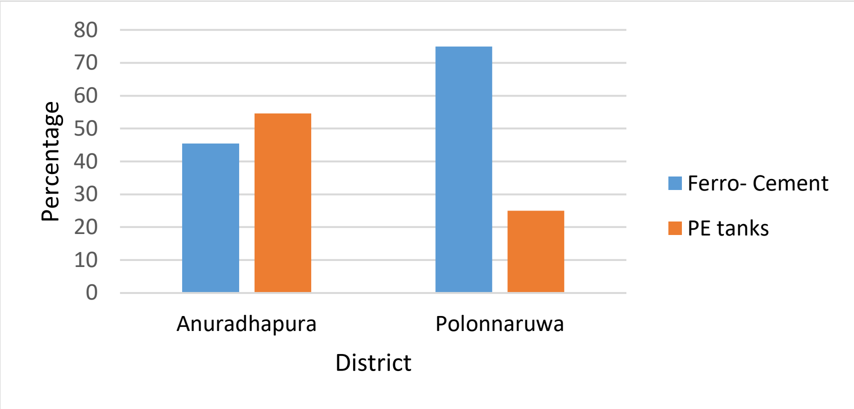
Table 5.1: Frequency of RWH Tanks (availability)

Availability of RWH tanks	Anuradhapura		Polonnaruwa		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Yes	133	63.03%	78	36.97%	211	100.00%
No	34	30.63%	77	69.37%	111	100.00%

Source: HARTI survey data, 2018

5.3.3 Building Materials of the Tanks

Figure 5.6 shows the building materials required for the RWH tanks. According to the data, 75% of the tanks are Ferro-cement in Polonnaruwa district. In Anuradhapura, 55% of the tanks are PE Tanks. According to the implementing organization majority of RWH systems implemented by NWS & DB are Plastic/PE tanks in Anuradhapura, and several other organizations mainly the LRWHF, have installed Ferro-Cement tanks.

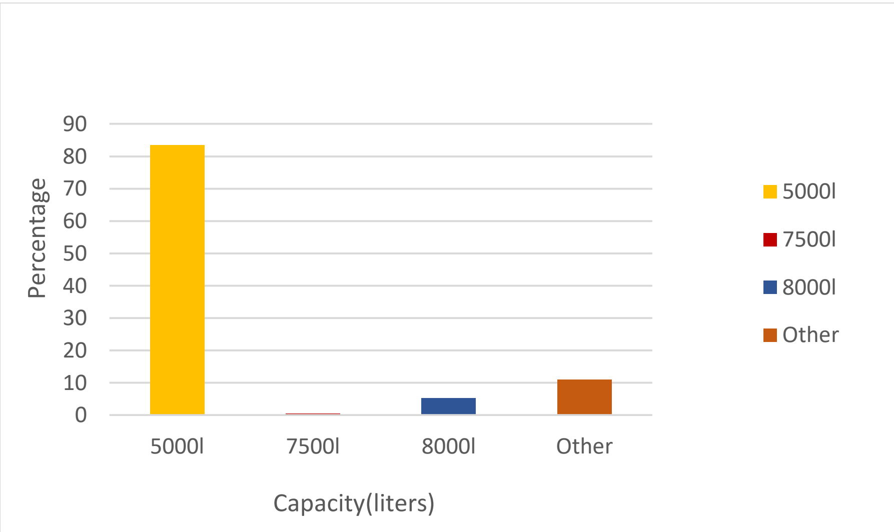


Source: HARTI survey data, 2018

Figure 5.6: Building Materials of the Tanks

5.3.4 Capacity of Rainwater Tanks

The capacity of the RWH Tanks in the sample population area ranges from 2000-10,000liters. The majority (82%) of the tanks are of 5000-liter capacity. Figure 5.7 illustrates the size distribution of tanks in the study areas.

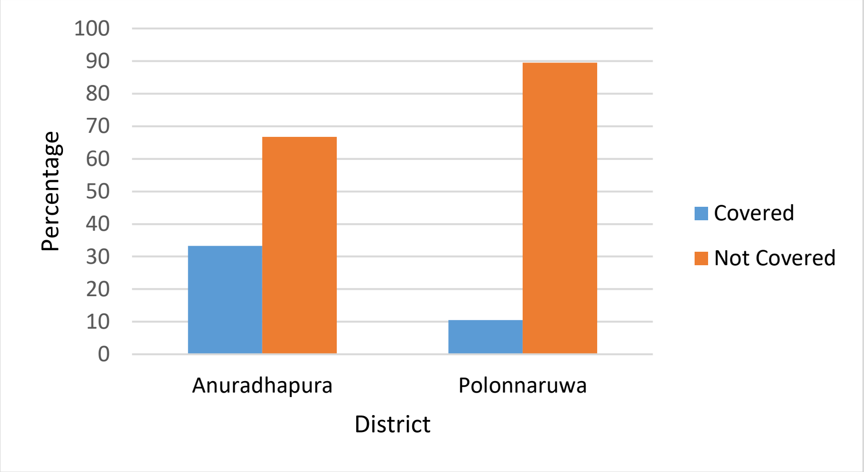


Source: HARTI survey data, 2018

Figure 5.7: Capacity of Rainwater Tanks

5.3.5 Availability of Shade for Rainwater Harvesting Systems

The survey reported that around 89**%** of the rainwater harvesting systems had no cover or shade in Polonnaruwa district and 68**%** in Anuradhapura**.** According to the survey data, there is no difference in the availability of cover between Ferro cement tanks and PE tanks**.** Majority of the covers or shades were aluminium materials and natural materials**.**

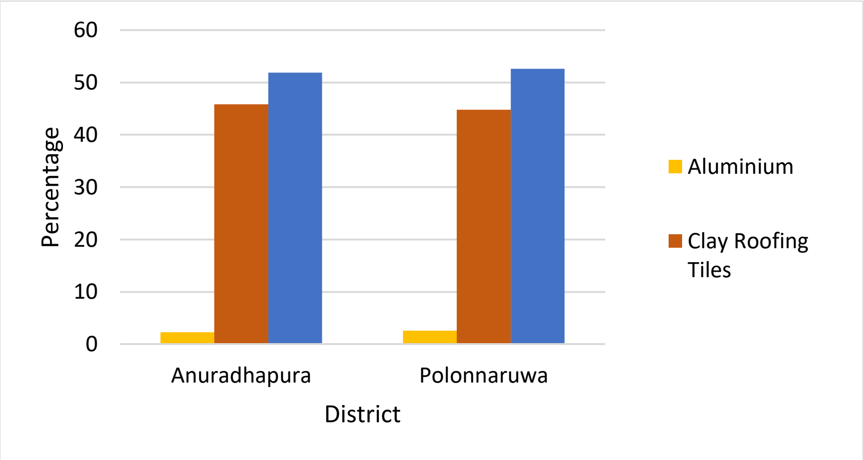


Source: HARTI survey data, 2018

Figure 5.8: Existing Situation of the Rainwater Tank Cover

5.3.6 Roofing Materials of the RWT Catchment Area

The survey informations in the study area, reveals that more than 50% of the roofs were covered asbestos sheets in both districts. Nearly 45 % had clay-roofing tiles. Many people like to have a clay tiled roof because they can use it as safe roofing material for the rainwater tank, as a safe catchment area.



Source: HARTI survey data, 2018

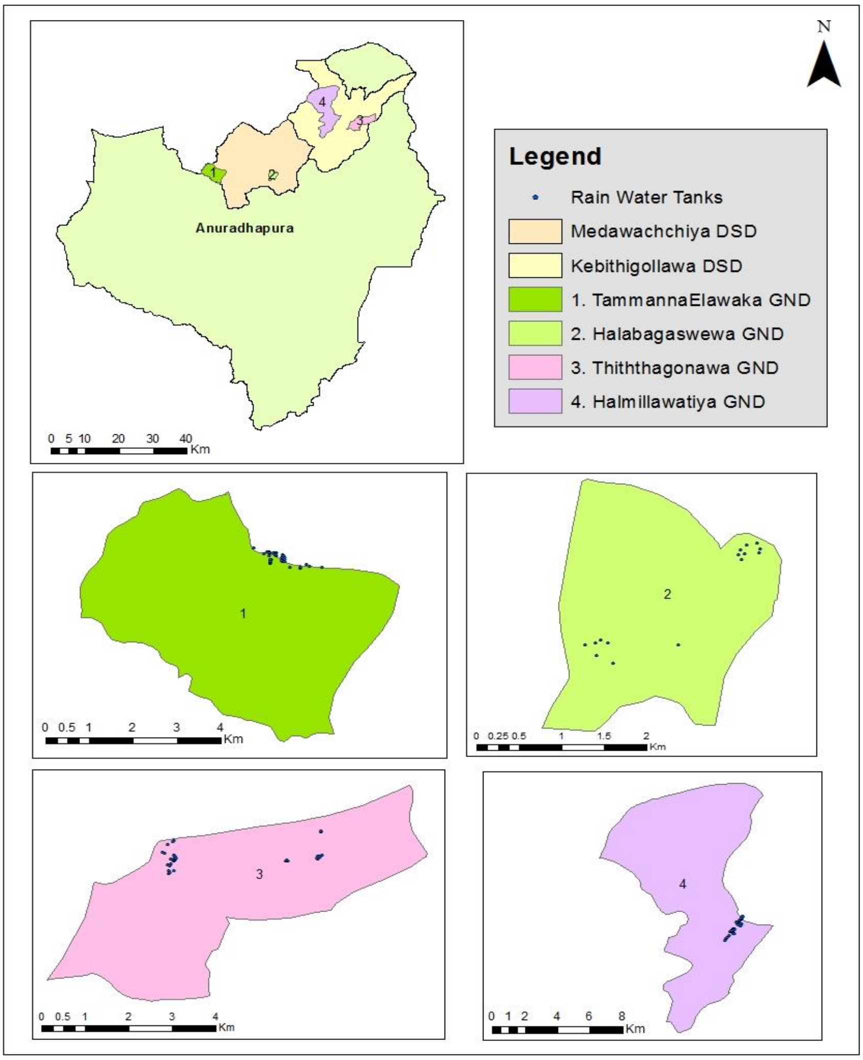
Figure 5.9: Roofing Material of the RWT Catchment Area

5.3.7 Harvested Rainwater Usage in the Study Area

A significant number of people depend on rainwater as potable because they have a rainwater tank at home. The updated number of RWH systems recorded in Anuradhapura and Polonnaruwa Districts, from the information received by the contacted organizations are Anuradhapura 5236 and Polonnaruwa 3506 (Lanka Rainwater Harvesting Forum data, 2017).

In addition, the rainwater tank can also be used as a storing tank. Duration of using the rainwater tanks in Anuradhapura and Polonnaruwa Districts depends on the extent of usage. They use rainwater for different purposes. Mostly for drinking and cooking. During the dry season, people used the harvested rainwater more, compared with the wet season. (HARTI survey data 2018).

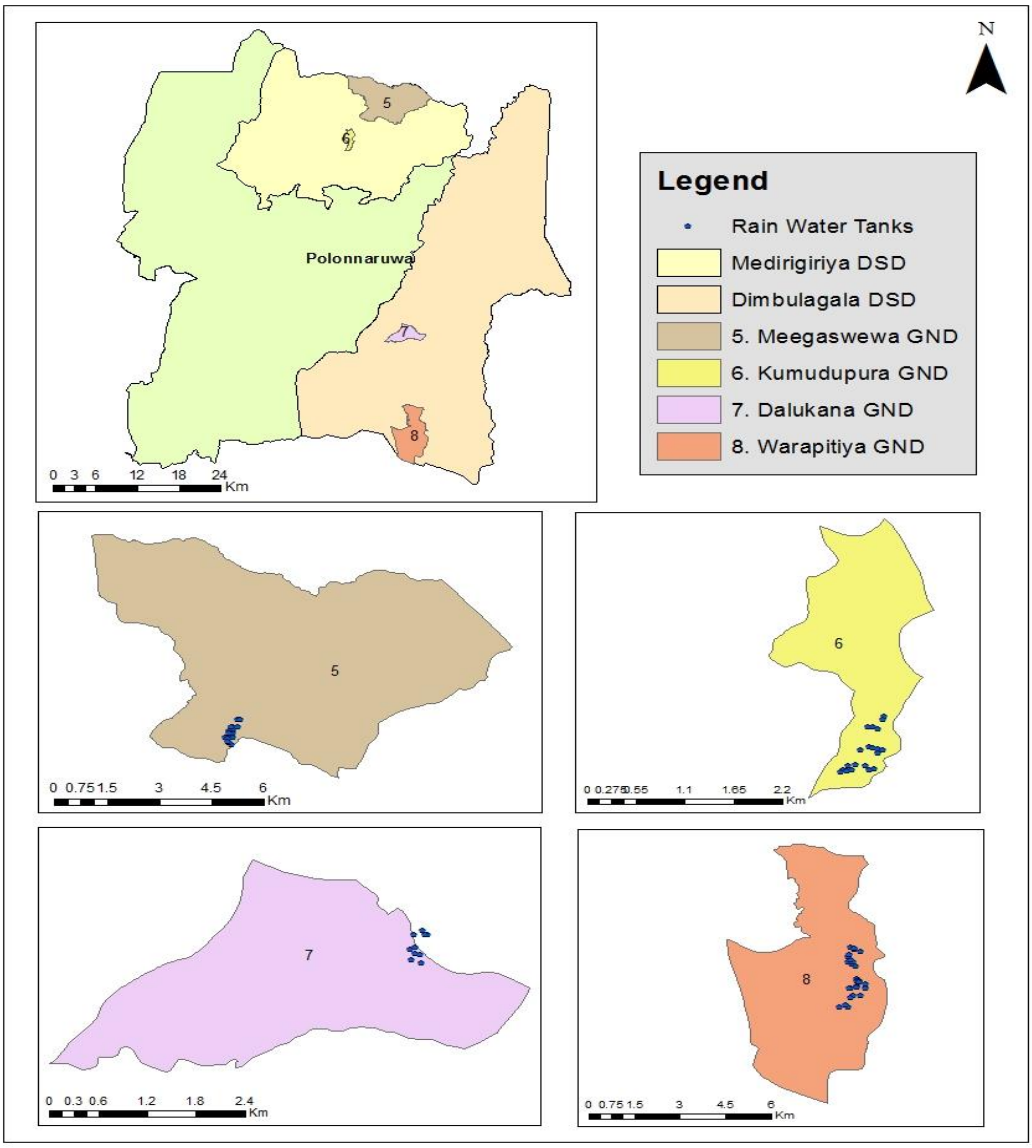
5.3.8 Locations of the RWH Tanks in Different GND's in the Study Area at Anuradhapura District



Source: HARTI survey data, 2018

Figure 5.10: Map 1: Locations of RWH in Different GND's in Anuradhapura District

5.3.9 Locations of the Selected RWH Tanks in Different GND's in the Sample Area at Polonnaruwa District

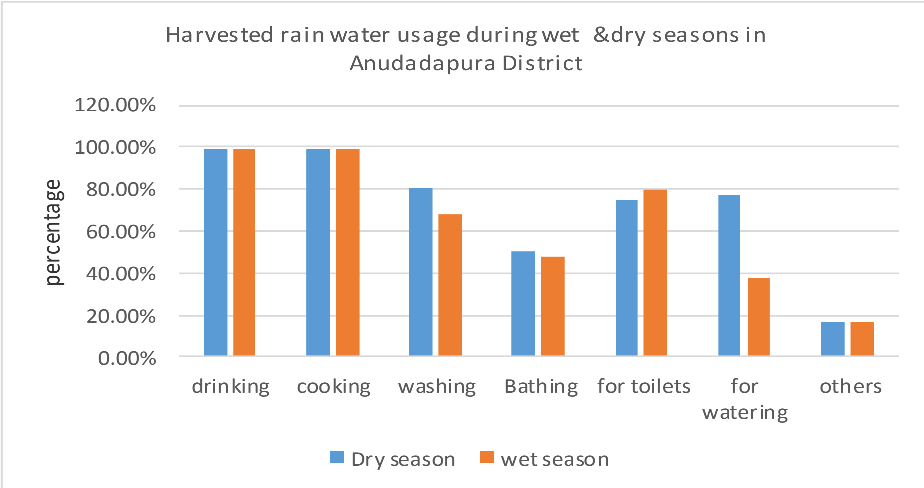


Source: HARTI survey data, 2018

Figure 5.11: Map 2: Locations of the Selected RWH Tanks in Different GND's in the Sample Area at Polonnaruwa District.

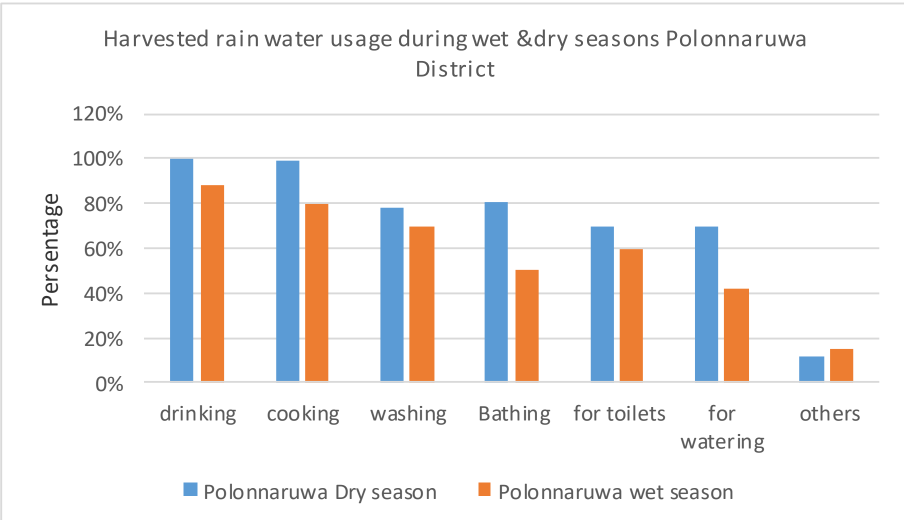
5.3.10 Harvested Rainwater Usage in Anuradhapura and Polonnaruwa

Figure 5.12 and 5.13 indicated the water usage in Anuradhapura and Polonnaruwa districts. Rainwater harvesting systems were constructed primarily to meet water security at household level by providing safe water. The harvested rainwater is used for drinking needs with or without treatment. However, people in the study area, use the RWH systems for various purposes including drinking and sanitation, cooking, washing clothes, bathing, gardening, and other household needs. Figures describe the level of practice of RWH systems for any purpose and rest are abandoned due to various reasons. The findings indicate that 62% of the rainwater harvesting tanks are being used either throughout the year or during the rainy period. However, about 33% from the total sample had been fully abandoned at the time of the survey. And another 5% of the tanks from the total sample are not used to harvest rainwater, used as a storage tank to store water from other sources.



Source: HARTI survey data, 2018

Figure 5.12: Harvested Rainwater Usage in Anuradhapura



Source: HARTI survey data, 2018

Figure 5.13: Harvested Rainwater Usage in Polonnaruwa

Among the people who have RWH tanks, percentage of rainwater users for drinking purpose were higher in Polonnaruwa district than in Anuradhapura district.

Table 5.2: Rain Water Tank Usage in Anuradhapura and Polonnaruwa Districts

Use rainwater for drinking purpose	District			
	Anuradhapura		Polonnaruwa	
	Frequency	Percentage	Frequency	Percentage
Yes	96	72.18%	65	83.33%
No	37	27.82%	13	16.67%
Total	133	100.00%	78	100.00%

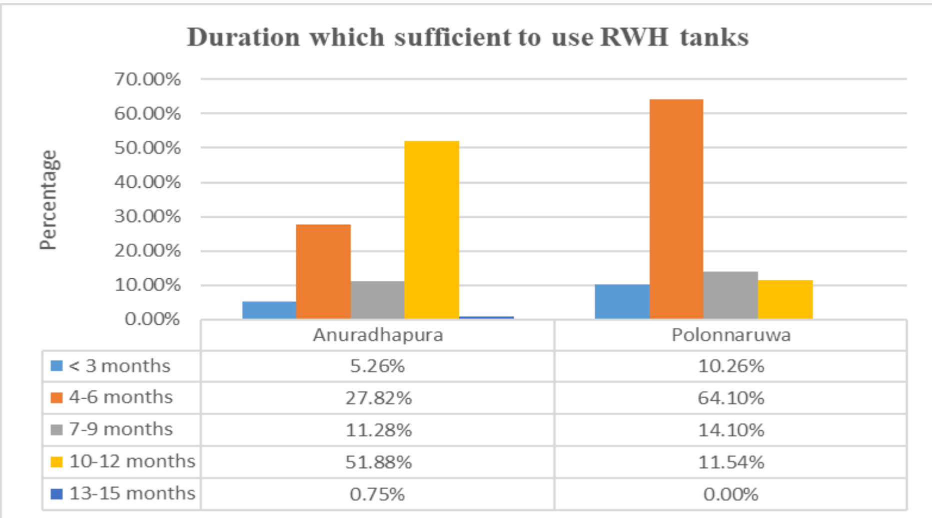
Source: HARTI survey data, 2018

5.3.11 Duration of Using the Rainwater Tanks

According to the survey data, nearly 28% of the consumers in Anuradhapura and 64% in Polonnaruwa can use their 5000 liters rainwater tank for about 4-6 months. If they fill the tank once, 52% use it for 10-12 months in Anuradhapura and 12% in Polonnaruwa.

A significant difference in water use in both districts. In Anuradhapura, 52% can keep their tank for 10-12 months; this may be due to the awareness. Because according to our survey data we observed, In Anuradhapura, there are more rainwater tanks and more training programs about rainwater harvesting, had been conducted in Anuradhapura.

According to our observation 80% of the rainwater tank owners told, they can fill the 5000L tank; two times within the year, and 14% can fill only one time for a year and 5% can fill three times for a year (HARTI survey data, 2018).



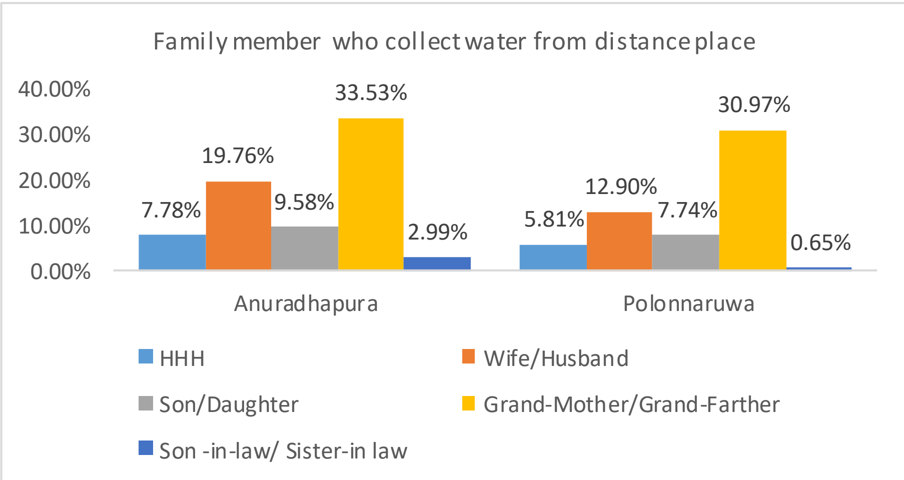
Source: HARTI survey data, 2018

Figure 5.14: Duration of Using the Rainwater Tanks

5.4 Reasons for Adapting to a Rainwater Tank and the Problems Faced when Collecting Water from other Water Sources.

5.4.1 Family Involvement in Collecting Water

In terms of survey data, nearly 10% of water samples collected from water sellers were not in the safe range (HARTI, survey data 2018). The existing water sources, now in use, do not have enough water throughout the year. Sometimes water sources, near the house do not have suitable water for drinking. Due to this problem, most of the people depend on common well water. They have to travel long distances to look for water (HARTI survey data, 2018) According to our survey data, nearly 34% of elder people involve in collecting water for their household use. This was perceived this in both districts (Figure 5.15). Because of most of the time youths are involved more in agricultural activities. Nearly 10% of small children also engaged in these activities (Figure 5.15). They have to waste their valuable time for this. Majority of people have to travel more than the 500m distance to bring water during both seasons.

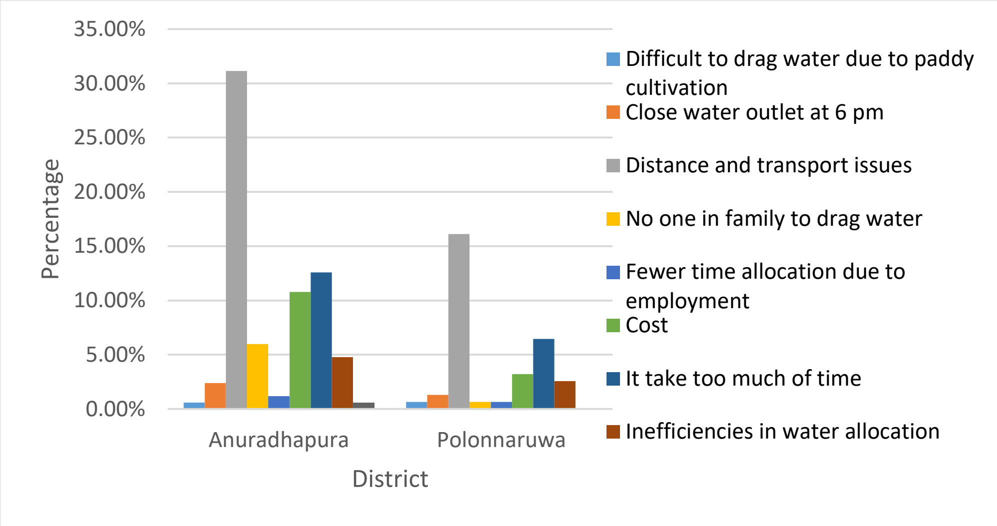


Source: HARTI survey data, 2018

Figure 5.15: Family Members Involved in Collecting Water

5.4.2 Problems Face in the Collection of Water

According to the survey data, a total of 167 HH from Anuradhapura and 155 HH from Polonnaruwa. They have to face many problems when collecting water, for their drinking purposes. People in these areas have many water quality problems because the existing water source does not have enough water throughout the year, groundwater contamination problems in the area and the CKDu are the problems they have to face. Due to these problems people in these areas use to drink RO plant water and filter water. Sometimes RO plant selling points close at 6 pm, after that time they could not get water. Distance to travel and the transport issue is the main factors. Some times with the cultivation activities, they could not get time to bring water for their houses. At such time, family members expressed, they use to drink less water to save the water they have at home.

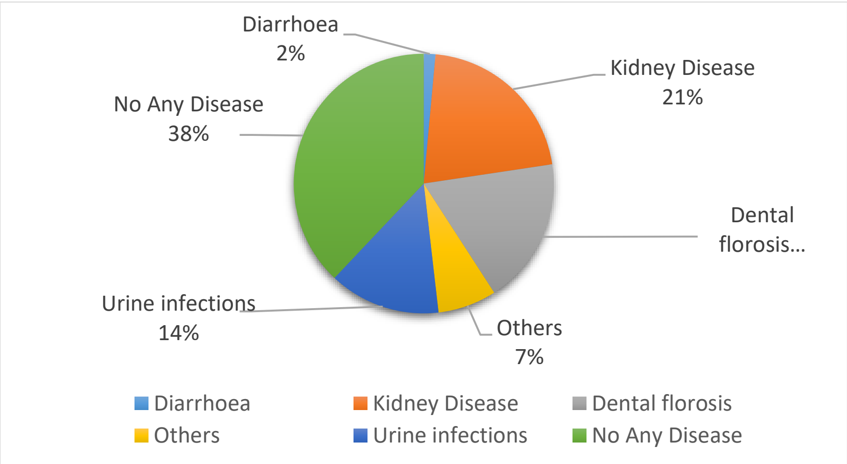


Source: HARTI survey data, 2018

Figure 5.16: Problems Faced when Collecting Water

5.4.3 Diseases due to the Drinking of Impurity Water

People think water is a factor for their health issues, conferring to our questionnaire survey in the study area 21% of them suffering from Kidney diseases of unknown etiology, 18% dental fluorosis and 14% from urine infections (HARTI survey data, 2018). According to the secondary data, usage of unclean water is one factor for these illnesses.



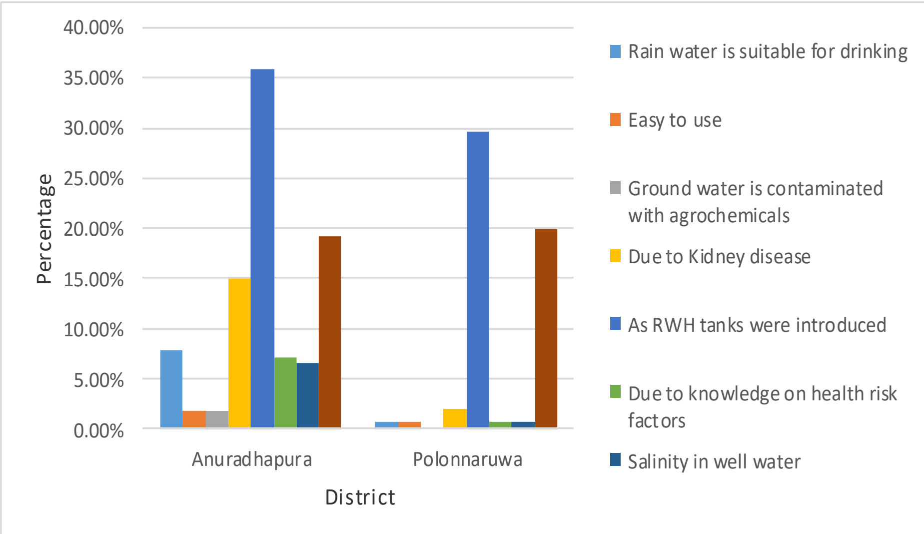
Source: HARTI survey data, 2018

Figure 5.17: Diseases due to the Drinking of Impurity Water

5.4.4 Reason for Adapting to a Rainwater Tank

Some people have to travel a long distance to bring water, they have to devote a lot of money and time on this. If they have a rainwater tank at their premises, it will be an advantage for them. They can reduce transportation cost and save time. They can use that time for leisure and other activities.

Availability of the rainwater tank at home, people perception on rainwater for drinking, and the existing water source do not have enough water throughout the year, groundwater is contaminated in the area, and kidney disease are the major factors in selecting the rainwater tanks. Figure 5.18 illustrated the reasons for using rainwater harvesting systems. According to the survey data, there are many factors affecting for selection of rainwater for drinking. Distance to travel to bring water is the main factor effect for selecting rainwater tank.



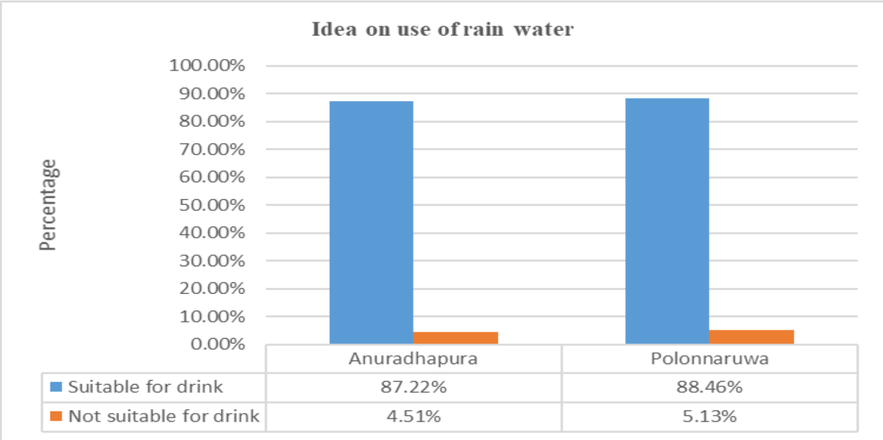
Source: HARTI survey data, 2018

Figure 5.18: Reason for Adapting to a Rainwater Tank

5.5 Villager's Awareness of Using Rainwater Tanks

5.5.1 Perception about the Drinking of Rainwater

According to survey data, 87% of people had a positive impression of drinking rainwater. Most of the people use to drink rainwater without any purification practices.



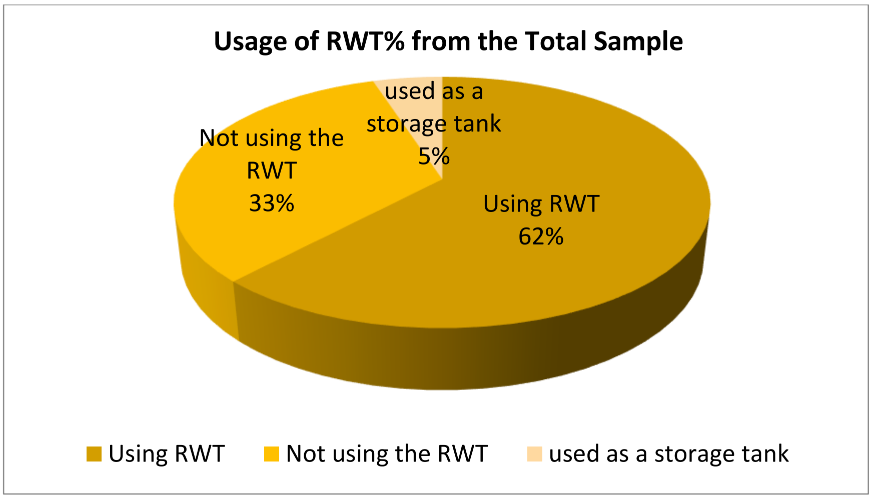
Source: HARTI survey data, 2018

Figure 5.19: Perception about the Drinking of Rainwater

According to survey data, 85%, from the people who do not have a rainwater tank, admitted rainwater is suitable for drinking and the desire to use a RWT (HARTI survey data, 2018).

5.5.2 Usage of Rainwater Tanks in the Study Area

According to the survey data, from the total sample, 62% used rainwater tanks, and 33% of them not using their tank, due to different issues (figure 5.20). And 5% of them use it as a storage tank, to collect, water from different sources. Since they could not fill their tank with the rains. There are many reasons for these issues, like no one at home to clean the tank, don't have awareness about the filling time, without having the tank cover, impure roof, inadequate roof area and some of them have uncertainty about the drinking of rainwater. This will highlight the training and awareness requirement for rainwater tank usage are remedial measures.



Source: HARTI survey data, 2018

Figure 5.20: Usage of Rainwater Tanks in the Study Area

Table 5.3: Average Rainwater Consumption for Drinking Purposes for a Five-member Family

District	Consumption Level (Liters per day)
Anuradhapura	12.34
Polonnaruwa	15.57

Source: HARTI survey data, 2018

According to the survey, data, for a five-member family monthly drinking water requirement is 371liters in Anuradhapura and 468 liters in Polonnaruwa. According to the Department of Health, recommended drinking 5 liters per day. According to that, the monthly water requirement for a 5 - member family is 750 liters. For a 5-member family they can use the 5000 L rainwater tank for 6 months to fulfill their drinking water requirement. According to our observations 80%of the rainwater tank owners claimed, they can fill the 5000L tank two times within the year (Figure 5.14).

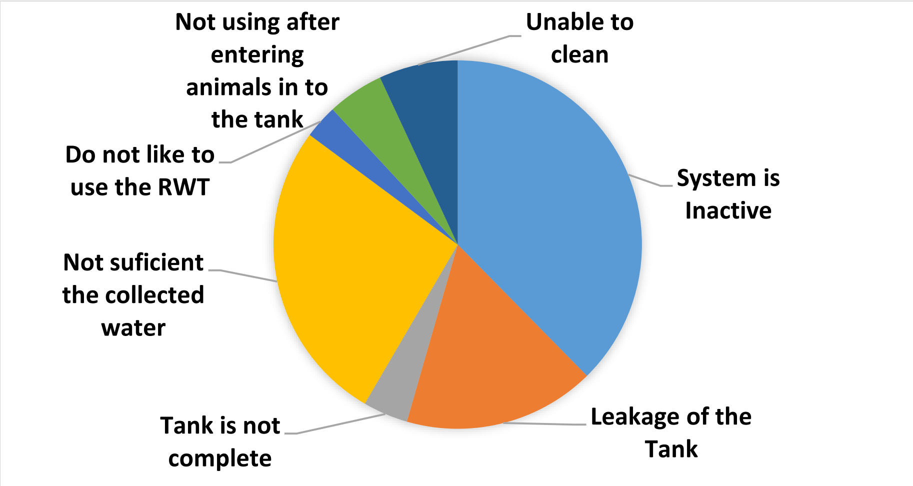
Table 5.4: Method of Using Rainwater as a Drinking Water Source

Frequency table				
District	**Boil**	**Filter**	**Do not filter**	**Total (with RWH tanks)**
Anuradhapura	7	78	12	133
Polonnaruwa	6	40	22	78

Source: HARTI survey data, 2018

5.5.3 Reason for Not Using the Tank

As (Figure 5.21) conveys a different reasons were adduced for not using their rainwater tank. The main thing is, the system is inactive, people have a different perception on, not using the tank 40% told tank filtration system is inactive, due to this reason there are not using the tank.28% of they told tank is not sufficient, this may be because the 5000 L tank is not sufficient for them with the family size (families with more than six members). The main reasons for not using these tanks were operational and mainteinance problems, which they have to face. From the sample, 70% is operational and maintenance problems. This will highlight the training and awareness requirement in rainwater tank usage.



Source: HARTI survey data, 2018

Figure 5.21: **Reasons for Not Using the Tank**

5.5.4 Distribution of Kdney Patients in the Study Area

North Central Province (NCP) in Sri Lanka reports the highest number of CKDu patients and mortality rates due to CKDu (Wanigasuriya, 2012). The NCP consists of two administrative Divisions namely Polonnaruwa and Anuradhapura Districts. Anuradhapura District reports the highest number and Polonnaruwa District reports the second-highest number of CKD patients. In the study area, which is a major agricultural area, Chronic Kidney Disease (CKDu) is a major health problem. The North Central Province is the worst affected province of CKDu. Northcentral, Province has been categorized as a CKDu endemic area.

Around 50% of the CKDu patients have died within the first year of diagnosis and more than 90% had died within a period of seven years since diagnosis. Only a few have survived more than five years after being diagnosed. The duration a person survives after being diagnosed of CKDu depends on how early the disease is identified and on how well the treatment is received and quality of life is maintained with good health practices, as drinking good quality water (Jayasinghe, 2011**).** The total number of CKDu patients in Anuradhapura was 14430 and 5890 in Polonnaruwa until 2015(Jayasumana, 2016).

Table 5.5: Distribution of Kidney Patients in Anuradhapura and Polonnaruwa Districts 2003 -2015 (in the study area)

Districts	Population	No.of DS Areas	Population Range of DS	No.of GND Areas	Total Number of Kidney Patients in the Study Area	
Anuradhapura	856232	22	22227-69590	557	Madawachchiya	2973
					Kabithigollewa	1020
Polonnaruwa	403335	07	364224-82138	292	Madirigiriya	1942
					Dibulagale	1382

Source: Ministry of Health data and Jayasumana C.S., 2016.

The total population of each DS and the total kidney patients of the area are indicated in this table.

Table 5.6: Yearly Distribution of Kidney Patients in Anuradhapura and Polonnaruwa Districts 2003 -2015 (in the study area)

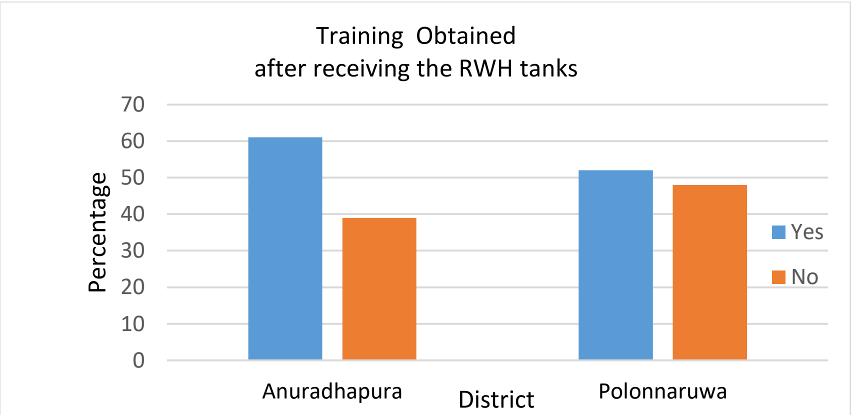
Year	2003-2008	2009	2010	2011	2012	2013	2014	2015
Anuradhapura								
Madawachchiya	1157	177	231	197	157	248	525	466
Kabithigollewa	532	151	137	66	100	120	250	222
Polonnaruwa								
Madirigiriya	497	101	134	145	121	268	339	337
Dibulagale	352	101	151	140	133	160	135	210

Source: Jayasumana C.S.2016.

Distribution of kidney patients in Anuradhapura and Polonnaruwa Districts 2003-2015 in the study area is illustrated in this table. Which notes that, the total number of patients proportionately increasing with the years, in most of the DS Divisions.

5.5.5 Training Obtained on RWT Usage

The survey data, figures out that 52% from Polonnaruwa and 61 % from Anuradhapura had received training on rainwater tank usage and maintenance at the initial stage, but 48% in Polonnaruwa and 39% from Anuradhapura did not have the training, at the time, they received the tank. This will highlight the training and regular monitoring of tanks, are of timely importance. A database of RWT owners is a timely requirement because according to the climatic zones, it is important to develop an app or a communication system to inform the RWT users about the rainwater collection time with the help of weather forecasts and weather predictions.



Source: HARTI survey data, 2018

Figure 5.22: Training Obtained on RWT Usage

CHAPTER SIX

RESULTS AND DISCUSSION

The Quality of the Rainwater and Other Water Sources in the Study Area

6.1 Introduction

This section discusses the parameters of water quality (important chemical, physical and biological parameters) of stored rainwater tanks in total number of 100 water samples. Determined water quality parameters of 100 samples from other water sources too was tested. RO plants filter water, well water and water samples from water sellers of relevant areas. The chemical, physical and biological parameters were identified using water quality testing. Sampling was done covering all the 8GN divisions, during the sampling period, in Anuradhapura and Polonnaruwa Districts.

6.2 Quality of Rainwater and Other Water Sources in the Study Area

6.2.1 Water Quality Parameters of Rainwater Tanks in Anuradhapura District

Kabithigollewa and Madawachchiya DS divisions were selected. And 50 rainwater samples were analyzed in this area during the months of April to August 2018. Sample were taken from the harvested rainwater from rains during December 2017. The mean, maximum and minimum and stranded division values of variables Parameters (Physical/Chemical &Biological) in each sampling group are given in Table 6.1 along with (SLS 614:2013) (UDC 663.6) recommended maximum permissible limits.

Table 6.1: Water Quality Parameters of Rainwater Tanks in Kabithigollewa and Madawachchiya DS Divisions

	Anuradhapura (Kabithigollewa) n =23				Anuradhapura (Madawachchiya) n =23				Maximum Requirement (SLS 614:2013) (UDC 663.6)
Parameters(Physical/ Chemical & Biological)	Mean	Max	Min	S.D	Mean	Max	Min	S.D	
Turbidity [NTU]	0.9246	1.53	0.74	0.2055	0.88	1.78	0.64	0.293	**2**
pH[At 25 ^{0}C +/- 0.05 ^{0}C]	7.354	**7.98**	6.64	0.4146	7.979	8.42	7.03	0.5773	**6.5-8.5**
Total Dissolves Solids [mg/l]	37.307	75	14	18.73	100.38	**700**	20	181.65	**500**
Total Hardness (as $CaCO_3$[mg/l]	15.076	36	4	10.63	47.230	**330**	4	86.3	**250**
Flouoride (as F) [mg/l]	0.0553	0.09	0.01	0.034	0.118	**0.48**	0.01	0.124	**0.1**
Coliform Bacteria in 100ml	31.69	**340**	0	94.74	1.53	20	0	5.547	**220**
E.coli in100ml of Sample	9.38	**104**	0	28.86	0.769	10	0	2.773	**70**

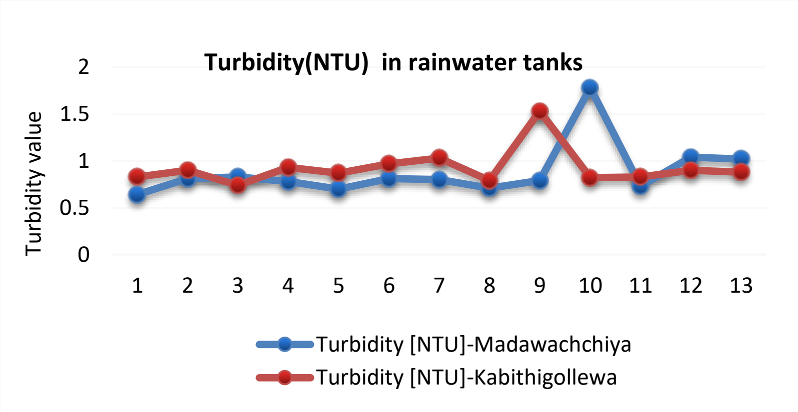
Source: HARTI survey data, 2018

Source: HARTI survey data, 2018

Figure 6.1: Ferrow Cement and PE Rainwater Tanks

When considering the water quality parameters of the rainwater samples, it was observed that total water hardness in all the samples were below the maximum requirement of 250 mg/l in both DS divisions. Only one sample from Madawachchiya exceeded standard rates as 330 mg/l. This is due to refilling the tank with surface water sources. The mean pH value varied between 6.6 -8.4 (Table 6.1) in all the DS divisions, not exceeding the maximum requirement for drinking purpose in all the 30 samples, according to the SLS 614:2013) (UDC 663.6) standards as 6.5-8.5 pH [At 25^{0} C +/- 0.050 ^{0}C].

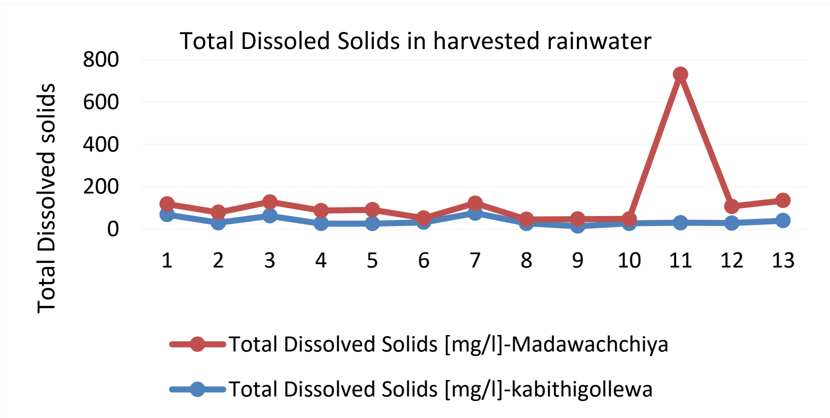
The pH, values are found to be within the recommended standards. A well designed and maintained RWH system can cause low health risks and high improvement in the health of humans (Ariyananda, 2003). This physical property is permissible for drinking, as shown in the average pH of rainwater obtained was found to be slightly acidic values in Kabithigollewa during the sampling period. But it is within the safe range.



Source: HARTI survey data, 2018

Figure 6.2: Turbidity Values in Harvested Rainwater Tanks

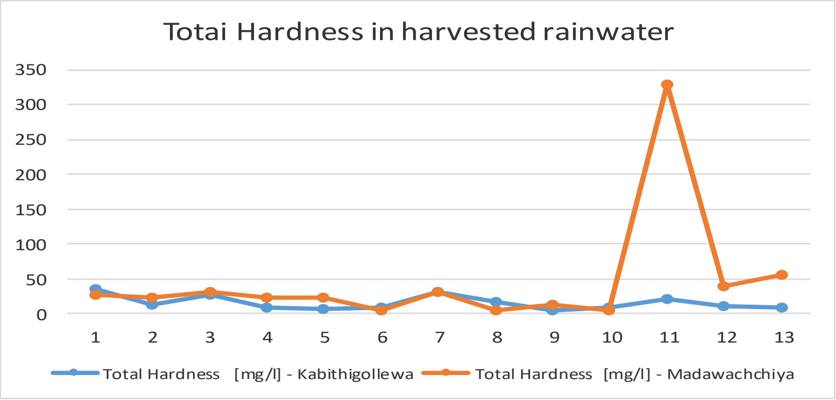
Slight turbidity has been observed in all the samples in harvested rainwater tanks in the study area but it did not exceed the recommended level (Figure 6.2). According to the data, the Turbidity of the harvested rainwater was below the maximum requirement according to SLS Standards as NTU 2. Slightly higher (1.78 NTU) turbidity has observed as the maximum turbidity in two rainwater sample in the Madawachchiya and Kabithigollewa DS divisions. Because some RWT uses, used to refile their tank with river water.



Source: HARTI survey data, 2018

Figure 6.3: Total Dissolves Solids in Harvested Rainwater Tanks

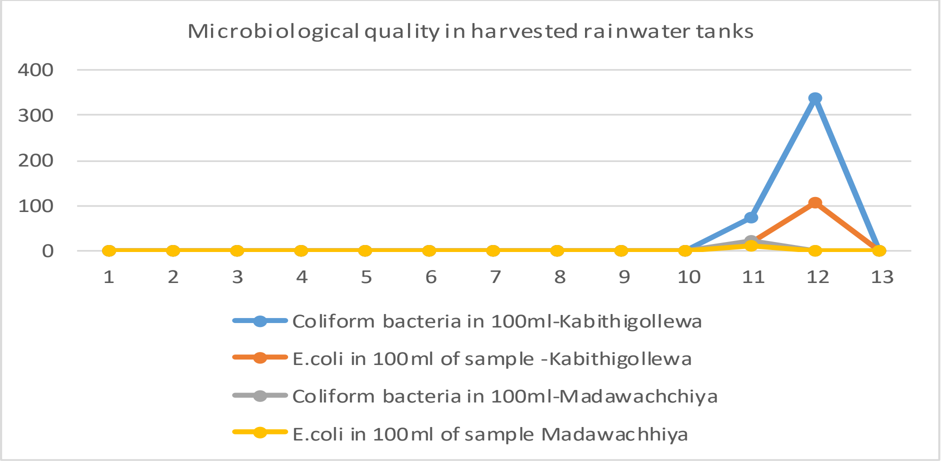
Total Dissolved Solids also straightaway related to each other in both districts, and a value below 500 mg/l is considered safe for drinking. All the samples in the Anuradhapura district did not exceed the safe range, but in only, one rainwater tank Total Dissolved Solids Content is 700 mg/l (Figure 6.3). It is due to the bad maintenance of the tank.



Source: HARTI survey data, 2018

Figure 6.4: Total Hardness in Harvested Rainwater Tanks

Total Hardness in all except one sample, were below the maximum requirement of 250 mg/l. The range of hardness varied between 4 mg/l to 330 mg/l (Figure 6.4) and is as per the standard guidelines without provoking any toxic effect on human health (without one sample in Madawachchiya). Consider the Fluoride content in harvested rainwater tanks; Fluoride (as F^-) in most of the samples was below the maximum requirement 0.1 mg/l (Table 6.1). Some tanks exceed the maximum requirement, because some rain water tank users refile their tank with river water.



Source: HARTI survey data, 2018

Figure 6.5: Microbiological Quality in Harvested Rainwater Tanks

The most common hazard in water sources obtained from roof catchments is contamination with microbial (biological and microbiological) organisms. These organisms are introduced into drinking water supplies by contamination with fecal material (from human or animal origin) or dead animals and insects. The most important indicator is the E-Coli. In this study E-coli and Coliform were found in only two rainwater tanks (Figure 6.5).

Rainwater from a well-managed tank is safe for drinking, except in heavy industrialized areas. Any contamination of water due to the contamination from the catchment system(roof), regular cleaning and maintenance of catchment area and gutters is important to ensure good quality water for drinking (Heijnen & Pathak, 2006).

6.2.2 Water Quality Parameters of Other Water Sources Used in Anuradhapura District

According to the findings, 70% of the people in this area use other water sources for their drinking purposes; shallow well water tube well water, tap water, RO plant water filter water and water from water sellers. (HARTI data 2018). Therefore, groundwater is the main drinking water resource and more than 85% of the drinking water requirements for the rural communities, which are obtained from shallow wells, deep wells and surface water. But according to our survey data, 45% of people used to buy RO plant water and filter water for drinking purposes with well water. And some in Kabithigollewa used to drink water from springs.

6.2.3 Water Quality Parameters of the Shallow Well Water in Anuradhapura District

Table 6.2: Water Quality Parameters of Well Water in Kabithigollewa and Madawachchiya DS Divisions

Well Water	**Anuradhapura(Kabithigollewa) n =11**				**Anuradhapura (Madawachchiya) n =11**				**Maximum Requirement (SLS 614:2013) (UDC 663.6)**
Parameters(Physical/ Chemical & Biological)	Mean	Max	Min	S.D	Mean	Max	Min	S.D	
Turbidity [NTU]	0.86	1.41	0.63	0.261	1.77	1.63	0.75	0.376	**2**
pH [At 25 ^{0}C +/- 0.05 ^{0}C]	7.361	7.82	6.86	0.3357	7.45	7.61	7.3	7.45	**6.5-8.5**
Total Dissolves Solids [mg/l]	351	6.37	165	138	465	729	320	190	**500**
Total Hardness (as $CaCO_3$) [mg/l]	**258**	**400**	104	87.42	**303**	**380**	**250**	59	**250**
Flouoride (as F^-)[mg/l]	**0.37**	**0.81**	**0.11**	**0.18**	**0.62**	**1.01**	**0.31**	**0.299**	**0.1**
Nitrate (as NO_3) [mg/l]	1.15	2.3	0.1	0.91	-	-	-	-	**50**
E.coli in 100ml of sample	**17.66**	**66**	**0**	**28.5**	**10**	**40**	**0**	**20**	<03
Coliform bacteria in 100ml	**123**	**400**	**92**	**189**	**40**	**160**	**0**	**80**	0

Source: HARTI survey data, 2018

The mean, maximum and minimum and stranded division values of variables Parameters (Physical/Chemical & Biological) in each sampling group are given in Table 6.2 along with **(**SLS 614**:**2013**)** **(**UDC 663**.**6**)** recommended maximum permissible limits. Table 6.2 shows, the water quality parameters of the well water in Anuradhapura, Kabithigollewa DS Division. Well -water samples were analyzed in this area during the months of April to August 2018. According to the results, most of the wells had clear water with turbidity less than 2NTU. The pH of water varied between 6.8 and 7.8(Table 6.2). All the wells show pH within the permissible limit of 6.5-8.5. But the total hardness and the Fluoride content were exceeding the maximum requirement in all the samples for drinking purposes. Microbial contamination in most of the well water in the sample area was observed. Tube well water also contained high amounts of hardness and Fluoride in Anuradhapura district.

Table 6.3: Water Quality Parameters of RO Plant water in Kabithigollewa and Madawachchiya DS Divisions

RO Plant Water	**Anuradhapura(Kabithigollewa) n =5**				**Anuradhapura (Madawachchiya) n =5**				**Maximum Requirement (SLS 614:2013) (UDC 663.6)**
Parameters (Physical/Chemical & Biological)	Mean	Max	Min	S.D	Mean	Max	Min	S.D	
Turbidity [NTU]	0.87	0.9	0.88	0.04	0.10 5	0.12	0.09	0.02	**2**
pH [At 25 ^{0}C +/- 0.05 ^{0}C]	6.375	6.4	6.35	0.03	6.36	6.42	6.3	0.08	**6.5-8.5**
Total Dissolves Solids [mg/l]	26	27	25	1.41	32.5	34	31	2.12	**500**
Total Hardness (as $CaCO_3$) [mg/l]	**6**	**8**	4	2.82	**22**	**43**	**1**	29.6	**250**
Fluoride (as F^-) [mg/l]	0.045	0.07	0.02	0.03	0.03 2	0.07	1.66	0.13	**0.1**
Nitrate (as NO_3) [mg/l]	-	-	-	-	-	-	-	-	**-**
E.coli in 100ml of sample	0	0	0	0	0	0	0	0	<03
Coliform bacteria in 100ml	0	0	0	0	0	0	0	0	0

Source: HARTI survey data, 2018

According to our survey data, 45% of the people used to buy RO plant water and filter water for drinking purposes, according to our water quality data in its suivey period that RO plant water within the safe range in both DS Divisions in the area. Most of the water samples taken from filter water sellers were within the safe range, but, 10% of the samples water fluoride content was exceeding the standard levels for drinking purposes.

Table 6.4: Water Quality Parameters of the spring Water Samples in Kabithigollewa DS Divisions

water springs	**Anuradhapura (Kabithigollewa) n =2**				**Maximum Requirement (SLS 614:2013) (UDC 663.6)**
Parameters Physical/Chemical & Biological)	Mean	Max	Min	S.D	
Turbidity [NTU]	0.89	0.9	0.88	0.014	**2**
pH [At 25 ^{0}C +/- 0.05 ^{0}C]	6.43	7.3	5.6	0.85	**6.5-8.5**
Total Dissolves Solids [mg/l]	94.5	106	83	16.26	**500**
Total Hardness (as $CaCO_3$) [mg/l]	32	36	28	5.65	**250**
Fluoride (as F^-)	0.015	0.02	0.01	0.007	**0.1**
E.coli in 100ml of sample	0	0	0	0	**70**
Coliform bacteria in 100 ml	0	0	0	0	220

Source: HARTI survey data, 2018

Source: HARTI survey data, 2018

Figure 6.6: "**Sinhaya**" **Water Spring**

The water quality parameters of the two water springs in Anuradhapura District, there are two water springs, we used for this study. They are "Gonamadiyawa" and "Sinhaya" water springs from Anuradhapura district. People in this area used to drink spring water as a reliable water source. The mean, maximum and minimum and stranded division values of variables Parameters (Physical/Chemical & Biological) in each sampling group are given in Table 6.4 along with **(**SLS 614:2013**)** **(**UDC 663.6**)** recommended maximum permissible limits. In all the samples, water quality parameters are below the maximum requirement. Except in one sample pH value is lower than the standard values (Table 6.4).

Table 6.5: Water Quality Parameters of Filter Water in Kabithigollewa and Madawachchiya DS Divisions

Filter Water	Anuradhapur(Kabithigollewa) n =7				Anuradhapura (Madawachchiya) n =7				Maximum Requirement (SLS 614:2013) (UDC 663.6)
Parameters (Physical/Chemical & Biological)	Mean	Max	Min	S.D	Mean	Max	Min	S.D	
Turbidity [NTU]	0.61	0.69	0.4	0.045	0.66	0.69	0.64	0.035	**2**
pH [At 25 ^{0}C ∓ 0.05 ^{0}C]	7.5	7.84	7.2	0.3	7.45	7.74	7.17	0.4	**6.5-8.5**
Total Dissolves Solids [mg/l]	78	144	48	58.2	88	132	44	62.2	**500**
Total Hardness (as $CaCO_3$) [[mg/l]	**34**	**50**	**18**	22.62	**34**	**50**	**18**	22.62	**250**
Flouoride (as F^-) [mg/l]	0.13	0.14	0.11	0.03	0.17	0.17	0.13	0.02	**0.1**

Source: HARTI survey data, 2018

The mean, maximum and minimum and stranded division values of variables Parameters (Physical/Chemical & Biological) in each sampling group are given in Table 6.5 along with **(**SLS 614:2013**)** **(**UDC 663.6**)** recommended maximum permissible limits.

The survey data reveals that, 45% of people used to buy RO plant water and filter water for drinking purposes, people used to buy filter water for drinking purposes. In terms of surveys water quality data, filter water is within the safe range in both DS divisions in the area. water samples taken from filter water seller's, were within the safe range but, some (three out of seven) of the samples water Fluoride content was exceeding the standard.

Table 6.6: Water Quality Parameters of the Tube Wells in Madawachchiya DS Divisions

Tube Well Water	Anuradhapura (Madawachchiya) n =5				Maximum Requirement (SLS 614:2013) (UDC 663.6)
Parameters (Physical/Chemical & Biological)	Mean	Max	Min	S.D	
Turbidity [NTU]	0.64	0.72	0.57	1.1	**2**
pH [At 25 ^{0}C +/- 0.05 ^{0}C]	7.11	7.44	6.78	0.46	**6.5-8.5**
Total Dissolves Solids [mg/l]	636.5	704	569	95.45	**500**
Total Hardness (as $CaCO_3$) [[mg/l]	**224.5**	**420**	**29**	276	**250**
Fluoride (as F^-) [mg/l]	1.005	1.05	0.96	0.063	**0.1**

Source: HARTI survey data, 2018

Water quality parameters of the tube well water in Anuradhapura, Kabithigollewa DS division, tube well water samples were analyzed in this area during the months of April to August 2018.

The mean, maximum and minimum and stranded division values of variables Parameters (Physical and Chemical) in each sampling group are given in Table 6.6 along with **(**SLS 614:2013**)** **(**UDC 663.6**)** recommended maximum permissible limits.

As indicated, in table 6.6 all the wells had clear water with turbidity less than 2NTU. The pH of water varied between 6.7 and 7.11, and in all the tube wells, pH was within the permissible limit of 6.5-8.5. But the total hardness and the Fluoride content were exceeding the maximum requirement in some samples for drinking purposes. Tube well water also contains high amounts of hardness and the Fluoride in Anuradhapura District.

6.2.4 Water Quality Parameters of Rainwater Tanks in Polonnaruwa District

Table 6.7: Water Quality Parameters of Rainwater Tanks in Dimbulagala and Madirigiriya DS Divisions

	Polonnaruwa (Dimbulagala) n =13				**Polonnaruwa (Madirigiriya) n =13**				**Maximum Requirement (SLS 614:2013) (UDC 663.6)**
Parameters (Physical/Chemical & Biological)	Mean	Max	Min	S.D	Mean	Max	Min	S.D	
Turbidity [NTU]	0.445	2.41	0.1	0.695	0.291	0.53	0.15	0.1417	2
pH [At 25 ^{0}C +/- 0.05 ^{0}C]	7.49	8.04	6.85	0.423	7.242	7.93	6.41	0.5393	6.5-8.5
Total Dissolves Solids [mg/l]	113.3	333	74	78.18	45.5	79	8	24.43	500
Total Hardness(as $CaCO_3$) [mg/l]	70.3	200	40	44.98	29.6	48	2	14.61	250
Flouoride (as F^-) [mg/l]	0.26	**1.04**	0.01	0.330	0.0128	0.02	0.01	0.0045	0.1
E.coli in 100ml of Sample	Nil	-	-	-	Nil	-	-	-	70
Coliform Bacteria in 100ml	Nil	-	-	-	Nil	-	-	-	220

Source: HARTI survey data, 2018

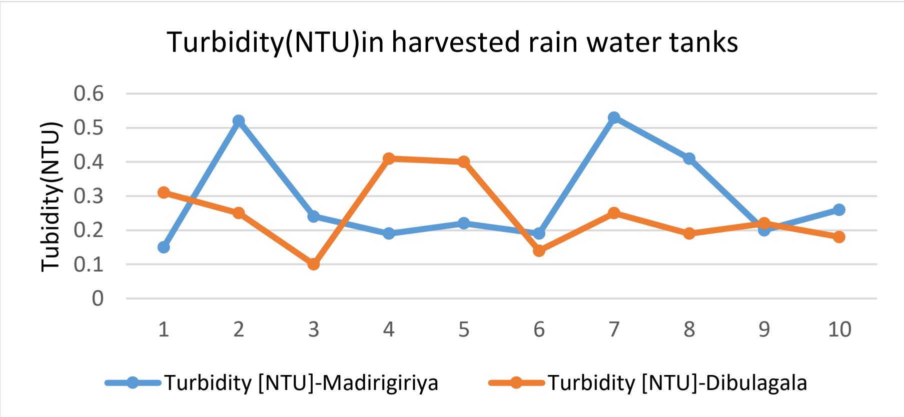
The mean, maximum and minimum and stranded division values of variables Parameters (Physical/Chemical &Biological) in each sampling group are given in Table 6.7 along with **(**SLS 614:2013**)** **(**UDC 663.6**)** recommended maximum permissible limits.

In the study locations of Dimbulagala and Madirigiriya DS divisions the total hardness as $CaCO_3$ mg/l in all the samples was below the maximum permissible level of 250 mg/l.

There were 50 rainwater samples analyzed in this area during the months April to August 2018. Most of the rainwater samples were collected from the rainwater tanks.

The turbidity of the harvested rainwater was below the maximum permissible level according to the SLS Standards as NTU 2. The mean pH value varied between 7.49 - 7.24(Table 6.7) in all the DS divisions, and it did not exceed the maximum requirement range for drinking purpose in all the 30 samples, according to the SLS 614:2013) (UDC 663.6) standards as 6.5-8.5 pH [At 25 ^{0}C +/- 0.05 ^{0}C].

All the rainwater samples in Polonnaruwa, district did not exceed the safe range, specific conductivity and Total Dissolved Solids for water. When considering the Total Hardness, in all the samples was below the maximum permissible level of 250 mg/l. The range of hardness varied between 2 mg/l to 200 mg/l and is as per the standard guidelines without provoking any toxic effect on human health. Fluoride (as F^-) in all the samples are below the maximum permissible level of 0.1 mg/l, except in one sample where exceeded the stranded level (Table 6.7). Microbiological quality in harvested rainwater tanks was at a safe level in all the samples.



Source: HARTI survey data, 2018

Figure 6.7: Turbidity in Harvested Rainwater Tanks

6.2.5 Water Quality Parameters of Other Water Sources Used in Polonnaruwa District

Table 6.8: Water Quality Parameters of Well Water in Dimbulagala and Madirigiriya DS Divisions

Well Water	Polonnaruwa(Dimbulagala) n =11				Polonnaruwa (Madirigiriya) n =11				Maximum Requirement (SLS 614:2013) (UDC 663.6)
Parameters (Physical/Chemical & Biological)	Mean	Max	Min	S.D	Mean	Max	Min	S.D	
Turbidity [NTU]	3.48	10	0.19	5.646	0.216	0.29	0.13	0.08	**2**
pH [At 25 ^{0}C +/- 0.05 ^{0}C]	6.376	6.13	5.57	0.225	6.707	7.23	6.38	0.46	**6.5-8.5**
Total Dissolves Solids [mg/l]	**136.33**	**205**	**93**	60.144	**540.6**	609	493	60.69	**500**
Total Hardness (as $CaCO_3$) [[mg/l]	56.66	70	40	15.275	**264.33**	300	230	35.019	**250**
Fluoride (as F^-) [mg/l]	**0.33**	**0.48**	0.11	-	1.41	**159**	1.29	0.159	**0.1**
Nitrate (as NO_3) (mg/l)	1.993	2.2	1.76	2.221	2	2.5	1.32	0.613	**50**
E.coli in 100ml of sample	0	0	0	0	0	0	0	0	<03
Coliform bacteria in 100ml	0	0	0	0	0	0	0	0	0

Source: HARTI survey data, 2018

The mean, maximum and minimum and stranded division values of variables Parameters (Physical/Chemical & Biological) in each sampling group are given in Table 6.8 along with **(**SLS 614:2013**)** **(**UDC 663.6**)** recommended maximum permissible limits. Analysis of the samples confirmed, most of the wells had clear water with turbidity less than 2NTU except in well number 1, where turbidity was very high. The pH of water varied between 5.5 and 7.2. Indicating a trend towards acidity. But the total hardness and the Fluoride content were exceeding the maximum permissible level in all the samples for drinking purposes. Also, this situation was observed in tube wells (HARTI survey data, 2018).

Table 6.9: Water Quality Parameters of RO Plant Water in Dimbulagala and Madirigiriya DS Divisions

RO Plant Water	**Polonnaruwa (Dimbulagale) n =5**				**Polonnaruwa (Madirigiriya) n =5**				**Maximum Requirement (SLS 614:2013) (UDC 663.6)**
Parameters (Physical/Chemical & Biological)	Mean	Max	Min	S.D	Mean	Max	Min	S.D	
Turbidity [NTU]	0.08	0.09	0.07	0.04	0.0875	0.1	0.07	0.0125	**2**
pH [At 25 ^{0}C +/- 0.05 ^{0}C]	**6.5**	**6.7**	**6.3**	**0.282**	**6.36**	**6.5**	**6.3**	**0.09**	**6.5-8.5**
Total Dissolves Solids [mg/l]	9.5	10	9	0.707	38.5	46	31	7.593	**500**
Total Hardness(as $CaCO_3$) [[mg/l]	1.5	2	1	0.7	3.25	5	1	1.7078	250
Flouoride (as F^-) [mg/l]	0.02	0.03	0.01	0.014	0.005	0	0.01	0.0057	**0.1**
Nitrate (as NO_3) (mg/l]	1.2	1.4	0.2	0.12	1.385	1.85	0.31	0.7228	**-**
E.coli in 100ml of Sample	0	0	0	0	0	0	0	0	<03
Coliform Bacteria in 100ml	0	0	0	0	0	0	0	0	0

Source: HARTI survey data, 2018

The mean, maximum and minimum and stranded division values of variables Parameters (Physical/Chemical & Biological) in each sampling group are given in Table 6.9 along with **(**SLS 614:2013**)** **(**UDC 663.6**)** recommended maximum permissible limits.

RO plant water was within the safe range in both DS divisions in the study area. Most of the RO plant water samples were within the safe range but in some samples (eight out of ten samples), water acidity was high because the pH content was lesser than the standard range 6.5-8.5(Table 6.9). Other water quality parameters were within the safe range in both DS Divisions.

Table 6.10: Water Quality Parameters of Filter Water Samples in Dimbulagala and Madirigiriya DS Divisions

Filter Water	Polonnaruwa (Dimbulagale) n =7				Polonnaruwa (Madirigiriya) n =7				Maximum Requirement (SLS 614:2013) (UDC 663.6)
Parameters (Physical/Chemical & Biological)	Mean	Max	Min	S.D	Mean	Max	Min	S.D	
Turbidity [NTU]	0.255	0.3	0.21	0.063	0.353	0.72	0.17	0.317	**2**
pH [At 25 ^{0}C +/- 0.05 ^{0}C]	7.18	7.49	6.87	0.438	6.7	6.99	6.57	0.211	**6.5-8.5**
Total Dissolves Solids [mg/l]	52	96	8	62.225	19.66	36	8	14.571	**500**
Total Hardness (as $CaCO_3$) [[mg/l]	30.5	60	1	41.71	3	4	2	1	**250**
Flouoride (as F^-) [mg/l]	**0.11**	**0.21**	**0.01**	**0.141**	**0.01**	**0.01**	**0.01**	**0**	**0.1**
Nitrate (as NO_3) [mg/l]	1.32	1.76	0.88	0.622	1.906	2.64	1.32	0.672	-
E.coli in 100ml of Sample	0	0	0	0	0	0	0	0	<03
Coliform Bacteria in 100ml	0	0	0	0	0	0	0	0	0

Source: HARTI survey data, 2018

The mean, maximum and minimum and stranded division values of variables Parameters (Physical/Chemical & Biological) in each sampling group are given in Table 6.10 along with **(**SLS 614:2013**)** **(**UDC 663.6**)** recommended maximum permissible limits.

Most of the filter water samples generally were within the safe range but, a few of the samples three out of ten) water fluoride content was exceeding the standards.

Table 6.11: Water Quality Parameters of Wewa in Dimbulagala and Madirigiriya DS Divisions

Surface Water Sources (wewa)	Polonnaruwa (Madirigiriya) n =4				Maximum Requirement (SLS 614:2013) (UDC 663.6)
Parameters (Physical/Chemical & Biological)	Mean	Max	Min	S.D	
Turbidity [NTU]	**2.775**	**2.9**	**2.65**	0.176	**2**
pH [At 25 ^{0}C+/- 0.05 ^{0}C]	**6.465**	**6.52**	**6.41**	0.0778	**6.5-8.5**
Total Dissolves Solids [mg/l]	60.5	63	58	3.535	**500**
Total Hardness (as $CaCO_3$) [[mg/l]	17.5	20	15	3.53	**250**
Fluoride (as F^-) [mg/l]	0.075	0.09	0.06	0.0212	**1**
Nitrate (as NO_3) [mg/l]	2.207	3.1	1.76	0.773	**10**
E.coli in 100ml of sample	**50**	**70**	**30**	28.28	<03
Coliform bacteria in 100ml	**98.33**	**220**	**75**	91.31	0

Source: HARTI survey data, 2018

In Madirigiriya some people used to drink water from wewa, and the analysis of water samples from this source indicated that, Nitrate and Microbial contaminations were exceeding the safe range for drinking. The water samples collected from wewa were contaminated with E. coli and Coliform bacteria (HARTI survey data, 2018). All the water samples exceeded the permissible level of turbidity 2NTU. The pH of water varied between 6.4 and 6.6, indicating a trend towards acidity. But the total hardness and the Fluoride contents did not exceed the maximum permissible level in all the samples. (HARTI survey data, 2018).

Table 6.12: Water Quality Parameters of Tube Well Water Samples in Dimbulagala and Madirigiriya DS Divisions

Tube well Water	**Polonnaruwa (Dimbulagala) n =5**				**Maximum Requirement (SLS 614:2013) (UDC 663.6)**
Parameters(Physical/Chemical & Biological)	Mean	Max	Min	S.D	
Turbidity [NTU]	0.85	**2.12**	0.21	1.10	**2**
pH [At 25 ^{0}C +/- 0.05 ^{0}C]	**6.69**	**7.13**	**6.4**	0.39	**6.5-8.5**
Total Dissolves Solids [mg/l]	311.66	**502**	146	179.27	**500**
Total Hardness (as $CaCO_3$) [[mg/l]	160	**270**	70	101.48	**250**
Fluoride (as F^-) [mg/l]	0.593	**1.04**	0.21	0.418	**1**
Nitrate (as NO_3^-) [mg/l]	1.326	1.78	0.88	0.450	**10**
E.coli in 100ml of Sample	0	0	0	0	<03
Coliform Bacteria in 100ml	0	0	0	0	0

Source: HARTI survey data, 2018

The mean, maximum and minimum and stranded division values of variables Parameters (Physical/Chemical & Biological) in each sampling group are given in Table 6.12 along with **(**SLS 614:2013**)** **(**UDC 663.6**)** recommended maximum permissible limits.

Water quality parameters of the tube well water in Polonnaruwa, Dimbulagala DS division, tube well water samples were analyzed during the months of April to August 2018. The analysis confirmed that, most of the wells had clear water with turbidity lesser than 2NTU except one tube well recorded maximum value as 2.12 NTU. The pH of water varied between 6.4 and 7.13. All the tube wells, pH within the permissible limit of 6.5-8.5. But the total hardness, Nitrate, and the Fluoride content were exceeding the maximum permissible level in most of the samples for drinking purposes. Tube well water contains significant amounts of Nitrates in the sample area.

Table 6.13: Water Quality Parameters Water from Water Sellers in the Study Area

Filter Water	**Polonnaruwa n =7**				**Anuradhapura n =7**				**Maximum Requirement (SLS 614:2013) (UDC 663.6)**
Parameters (Physical/Chemical & Biological)	Mean	Max	Min	S.D	Mean	Max	Min	S.D	
Turbidity [NTU]	0.265	0.3	0.21	0.063	0.353	0.71	0.07	02317	**2**
pH [At 25 ^{0}C+/- 0.05 ^{0}C]	7.28	7.8	6.87	0.438	6.7	6.99	6.57	0.211	**6.5-8.5**
Total Dissolves Solids [mg/l]	52	196	18	62.225	19.66	136	28	14.571	**500**
Total Hardness (as $CaCO_3$)[[mg/l]	98	169	41	51.71	120	174	42	71	**250**
Flouoride (as F^-) [mg/l]	**0.51**	**0.2**	**0.01**	**0.141**	**0.5**	**0.01**	**0.01**	**0**	**1**
Nitrate (as NO_3^-) [mg/l]	5.32	1.76	0.88	0.622	1.906	7.64	1.32	0.672	**10**
E.coli in 100ml of Sample	0	0	0	0	0	0	0	0	<03
Coliform Bacteria in 100ml	0	0	0	0	0	0	0	0	0

Source: HARTI survey data, 2018

Water quality parameters of the 30 water samples from water sellers in Polonnaruwa and Anuradhapura districts were analyzed during the months of April to August 2018. According to the results, most of the samples had clear water with turbidity lesser than 2NTU. The pH of water varied between 6.5 and 7.8. All the samples pH value was within the permissible limit of 6.5-8.5. But the total hardness in the samples of water sellers was 41 -174 mg/l.

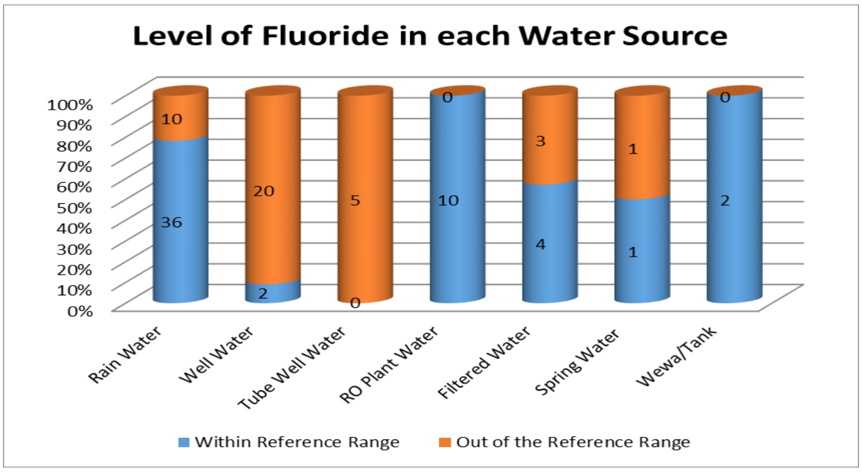
The Fluoride content exceeded the maximum permissible level for drinking purposes in most of the samples. In three samples, Nitrate as Nitrogen content was reaching the stranded levels. And 10% of the samples, tested exceeded the standard levels in Fluoride levels and Nitrate content reaching the stranded. 10% of all the 30 samples were not suitable for drinking purposes.

6.2.6 The General Distribution of the Quality of Rainwater and Other Water Sources in the Study Area

Level of Fluoride in each water source

Figure 6.8 indicates the general distribution of the rainwater and other water sources Fluoride level in the study area. According to the distribution, all the tube wells exceeded the reference level. This was proved by some findings as Fluoride levels in the dry zone groundwater in NCP have been found to be in a higher range (0.2–8 mg/l) compared to those of the wet zone (0.2–0.8 mg/l) in Sri Lanka (Jayawardana et al., 2010*).* Fluoride in water may cause long-term adverse effects on human health, such as severe dental Fluorosis, Skeletal Fluorosis and weakened bones (Fawell et al., 2006). Fluoride in water may cause long-term adverse effects on human health, such as severe dental Fluorosis, Skeletal Fluorosis and weakened bones (Fawell et al., 2006).

From the 22 well water samples, only two samples were within the reference range.RO water was free from Fluoride. From the 46 rainwater tanks, 10 samples exceeded the tolerance range. This is due to the refilling of rainwater tanks with river water. Due to the literature rainwater absence with Fluoride.

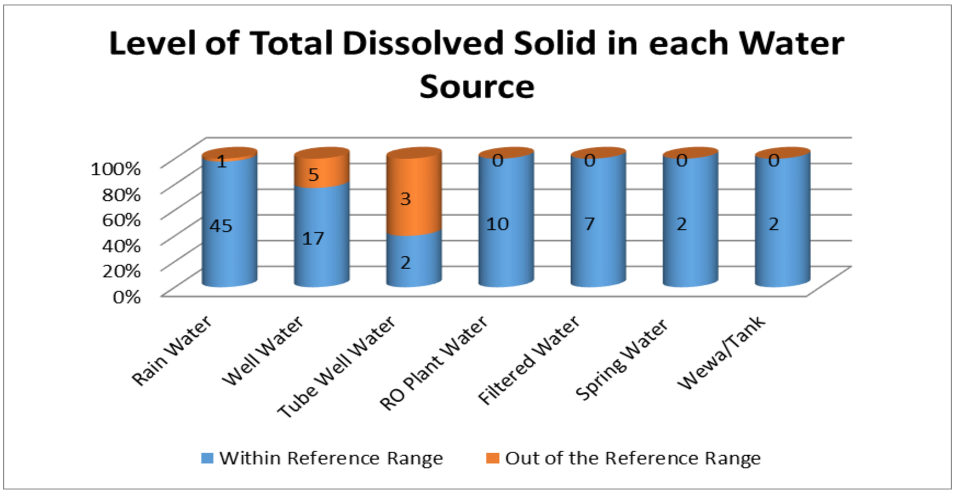


Source: HARTI survey data, 2018

Figure 6.8: **Level of Fluoride in Each Water Source**

Level of Total Dissolved Solid in Each Water Source

Figure 6.9 indicates the general distribution of the rainwater and other water sources TDS level in the study area. According to the distribution, some tube wells exceeded the reference level. From the 22 well water samples, 17 samples were within the reference range. RO water was free from TDS. RO water is within the permissible TDS range. Out of the 46 rainwater tanks, only one sample exceeded the permissible level.

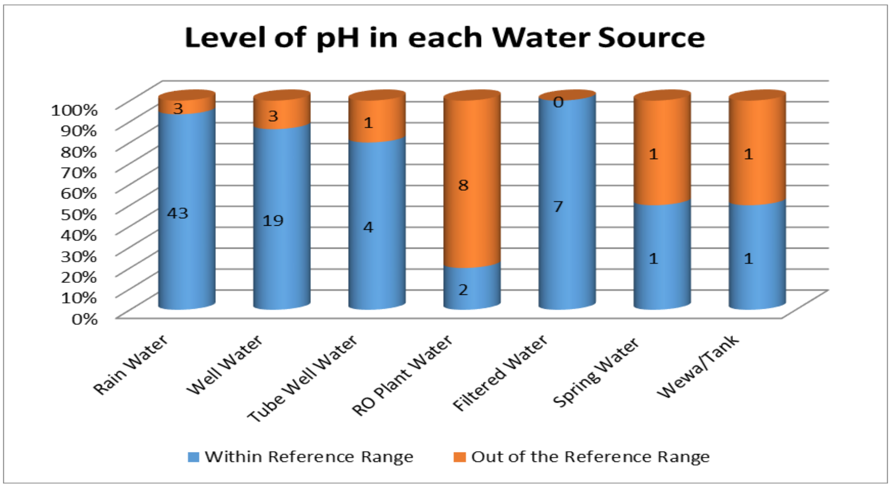


Source: HARTI survey data, 2018

Figure 6.9: **Level of Total Dissolved Solid in Each Water Source**

Level of pH in Each Water Source

The pH was high in the new ferro-cement rainwater tanks because of cement getting dissolved with water. This improved after the tanks were washed and flushed two or three times. Only 7% exceeds the stranded levels. Out of eight from tested RO, plant water exceeded the standard levels.

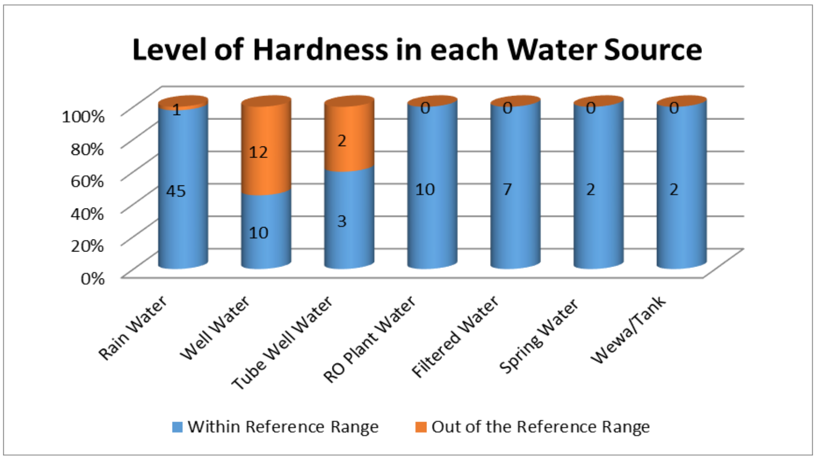


Source: HARTI survey data, 2018

Figure 6.10: Level of pH in Each Water Source

Level of Hardness in Each Water Source

Recommended standards on the total hardness of drinking water had been maintained for all rainwater tanks except one. And shallow well water (12 out of 22) and tube well water (2 out of 3) total hardness had exceeded the standards.

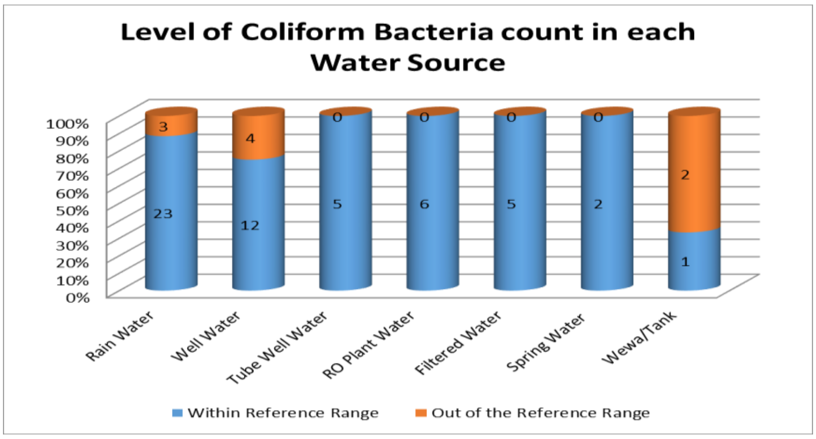


Source: HARTI survey data, 2018

Figure 6.11: Level of Hardness in Each Water Source

Level of Coliform Bacteria Count in Each Water Source

Overall 80% of the tested rainwater tanks recorded without the coliform bacteria, the recommended value for drinking water (well water) total number of all types of coliform bacteria present in 100 ml sample at 37^0C is <10.

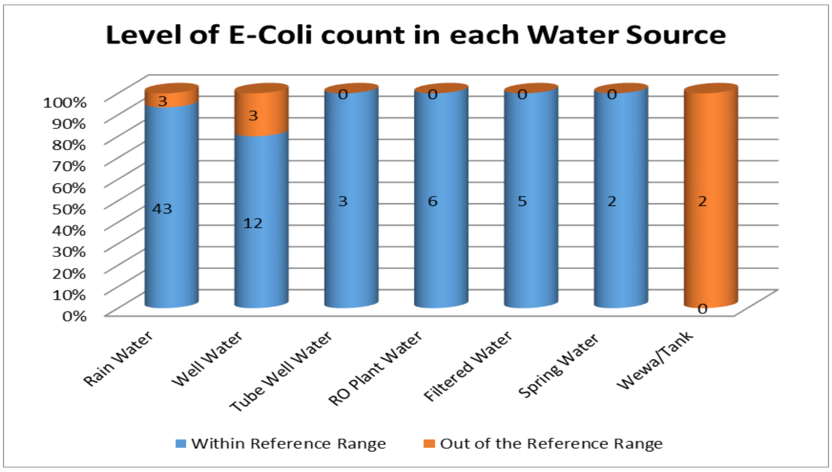


Source: HARTI survey data, 2018

Figure 6.12: Level of Coliform Bacteria Count in Each Water Source

Level of E-Coli count in harvested rainwater tanks

Having a simple charcoal and gravel filter and first flush systems reduce the contamination levels in the tanks markedly (Ariyabandu, 1999) E. coli levels in the tanks receiving rainwater from G.I roof are lesser than from other (HARTI survey data, 2018), roofs due to the heating of the G. I roof which result in perishing of E. coli in the roof (Vasudeva et al., 2001).



Source: HARTI survey data, 2018

Figure 6.13: Level of E-Coli Count in Harvested Rainwater

During this study, mosquito breeding was observed in some abandoned tanks. This could be prevented by raring fish in these tanks, or else, if the tank is tightly sealed, it serves both in preventing the breeding of mosquito larvae and the growth of algae and thereby improves the quality of the harvested rainwater.

6.3 The General Distribution of CKDu Patients in the Area, the Water Sources Used in the Study Area and the Factors Impacting on the Use of Rainwater for Drinking Purpose

So far as drinking water sources (before establishing RWHT) in selected DS divisions, the majority of the people in Madawachchiya DS division used well water as their drinking water source (Table 6.14). Similarly, people in both Kabithigollewa and Dimbulagala DS divisions, used well water as their main drinking water source and the Madirigiriya DS division, RO plant was the main drinking water source, and then the well water. According to table 6.15, in Madawachchiya DS 69% were suffering from CKDu it may be due to using of unreliable water sources for drinking (Surface water and tube well water). Only 50% were using reliable water sources (RO water, filter water, and spring water).

Table 6.14: Water Sources Used in the Study Area, for Drinking Purposes

Drinking Water Source	Anuradhapura				Polonnaruwa			
	Madawachchiya		Kabithigollewa		Madirigiriya		Dibulagala	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Well	29	38.67%	53	57.61%	24	31.58%	50	64.10%
Tube well	6	8.00%	9	9.78%	1	1.32%	3	3.85%
Spring	5	6.67%	25	27.17%	12	15.79%	2	2.56%
Tap water	1	1.33%	0	0.00%	0	0.00%	9	11.54%
Filters	26	34.67%	1	1.09%	12	15.79%	11	14.10%
RO plant	7	9.33%	3	3.26%	27	35.53%	1	1.28%
Both well and stream	0	0.00%	1	1.09%	0	0.00%	1	1.28%
Both filter and RO plant	1	1.33%	0	0.00%	0	0.00%	1	1.28%
Total	**75**	**100.00%**	**92**	**100.00%**	**76**	**100.00%**	**78**	**100.00%**

Source: HARTI survey data, 2018

According to our survey data during the data collection period, the total number of kidney patients reported in the study area is 239 (74.45% from the sample). Among them, the majority was reported from Polonnaruwa district (Madirigiriya 78.95% and Dimbulagala 73.07%). Most of them had not used a reliable water source (Ro water, spring water or filter water) for drinking purposes.

Kidney disease in the selected area

Table 6.15: Frequency distribution of CKDu in the Study Area

Kidney Disease	Anuradhapura				Polonnaruwa			
	Madawachchiya		Kabithigollewa		Madirigiriya		Dimbulagala	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Yes	52	69.33%	70	23.91%	60	78.95%	57	73.07%
No	23	30.67%	22	76.09%	16	21.05%	21	26.58%
Total	75	100.00%	92	100.00%	76	100.00%	78	100.00%

Source: HARTI survey data, 2018

In the course of the study, identified, people who were affected with kidney disease were identified and the majority of them had used shallow well water as their main drinking water source (before CKDu was identified), especially in Kabithigollewa and Dimbulagala (Table 6.14),

In Kabithigollewa only 5% and Dimbulagala nearly 17% had used RO plant water and filter water for drinking purposes, also used to drink well water, tube well water or spring water for drinking.

Table 6.16: Frequency Distribution of the CKDu Patients and the Water Source Use for Drinking (before identifying the disease)

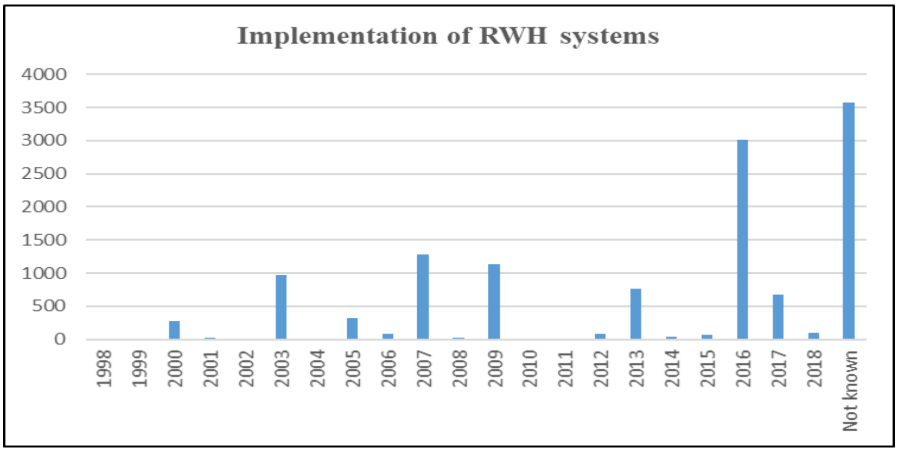
Drinking Water Source	Suffer from Kidney Disease			
	Yes		No	
	Frequency	Percentage	Frequency	Percentage
Well	**124**	**64.92%**	**32**	**24.62%**
Tube well	**9**	**4.71%**	**10**	**7.69%**
Stream	**19**	**9.95%**	**25**	**19.23%**
Tap water	**1**	**0.52%**	**9**	**6.92%**
Filters	22	11.52%	28	21.54%
RO plant	15	7.85%	23	17.69%
Both well and stream	**1**	**0.52%**	**1**	**0.77%**
Both filter and RO plant	0	0.00%	2	1.54%
Total	191	100.00%	130	100.00%

Source: HARTI survey data, 2018

Table 6.16, indicates the frequency distribution of the CKDu patients and the water source used for drinking (before identifying the disease). Nearly 60% of them had used water from unsafe sources like shallow wells, Tube wells, streams and unpurified tap water.

When considering the association between the drinking water source and kidney problem. Observed the presence of kidney disease is strongly associated with the drinking water source of those people.

Figure 6.14 shows the total number of RWH tanks constructed according to the implementing years. According to the records, the project period, the implemented year is taken as the completed year. Some records do not specify the implementing years. These are displayed as “Not known” in the graph. The highest number of RWH tanks had been implemented in 2016 in CKDu areas.



Source: RWHF survey data, 2018

Figure 6.14: **Implementation of Harvested Rainwater Tanks**

Factors impacting on the use of rainwater for drinking purpose

For this regression, selected sample was, people who had rainwater harvesting tanks and the dependent variable as to whether people used rainwater for drinking purpose or not**.** According to the logistic regression results, no variables except occupation and capacity of rainwater tank have significantly affected on behaviour of drinking of rainwater at 95% confidence interval. However, people whose main occupation is farming have got used to drink rainwater over the people who are engaging in other jobs. Results discriminate; there are 400 odds of having so at 95% confidence interval. That means farmers have persuaded to use rainwater in 400 times over the others at 95% confidence interval. As well, the capacity of the rainwater tank was the other only variable significant at 95% confidence interval. Accordingly, people who use 5000L of the rainwater harvesting tank have 119 odds to use rainwater over the 7500L of rainwater harvesting tank users at 95% confidence interval. That means, people who use 5000L of rainwater harvesting tanks have 119 times of willingness to use rainwater over the 7500L of rainwater harvesting tanks at 95% confidence interval. The below table illustrates how was the variables have activated on the behaviour of drinking of rainwater at 95% confidence interval.

Table 6.17: Factors impacting on the use of Rainwater for Drinking Purpose

Variable	Coefficient	Standard Error	df	Wald	P-value	Odd ratio
Constant	-11.241	$8.038*10^{4}$	1	$1.955*10^{-8}$	1.000	$1.312*10^{-5}$
DSD			3		0.766	
Medawachchiya	-1.714 ns	1.686	1	1.147	0.310	0.180
Kebithigollewa	-1.208 ns	1.671	1	1.032	0.470	0.299
Medirigiriya	-1.559 ns	1.707	1	0.522	0.361	0.210
Gender			2	0.834	0.083	
Male	5.306 ns	$5.684*10^{4}$	1	$8.715*10^{-9}$	1.000	201.631
Female	-1.697 ns	$5.684*10^{4}$	1	$8.917*10^{-10}$	1.000	0.183
Age	0.128 ns	0.724	1	0.031	0.859	1.137
Education level			7	1.197	0.991	
No schooling	20.455 ns	$4.019*10^{4}$	1	$2.589*10^{-7}$	1.000	$7.643*10^{8}$
Primary (Grade 1-5)	21.368 ns	$4.019*10^{4}$	1	$2.826*10^{-7}$	1.000	$1.905*10^{10}$
Grade 6-8	22.127 ns	$4.019*10^{4}$	1	$3.030*10^{-7}$	1.000	$4.169*10^{10}$
Up to G C E O/L	21.278 ns	$4.019*10^{4}$	1	$2.802*10^{-7}$	1.000	$1.742*10^{10}$
Up to G C E A/L	20.622 ns	$4.019*10^{4}$	1	$2.632*10^{-7}$	1.000	$9.033*10^{9}$
Degree and above	38.771 ns	$5.684*10^{4}$	1	$4.652*10^{-7}$	0.999	$6.888*10^{16}$
Diploma	37.780 ns	$5.684*10^{4}$	1	$4.417*10^{-7}$	0.999	$2.556*10^{16}$
Employment			7	9.781	0.201	
Farming	**5.994 ****	**2.711**	**1**	**4.888**	**0.027**	**400.917**
Agriculture labour	0.428 ns	2.864	1	0.022	0.881	1.534
Hired labour	22.579 ns	$2.792*10^{4}$	1	$6.539*10^{-7}$	0.999	$6.399*10^{9}$
Animal husbandry	4.325 ns	3.071	1	1.984	0.159	75.551
Business	4.371 ns	3.286	1	1.769	0.183	79.104
Drinking water source			7	6.721	0.459	
Well	-19.849 ns	$4.019*10^{4}$	1	$2.438*10^{-7}$	1.000	$2.396*10^{-9}$
Tube well	-24.253 ns	$4.019*10^{4}$	1	$3.641*10^{-7}$	1.000	$2.931*10^{-11}$
Stream/canal	-21.735 ns	$4.019*10^{4}$	1	$2.924*10^{-7}$	1.000	$3.637*10^{-10}$
Pipe born water	-47.401 ns	$4.754*10^{4}$	1	$9.941*10^{-7}$	0.999	$2.595*10^{-21}$
Water filters	-21.649 ns	$4.019*10^{4}$	1	$2.901*10^{-7}$	1.000	$3.960*10^{-10}$
Ro Plant	-21.017 ns	$4.019*10^{4}$	1	$2.734*10^{-7}$	1.000	$7.452*10^{-10}$
Both well and stream	4.934 ns	$4.682*10^{4}$	1	$1.110*10^{-8}$	1.000	138.921
Kidney disease	-0.082 ns	1.207	1	0.005	0.946	0.921
Taste (rain water)	0.012 ns	3.800	1	$1.042*10^{-5}$	0.997	1.012
Colour of rain water	2.303 ns	1.607	1	2.054	0.152	10.000
Odour of rain water	1.905 ns	1.575	1	1.464	0.226	6.722
Changes in rain water with time	4.277 ns	2.610	1	2.685	0.101	72.006
Building material of RWHT (Ferro cement)	-0.370 ns	1.048	1	0.125	0.724	0.690
Availability of cover for RWHT	0.286 ns	1.274	1	0.51	0.822	1.332

Capacity			3	7.490	0.058	
7500 l	25.034 ns	$4.019*10^4$	1	$3.879*10^{-7}$	1.000	$7.447*10^{10}$
5000 l	**4.780 ****	**2.330**	**1**	**4.207**	**0.040**	**119.107**
Nature of Roof			2	1.945	0.378	
Coconut leaves	1.783 ns	2.320	1	0.590	0.442	5.945
Aluminium	-1.036 ns	0.885	1	1.370	0.242	0.355
Training on use of rain water	0.855 ns	0.754	1	1.287	0.257	2.352
Number of observation	211					
Cox and Snell R^2	0.366					
Nagelkerke R^2	0.644					

Source: HARTI survey data, 2018

Dependent variable: Rainwater used for drinking purpose or not. ** Significant at 0.05 probability level, *-Significant at 0.1 probability level, ns- Not significant

CHAPTER SEVEN

Conclusion and Recommendations

7.1 Conclusion

According to the survey data, a total of 167 HH from Anuradhapura and 155 HH from Polonnaruwa, they have to face many problems when collecting water, for their drinking purposes. People in these areas have many water quality problems because the existing water source does not have enough water throughout the year, groundwater contamination problems in the area and the kidney disease of unknown etiology are the problems they have to face.

The rainwater tank owners used the tank for all the purposes during rainy seasons as well as in the dry seasons. There are no health issues recorded resultant on the drinking of rainwater when comparing the health issues between the users and non-rainwater users. A rainwater system, offers the people a lot of advantages. Rainwater harvesting is a feasible strategy to mitigate the increasing water crisis. The past, present and future predictions on rainfall indicate that there would be a drastic reduction in rainfall during the *Maha* and the *Yala* seasons and therefore additional irrigation water must be developed in NCP. Reductions in rainfall will pose severe threats to safe and clean water for drinking purposes; therefore, to collect rainwater during the rainy season is very important, in NCP with special reference to climatic change impacts.

Some people are reluctant to drink rainwater, due to misunderstanding and misinformation about the quality of the rainwater. In Sri Lanka, rainwater can be considered as the best source of safe water for consumption, due to such reasons as availability and leser contamination.

According to the results, harvested rainwater water quality was found to be better than that of the water in the samples tested from shallow wells. Rainwater was found not to have been biologically contaminated to the extent of more than 90 percent. And 10% biological contamination was due to the improper maintenance of their tank and mixing rainwater with surface water, when the tank gets empty, uses it as a storage tank. Chemical and physical parameters in rainwater tanks were within the safe range for drinking purposes, under the maximum tolerant level according to the standards (SLS 614:2013) (UDC 663.6).

According to the survey, the physical and chemical quality of rainwater, meet the prescribed standards. According to the results, harvested rainwater water quality was found to be better than the samples tested from shallow well water. According to the findings, there is a relationship between the source of water drinking and the CKDu. Due to that good quality water help to control the CKDu. Water obtained from rainwater is in good quality and low cost and considered suitable and reliable water source for consumption for CKDu patients.

Water quality parameters of filter water samples collected from water sellers, Kabithigollewa and Madawachchiya DS divisions, observed that the Fluoride content had exceeded the standard levels. This may be that the water sellers had fraudulently adulterated filter water with surface water before selling or due to the technical or maintenance issues in the filters.

Nearly 10% of the water samples collected from water sellers were not in the safe range. But the people of the area, have to spend money to buy this water. According to the findings, In the Polonnaruwa 54% and 66% in Anuradhapura. Theses HHs income values were above Rs. 30,000 per month. It is within the national real median household income per month. It was found that 75**%** of families in the Polonnaruwa district spend up to Rs 2000 to buy water**.** According to the findings, 80**%** of the total population **(**Anuradhapura**)** income level is more than Rs 15000**.** When we consider the Rs 15000 as the minimum level of income, they have to spend 13**.**3**%** of their earnings to buy water**.** This is a considerable value**.** From the population 8**.**3**%** from Polonnaruwa, have to spend Rs 10000 **-** Rs20000 to buy water**.** This will due to the lack of total number of rainwater tanks in Polonnaruwa comparing with Anuradhapura District**.** In Anuradhapura, 64**.**3**%** have to spend up to Rs 2000 to buy water**.**

The existing water sources, now in use, do not have enough water to last the year. Sometimes water sources, near the house not suitable for drinking. Due to this problem, most of the people to depend on common well water. Some have to cover long distances to fetch water, nearly 34% of elder people are along involve in collecting water for their houses. Perceived this in both districts. Because of most of the time young people involved in agricultural activities.

A number of RO plants have been installed in the affected districts by the NWS & DB, the Sri Lanka Navy, Presidential Task Force on CKDu prevention, some NGOs and water sellers. Private plants cost around Rs. 1 million and are managed by the community based organizations in the respective areas. Water purified by RO plants (private plants) is sold at Rs. 1.50-3.00 per liter, and a person needs about 4 liters of potable water per day. Water sellers use to sell RO plant water at the villager's premises by using tractors, land masters and bowsers. They do not have a fixed rate for water. A considerable amount of money has to be spent by those who are affected by CKDu to buy water. Some RO plant outlets close at 6 pm. Further, installation and maintenance cost of a RO plant is expensive and are not available at all the places affected by CKDu. Hence, it is necessary that alternate sources of pure water be found. Rainwater is the purest form of water. And good quality rainwater can be collected and stored by the rainwater harvesting system if it managed and operated efficiently. By the roof is kept clean, first flush device and filters are used and the tank is kept closed to prevent exposure to the sunlight entering which promote algal growth and mosquito breeding. From the total sample, 62% used the rainwater tank, and 33% of them did not use their tank, for different reasons. The main reason being the existing tanks had operational and maintenance problems, which they have to face.70% is operational and maintenance problems. This highlights the need for training and awareness programmes about the maintainernce about the rainwater tanks. As a reliable water source rainwater harvesting is the best solution to water shortage. Therefore it requires correct directions, training, and awareness for the rainwater harvesting as a mean of safe water for consumption.

When taking these facts into account rainwater harvesting is undoubtedly the most rational, cost-effective, socially acceptable and ecologically sustainable method of providing clean drinking water to widely scattered rural households in the CKDu affected dry zone.

According to the findings, in Polonnaruwa district, nearly 47% of them have a rainwater tank (HH level). Anuradhapura district 63% of them have a rainwater tank, this is due to the highest number of total RWT in Anuradhapura (5236) comparing to the Polonnaruwa (3506). According to the findings, about 78% of the RWT systems in the study locations are constructed under a fully subsidized approach.25% partially subsidized approach as they have to contribute to the labour cost. Most of the fully subsidized approach it is implemented for a period of 10-15 years from 2018.

74% of the tanks are Ferro-cement in Polonnaruwa district. In Anuradhapura, 53% of the tanks were PE tanks, according to the implementing organizations, majority of RWH systems implemented by NWS & DB are Plastic/PE tanks in Anuradhapura, and most other organizations have installed Ferro-cement tanks.RWH Tanks in the sample population range from 2000- 10,000liters. The majority (82%) of the tanks are 5000-liter capacity.

Roofing material of the RWT catchment area, in the study area, more than 50% of the roofs were asbestos in both districts. Nearly 45 % is clay-roofing tiles. And most of the people like to have a clay tile roof because they can use it as a safe roofing material for the rainwater tank. As a safe catchment area.

According to the survey data, nearly 28% of the HH can use their 5000 L rainwater tank for about 4-6 months in Anuradhapura and 64% in Polonnaruwa. If they fill the tank once, 52% can use it for 10-12 months in Anuradhapura and 12% in Polonnaruwa. A significant difference in water use in both districts. In Anuradhapura, 52% can keep their tank for 10-12 months; this may be due to the awareness. Because according to our survey data we observed, In Anuradhapura, there are more rainwater tanks and more training programmes about rainwater harvesting, had been conducted in Anuradhapura.

Some people have to travel long distances to fetch water; they have to devote a lot of money and time on this. If they have a rainwater tank at their premises, it will be an advantage for them. They can reduce transportation cost and save time. They can use that time for leisure and other activities. If they have a rainwater tank at their premises will be an advantage for them. They can reduce transportation and save time. they can use that time for leisure and other activities.

7.2 Recommendations

Adaptation Measure for Climate Change

1) According to the research findings in Sri Lanka, the past, present and future predictions on rainfall indicate that there would be drastic reductions in rainfall during *Maha* and *Yala* seasons and cannot receive the rainfall at the monsoon period. Therefore additional irrigation water must be developed in NCP**.** Reductions in rainfall will pose severe threats to safe and clean water for drinking purposes; therefore, to collect rainwater during the rainy season is vital importance in NCP with special reference to climate change impacts.

Social and Economic Benefits

2) By having a rainwater tank, people will get many advantages**.** They will have pure water free of cost at their premises**.** Most of the people depend on rainwater for drinking and cooking during the dry season and during the rainy season, they use rainwater for all purposes. There are no health effects recorded due to drinking rainwater. By having an RWH system people have many advantages. They save time and money. According to the districts and monthly expense cross**-**tabulation**.** It was found that 75 **%**of families in Polonnaruwa and 64**%** in Anuradhapura district spend up to Rs 2000 per month to buy water**.**

3) The survey, revealed that 31% from the sample expressed, distance and transport as the main issue they have to face in Anuradhapura. If they have a tank, they do not have to spend time for fetching water and spend money on buying water. Having water at their premises, obtain pure water free of cost. They will have more time to spend with their families.

4) According to our survey, nearly 34% of elder people use to bring water in both districts. Because of most of the time young people involved in agricultural activities. Nearly 10% of small children also engaged in these activities. Involvement in small and elder people in these activities will cause social problems.

The Requirement of the Tank

(5) The construction of RWH systems has considerably increased after 2006 by ADB, NWDB, the World Bank-funded CWSSP, LRWHF, and other NGOs. About 82% of the RWH systems have a 5m^3 capacity storage tank and 99% were surface tanks 5000 L tank (Ferro-cement or PE tank) is identified as the most preferred tank in terms of the survey findings.

According to the findings, nearly 28% can use their 5000 L rainwater for about 4-6 months in Anuradhapura and it was 64% in Polonnaruwa. If they fill the tank once.52% use it for 10-12 months in Anuradhapura and 12% in Polonnaruwa.

It is estimated that a family consisting of 5 persons, would require approximately 30 liters of water per day for drinking and cooking purposes (6 liters/person/day). For over five months with the household water requirement calculated as nearly 5000litres. During the months of October, November and December usually bring heavy rainfall to the dry zone. The average rainfall is 1368 mm. A 50 square meter surface, an average roof area, under minimal rain conditions would provide enough rain to fill up a household tank of 5,000 l in about three days. This structure will ensure a family of five persons from six months of dry weather (April- September) by providing adequate water for drinking.

6**)** The initial cost of the tank 5000 l is Rs 65000 for a PE tank **(**without filtering systems**)** and Rs 70000 for an 8000 l Ferro cement tank with the labour cost**.** The initial cost of the tank is still high for most householders. Therefore, a government subsidiary or a credit facility scheme should be developed to encourage these groups. And 85% of the people who required a tank told, they can give the labour force and implement a 25% partial subsidized approach as they have to contribute to the labour cost. The initial cost of the system can be lowered by using a low cost alternative material for tank construction.

The main reason for not using the existing tanks was operational and maintainernce problems (70%). It is very important to repair the existing damaged tanks.This will help to reduce the money, that government has to spend for implementing new water supply systems.

And Local authorities can advise the people about the benefits of implementing a rainwater tank for the new house developments in water shortage areas, when getting approval from local authorities for house construction by people.

7) Rainwater harvesting for drinking purposes shall be a promising option for all the water shortage districts, used with a 5000 L tank from a 50 m^2 rooftop catchment. Effectiveness can be enhanced if the rooftop catchment can be improved, by proper maintenance of catchment area, gutter system and the first flush system, and appropriate maintenance of the tank system. Further to this, the initial cost of the system can be lowered by using a low cost alternative material for tank construction.

8) According to the literature, physical factors affect the quality of the RWT. The air, water, and soil pollution present within the area, resulting from industrial and agricultural activities and geology directly influence the water quality of the RWH system. Mostly these factors are difficult to influence but should be taken into account when starting an RWH in rural areas, where the influence of these factors is relatively small and can often be left out.

9) Using non-toxic materials for roofing, such as clay, cement, corrugated and galvanized iron. Metal roofs subjected to atmospheric corrosion, frequently

cleaning and clearing of the catchment surface (from human, animal and organic matter) and removing overhanging branches.

The larger the catchment surface, the bigger the chance for contamination due to the more complex management of the catchment. The conveyance can be described as the means of transportation of the collected rainfall from the catchment surface to the storage system. Depending on the type of RWH systems, several conveyances can be defined: gutters, inlet pipes, and collection and inlet canals. Contamination can be prevented by using non-toxic materials, frequent cleaning of the conveyances. Contamination might have occurred in the previous level (the catchment area). Therefore, filters should be installed at the entrance or end of the gutters or inlet canals to prevent (small) animals, organic matter and debris from entering the RWH system. A first-flush device should be installed to divert the first rainfall, which contains the main load of pollution.

A Good Solution for CKDu Problem

10) According to the findings, there is a relationship between the source of drinking water and the CKDu, and good quality water helps to control the CKDu. There is a significant control in CKDu stagers within the people who were used to drink rainwater. Prevention of CKDu is important. Hence, various strategies have been implemented to prevent the occurrence of CKDu. These strategies are mainly aimed at providing good quality water. Water obtained from rainwater tanks is of good quality and low cost and considered to be suitable for consumption. With the present drought in some endemic areas, CKDu will affect more people; when taking these into account rainwater harvesting is undoubtedly the most rational, cost-effective, socially acceptable and ecologically sustainable method of providing clean drinking water to widely scattered rural households in the CKDu affected dry zone.

The need for the Training and Awareness Programmes

11) One of the specific objectives was, to look into the ways of guiding and making people aware of the importance of rainwater consumption**.** The main reason for not using the existing tanks was operational and maintainernce problems (70%). Identified, as a reliable water source rainwater harvesting, requires correct direction, training, and the dissemination of awareness about rainwater harvesting.

12) Human conduct and level of education, reflected in the level of awareness of the relation between water and health, hygiene and sanitation, management and maintenance skills of RWH systems are social factors controlling water quality of an RWH system. According to the findings 45% had studied at least up to GCE O/L, in Anuradhapura district and 33% from Polonnaruwa district. This will highlight the training and awareness requirement for rainwater tank use. This can be coordinated by the Hector Kobbekaduwa Agrarian Research and Training

Institute with experienced resource persons, especially from rainwater harvesting forum.

13) Awareness programmes on maintenance and operation of the system should be a mandatory requirement for all rainwater harvesting programmes to ensure collection of good quality water simple techniques of improving the quality of stored water to meet the drinking water quality standards should be incorporated into the system with the help of rainwater harvesting forum. Training programmes for DAD officers and extension officers, and these officers can guide the RWT users in their region.

14) Proper monitoring system by the authorities after project completion is needed. A systemic water quality survey should be conducted taking into account different variabilities to give recommendation for best operation and maintenance practices.

15) School children can be educated about rainwater harvesting. According to the new curriculum, there are some sections about rainwater harvesting. But this should be enhanced by including more details about rainwater harvesting methods and rainwater harvesting as a climate change adaptation method for Sri Lanka.

16) National policy on rainwater harvesting in Sri Lanka was officially implemented on September 27, 2005. The RWH policy was formulated by the RWH Secretariat of the Ministry of Urban Development and Water Supply and the National Water Supply and Drainage Board jointly with the Lanka Rain Water Harvesting Forum. From our key person interviews, we have identified the need for implementing the rainwater policy.

Water Quality

17) According to the survey data, the physical and chemical quality of rainwater in terms of colour, odour and taste, pH, total dissolved solids (TDS) and total hardness (TH), meet the prescribed standards. According to the results, harvested rainwater water quality was found to be better than the samples tested from well water. Rainwater found not to have been biologically contaminated was to the extent of more than 90%. And 10% biological contamination was due to the bad maintenance of their tank

18) Provide safe drinking water to the affected population accelerated efforts to provide safe drinking water in the short term and long term, mainly focusing on technologies that are affordable and sustainable. Conducting a feasibility study to introduce cost-effective and appropriate water treatment systems and rapid assessment of water treatment technologies are of vital importance. Simple techniques of improving the quality of stored water to meet the drinking water quality standards should be incorporated into the system. Rainwater harvesting

for drinking purposes shall be a promising option for all the government institutes.

19) In the study area, some people with low income used to drink water from wewa, according to the results, Nitrate and microbial contamination are exceeding the safe range for drinking. For a short-term remedy, Presidential taskforce on CKDu prevention can distribute more rainwater tanks and implement more RO plant units to the CKDu areas.

20) Most of the water samples collected from water sellers were not in the safe range (nearly 10% from the tested sample). Management and technical problems in RO plants were observed and water sellers and private plant owners, don't have a fixed rate for water, due to this problem, there should be a proper procedure to control the water standards for the water sellers by issuing a licensing system and renewing it with the help of NWSDB.

21) According to results, it was observed that water sources in NCP were contaminated due to man-made activities; Regular monitoring of agrochemicals and their residues in food, water, and the environment, and a training programme for farmers and extension officers on the appropriate use of agrochemicals, needs immediate focus and implement alternate pest control methods and it is recommended to develop sustainable farming practices, with a special focus on CKDu-endemic areas. Establish and update the maximum residues limits (MRL) data for pesticides based on total diet studies carried out in Sri Lanka long-term remedy.

22) According to the observations, most of the tanks distributed or donated without a proper need survey, due to this target beneficiary must be carefully selected considering their real need, willingness to contribute for the project and other socio economic characteristics such as family size, roof area, and quality and the surrounding environment.

Weather Indicator

23) According to the agro-ecological zones, it is important to develop an app or a communication system (SMS alert system) to inform the RWT users about the rainwater collection time with the help of weather forecast and weather predictions. This can be achived with the help of the regional agrarian development office. Should develop a network with Regional Agrarian Development officers and meteorology department.

    In Sri Lanka, it seems that rainwater is the best source of safe water consumption due to reasons such as availability. Therefore it requires correct guidance and provisions of the awareness required for the rainwater harvesting as a mean of safe water consumption.

REFERENCES

Annual Health Bulletin, (2015), The Ministry of Health, Sri Lanka: The Ministry of Health.

Ariyananda, T., (2010), Paper presented at Trainers' Training Programme on "Sustainable Rainwater Harvesting and Ground Water Recharge in Developing Countries - HRD and Technology Transfer", 22 – 27 February 2010. Bengaluru, India.

Ariyananda, T.N., (2003), Health Risk Due to Drinking Domestic Roof Water Harvested. Paper submitted to XI IRCSA conference August 2003. Mexico.

Ariyabandu, R.de S., (1999), Development of Rainwater Harvesting for Domestic Water Use in Rural Sri Lanka, Asia-Pacific Journal of Rural Development, 9 (1), pp. 1-14.

Ariyananda, T., (2000), Quality of Collected Rainwater from Sri Lanka, paper 26th WEDC conference. Bangladesh, Dhaka.

Bandara, P., Dissanayaka, D.M. and Adikari, S.B., (2013), Geographical distribution of chronic kidney diseases of unknown origin in North Central Region of Sri Lanka.

Bandara, J.M.R.S., Seneviratna, D.M.A.N., Dassanayaka, D.M.R.S.B., Herath, V., Bandara, J.M.R.P., Abeysekara, T.A.D. and Rajapaksha, K.H., (2008), Chronic Renal Failure among farm families in cascade irrigation systems in Sri Lanka associated with dietary cadmium levels in rice and freshwater fish(Tilapia), Environ Geochem Health, 30, PP.465-478.

Central Bank of Sri Lanka, (2010), Annual Report 2010.

Chandrajith, R., Nanayakkara, S., Itai, K., Aturaliya, T. N. C., Dissanayake, C. B., Abeysekera, T. and Koizumi, A., (2011), Chronic Kidney Diseases of uncertain etiology (CKDu) in Sri Lanka: geographic distribution and environmental implications. Environmental geochemistry and health 33 (3), pp. 267-278.

Chandrajith, R., Dissanayake, C. B., Ariyarathna, T., Herath, H. M. J. M. K., and Padmasiri, J. P., (2011), Dose-dependent Na and Ca in fluoride-rich drinking water another major cause of chronic renal failure in tropical arid regions, The science of the Total Environment, 409 (4), pp. 671-675.

Chandrajith, R., Padmasiri, J. P., Dissanayake, C. B., and Prematilaka, K. M., (2012), Spatial distribution of fluoride in groundwater of Sri Lanka, Journal of the National Science Foundation of Sri Lanka, 40 (4).

Climate Change Secretariat Ministry of Mahaweli Development and Environment, (2016), National Adaptation Plan for Climate Change Impacts in Sri Lanka 2016-2025. Available at:https://www4.unfccc.int/sites/NAPC/Documents%20NAP/National%20Reports/National%20Adaptation%20Plan%20of%20Sri%20Lanka.pdf [Accessed October 12. 2018].

De Silva, C. S., (2013), Impact of climate change on water resources and agriculture in Sri Lanka.

De Silva C.S., (2014), Rainwater harvesting as an adaptation measure for the Impact of climate change on water resources in Central Hills of Sri Lanka, Harvesting symposium. 5 September 2014.

De Silva, C. S., Weatherhead, E.K., Knox, J.W. and Rodriguez-Diaz, J.A., (2007), Predicting the impacts of climate change, A case study of paddy irrigation water requirements in Sri Lanka, Agricultural Water Management, 93 (1), pp. 19-29. Amsterdam, Netherlands: Elsevier.

De Silva, C. S., Weatherhead, E.K., Knox, J.W. and Rodriguez-Diaz, J.A., (2007), Predicting the impacts of climate change, A case study of paddy irrigation water requirements in Sri Lanka, Agricultural Water Management, 93 (1), pp. 19-29. Amsterdam, Netherlands: Elsevier.

Dharmagunawardhane, H.A. and Disanayake, C.B., (1993), The fluoride problem in the groundwater of Sri Lanka-environmental management and health, Environmental Management and Health, 4, pp. 9–16.

Dissanayake, C.B., (2005), Of stones and health: medical geology in Sri Lanka, 309, pp. 883–885.

Dissanayake, C.B., (1991), The fluoride problem in the groundwater of Sri Lanka - environmental management and health, International Journal of Environmental Study, 38, pp. 137-155.

Department of Meteorology, Sri Lanka, (2016), Climate of Sri Lanka. Available at: http://www.meteo.gov.lk [Accessed Oct 12. 2018].

Department of Survey, Sri Lanka, (2016), Area of Sri Lanka by Province and District. Available at: http://www.survey.gov.lk [Accessed Oct 12, 2018].

Dissanayaka, C.B. and Weerasooriya, S.V.R., (1986), Fluorine as an indicator of mineralization -Hydro geochemistry of a Precambrian mineralized belt in Sri Lanka. 56 (4): 257-270. Available at: https://doi.org/10.1016/0009-2541(86)90007-0. [Accessed 3 October 2019].

Fawell, J., Bailey, K., Chilton, J., Dahi, E., Fewtrell, L., and Magara, Y. (2006) Fluoride in drinking-water, World Health Organization, ISBN 92-4-156319-2, Human Health Effects, pp 29–36.

Glaser J., Lemery J. and Rajagopalan, B., (2016), Climate change and the emergent epidemic of CKD from heat stress in rural communities: the case for heat stress nephropathy, Journal of American society of nephrology, 11, pp.1472–1483.

Hallett, B. M., Dharmagunawardhane, H. A., Atal, S., Valsami-Jones, E., Ahmed, S., and Burgess, W.G., (2015), Mineralogical sources of groundwater fluoride in Archean bedrock/regolith aquifers: Mass balances from southern India and north-central Sri Lanka, Journal of Hydrology, Regional Studies, 4, pp. 111-130.

Hector Kobbekaduwa Agrarian Research and Training Institute survey data, 2018. Project potential of promoting rainwater as a source of safe water consumption in North Central Province.

Heijnen, H. and Pathank, N., (2006), Rain Water Quality Health and Hygiene Aspects, Proceeding of International Work shop in Rain Water Harvesting, Kandy, Sri Lanka.

Herath, K.R.P.K., Illeperuma, O.A., Dharmagunawardhane, H.A. and Haller K.J., (2005), 31st congress on Science and Technology: Environmental health risk for the chronic renal failure in Sri Lanka paper. October 2005. Suranaree University of Technology, Thailand.

Hoek, W.V.D., Ekanayaka, L., (2003), Prevalence and distribution of enamel defects and dental carries in a region with different concentration of fluoride in drinking water in Sri Lanka, International Dental Journal 53(4), PP 243-248.

Ileperum, O.A., Dharmagunawardena, H and Herath, K.R.P.K., (2014), Chronic Renal Failure in the Anuradhapura District, Awareness Raising on Millennium Development Goals in Water Supply and Sanitation through WASH programme and Dissemination of Water Supply and Sanitation Research Findings. Colombo, Sri Lanka.

Jayasinghe, S., Friel, S., Chiang, T.L., Cho, Y., Guo, Y., Hanshimoto, H., Loring, B., Matheson, D., Nguyen, H.T. and Rao, M., (2011), Review Article: Freedom to Lead a Life We Have Reason to Value? A Spotlight on Health Inequity in the Asia Pacific Region, 23, pp. 246-263.

Jayasinghe, Y.K.R.T., (2011), Chronic kidney disease (Risk factor identification) Secondary data analysis). 21 April 2011, University of Peradeniya, Faculty of Agriculture, Internship-IWMI.

Jayasumana, M.A.C.S., Paranagama, P.A., Amarasinghe, M.D., Wijewardane, K.M.R.C., Dahanayake, K.S., Senanayake, V.K., (2013), Possible link of chronic arsenic toxicity with Chronic Kidney Disease of unknown etiology in Sri Lanka, Journal of Natural Sciences Research, 3(1), pp. 64-73.

Jayasumana, C.S., (2016), “wakugadu satane”. Sri Lanka: Nugegoda sarasawi publications.

Jayasumana, C., Paranagama, P., Agampodi, S., Wijewardane, C., Gunatilake, S. and Siribaddana, S., (2015), Drinking well water and occupational exposure to Herbicides is associated with chronic kidney disease, in Padavi-Sripura, Sri Lanka.

Jayasekara, K. B., Dissanayake, D. M., Sivakanesan, R., Ranasinghe, A., Karunarathna, R. H., and Kumara, G. W. G. P., (2015), Epidemiology of Chronic Kidney Disease, With Special Emphasis on Chronic Kidney Disease of Uncertain Etiology, in the North Central Region of Sri Lanka, Journal of Epidemiology, 25 (4), p. 275.

Johnson, S., Misra, S.S., Sahu, R. and Saxena, P., (2012), Environmental contamination and its association with Chronic Kidney Disease of Unknown Etiology in North

Central Region of Sri Lanka. Available at: www.cseindia.org. [Accessed 25 September 2019].

Jayawardana, D.T., Pitawala, H.M.T.G.A. and Ishiga, H., (2010),Geological evidences from soil and water leading to chronic renal failure of unknown etiology in dry zone Sri Lanka. In: Water quality and human health: challenges ahead. University of Peradeniya, Sri Lanka.

Kandasamy, K. and Nilmini, K.P.I., (2014), To Assess the Socio Economic Impacts of the rainwater harvesting project Implemented in Vavuniya District. Rainwater harvesting forum symposium, 5 September 2014.

Karunaratne, N., (1983), Some Problems encountered in groundwater exploration in Anuradhapura district. Hydrogeological Workshop on Groundwater Resources. Institute of Geological Sciences and the Water Resources Board, 14–23 March 1983, Sri Lanka.

Manocha, S.L., Warner, H., Olkowski, Z.L. and Histochem, J., (1975), Cytochemical response of kidney, liver and nervous system to fluoride ions in drinking water, 7, pp. 343-355. Available at: https://doi.org/10.1007/BF01007019. [Accessed 15 September 2019].

Noble, A., Amerasinghe, P., Manthrithilake, P. and Arasalingam, S., (2014), Review of literature on Chronic Kidney Disease of unknown etiology (CKDu) in Sri Lanka. Padmasiri, J.P. and Wickramasingha, N.I., (2004), Community-based De-fluoridation of fluoride-rich water in Dry Zone in Sri Lanka. Awareness Raising on Millennium Development Goals in Water Supply and Sanitation through WASH programme and Dissemination of Water Supply and Sanitation Research Findings. Colombo, Sri Lanka.

Panabokke, C.R., (2007), Groundwater conditions in Sri Lanka.

Panabokke, C R. (2003), Nature of occurrence of the regolith aquifer in the hard rock region of the North Central dry zone and its rational exploitation for agro-well development: In Pathmarajah, S. (Ed.), Use of groundwater for agriculture in Sri Lanka: Proceedings of a symposium, Peradeniya, Sri Lanka: Agricultural Engineering Society of Sri Lanka (AESSL), Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, pp.10-22.

Pereira, L.S., Cordery, I. and Lacovides, L., (2012), Improved indicators of water use performance and productivity for sustainable water conservation and saving. Journal of Agricultural Water Management, 108, pp. 39-51.

Poulter, N.R. and Mendis, S., (2009), Finalized multidisciplinary research proposal on Chronic Kidney Disease of unknown etiology of uncertain etiology (CKDu) in Sri Lanka. World Health Organization, Country office.

Presidential Task Force on Prevention of Kidney Disease of Uncertain Etiology. Available at: http://www.presidentialtaskforce.gov.lk/en/kidney.html#. [Accessed 20 March 2019].

Rainwater Harvesting Forum Sri Lanka, (2019), Available at: http://lankarainwater.org/wp/ [Accessed 20 December 2018].

Rajasooriyar, L.D., Boelee, E., Prado, M.C., and Hiscock, K.M., (2013), Mapping the potential human health implications of groundwater pollution in southern Sri Lanka. Water Resources and Rural Development, 1, pp. 27-42.

Siriwardhana, E.A.R.I.E., Perera, P.A.J., Sivakanesan, R., Abeysekara, T., Nugegoda, D. B., and Jayaweera, J.A.A.S., (2015), Dehydration and malaria augment the risk of developing chronic kidney disease in Sri Lanka, Indian Journal of Nephrology, 25 (3), pp. 146-151.

(SLS 614:2013) (UDC 663.6) - Specification for potable water physical ,chemical and Biological requirements ,Sri Lanka Standards Institution Test Method / Standard against which tests are performed.

Tawatsupa, B., Lim, L.L. and Kjellstrom, T., (2012), Association between occupational heat stress and kidney disease among 37,816 workers in the Thai Cohort Study (TCS), Japan Epidemiology Association, 22 (3), pp. 251–260.

Tawatsupa, B., Lim L.L. and Kjellstrom T., (2012), Association between occupational heat stress and kidney disease among 37,816 workers in the Thai cohort study (TCS), Japan Epidemiol. Association, 22 (3), pp.251–260.

Vasudevan, P**.**, Tandon, M**.**, Krishnan, C**.** and Thomas, T., **(**2001**)**, Bacteriological Quality of Water in DRWH, Proceeding of workshop on Rain water harvesting, IIT Delhi, April 2001.

Wanigasuriya, K., (2012), Aetiological factors of Chronic Kidney Disease in the North Central Province of Sri Lanka: A review of evidence to-date, Journal of the College of Community Physicians of Sri Lanka, 17 (1), pp. 21–42.

Ward, S., Memon, S.A. and Butler, D., (2012), Performance of a large building rainwater harvesting system, 46 (16), pp. 5127-5134.

Wijewardena, D.A., (2012), World Health Organization urges government to test fertilizers for toxic chemicals Killer Kidney Disease, 28 August 2012, The Island.

WHO (World Health Organization), (2012), Investigation and evaluation of Chronic Kidney Disease of unknown etiology of uncertain etiology in Sri Lanka, Final Report. Ministry of Health.

World Health Organization, Country Statistics and Global Health Estimates by WHO and UN Partners, Sri Lanka, 2012. Available at: http://www.who.int/gho/countries/lka.pdf?ua=1. [Accessed 20 December 2018].

World Health Organization. International Expert Consultation on Chronic Kidney Disease of Unknown Etiology, 2016. Available at: http://www.searo.who.int/srilanka/documents/report_international_expert_consultation_on_ckdu.pdf. [Accessed 16 December 2018].

Wimalawansa, S. J. (2014) Escalating chronic kidney diseases of multi-factorial origin in Sri Lanka: causes, solutions, and recommendations, Environmental health and preventive medicine, 19 (6), pp. 375-394.

Weeraratna, C.S. and Ariyananda, T., (2009), Lanka Rainwater Harvesting Forum, Subadrarama Lane, Nugegoda, Sri Lanka. Importance of Rainwater Harvesting in Human Health, 14th IRCSA Conference, Kula Lumpur, Malaysia, 3-6th August 2009.

Young, S.M., Pitawala, A. and Ishiga, H., (2011), Factors controlling fluoride contents of groundwater in north-central and north-western Sri Lanka, Environmental Earth Sciences, 63 (6), pp. 1333-1342.

Young, S.M., Pitawala, A. and Ishiga, H., (2010), Factors controlling fluoride contents of groundwater in north-central and northwestern Sri Lanka, Environmental Earth Sciences. DOI 10.1007/s12665-010-0804-z.