EFFECTS OF WATER PIPE BURST ON WATER QUALITY AND NON REVENUE WATER IN ARUSHA CITY: A CASE STUDY OF AUWSA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ENVIRONMENTAL STUDIES (MANAGEMENT) OF

THE OPEN UNIVERSITY OF TANZANIA

CERTIFICATION

I declare that this work has been read and approved as having satisfied the requirement for the award of Masters of Environmental Studies in Faculty of Science, Technology and Environmental Studies (FSTES) of the Open University of Tanzania.

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DECLARATION

I, Mosha Hortencia Dominic, declare that this dissertation was composed by myself and that the work contained therein is my own work and where other people's research was used, they have been dully acknowledged. I also declare that this work has not been submitted for any other degree or professional qualification except as specified.

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I would like to express my sincere gratitude to our Almighty God, the creator and sustainer of life. It is by his power and care that this dissertation has been produced.

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DEDICATION

To my parents for their parental care and educational foundation, teachers and relatives who provided me with financial support and foundation skills from the grass root level in this long journey of professional development

ABSTRACT

Chronic water losses have been the hallmark of Tanzania especially AUWSA water management over the decades. The rapid growth of Tanzanian cities including Arusha City, coupled with increased volumes of water for irrigated agriculture and industry, has meant that there is much less water to go around in the urban centers. The estimated annual volume of NRW in AUWSA water utilities is in the order of 5,764,621.08 m^3 which is around 41.0% while the Government is struggling to reach 20% or below.

The aim of this research was to assess effects of water pipe leaks on water quality and on non revenue water. (NRW) in Arusha Urban Water supply and Sewerage Authority (AUWSA). There are several ways identified as major contributor to high NRW these includes unauthorized connections (illegal and by pass) account to 24% of that about 30% of respondents pointed out that the main causes of NRW in AUWSA was caused by leakages from water system (transmission mains, Distribution mains, Utility's reservoirs, service connections); 16% mentioned that the causes of water losses caused by stopped/malfunctions water meters (Bulk and customer water meters), whilst 14% respondents enumerated that Non revenue water was caused by other reasons like corruption and bribery among meter readers. It is recommended that successful utilities actively address NRW by controlling physical losses, ensuring customer meters are accurate and making all efforts to keep the number of illegal connections to minimal. Taking these measures can boost revenue by increasing the amount of water that can be billed while reducing wastage of the product. This increases profitability and improves the return on investment.

ABBREVIATIONS

ACC	Arusha City Council
ADB	African Development Bank
AMC	Arusha Municipal Council
AUWSA	Arusha Urban Water Supply and Sewerage Authority
EWURA	Energy and Water Utilities Regulatory Authority
FSTES	Faculty of Science, Technology and Environmental Studies.
NRW	Non Revenue Water
IWA	International Water Association
MajIs	Maji Information System
KPI	Key Performance Indicators
AWWA	American Water Works Association
UWSC	Urban Water Services Corporations
EAC	East African Community
MGD	Millions Gallons per Day
O&M	Operations and Maintenance
PSI	Pounds per Square Inch
UNICEF	United Nations International Children's Emergency Fund
URT	United Republic of Tanzania

UWSD’s	Urban Water and Sewerage Department
WHO	World Health Organization

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Water constitutes about two thirds of the whole earth surface yet it is sadly limited in its availability as a freshwater to man. The importance is on freshwater resources since it is freshwater resources that are used for consumption, agricultural and industrial purposes (Yeboah, 2008). Water resources are under major stress around the world. Rivers, lakes, and underground aquifers supply fresh water for irrigation, drinking, and sanitation, while the oceans provide habitat for a large share of the world's food supply. Today, however, expansion of agriculture, damming, diversion, over-use, and pollution threaten these irreplaceable resources in many parts of the globe (Pye,.*et al.*, 2010).

The significance of protecting our water resource cannot be overstated. In economic terms, the quantifiable contribution of water to the World's economy is hard to estimate. In environmental conditions, water is the livelihood of the earth. Without a stable supply of clean, fresh water as well as human, would cease to exist (Allender, 2006). To provide safe drinking water for the more than 1 billion people who currently lack it is one of the greatest public health challenges facing national governments today and Tanzania is not exception. In many developing countries, safe water, free of pathogens and other contaminants, is unavailable to most of the population and water contamination remains a concern even for developed countries with good water supplies and advanced treatment systems. Over-development, especially in coastal regions and areas with strained water supplies, is leading many regions to seek water from more and more distant sources. The availability and quality of water at all times have played an important part in determining not only where people can live, but also their quality of life. Even though there always has been plenty of fresh water on earth, water has not always been available when and where it is needed, nor is it always of suitable quality for all uses. Water must be considered as a finite resource that has limits and boundaries to its availability and suitability for use (Mukheibir, 2007). Water supply and sanitation in Tanzania is characterized by low levels of access, in particular in urban and in rural areas, as well as poor service quality in the form of intermittent water supply (Blakely, 1987). Access to water and sanitation remains low in Tanzania. Determining data on access is particularly difficult because different definitions and sources are used, which results in significant discrepancies. Household surveys regularly return lower rural water supply coverage than estimates by the Ministry of Water (which is collected by district water engineers and urban water and sanitation authorities) (URT, 2009). For urban areas, survey data are consistently higher because they also include households that are not connected to the formal water supply network and access water from neighbors, protected wells or boreholes (Mukoyogo, 1987).

One of the major strategies during the 1990s' the water sector had been re-organizing, in line through the civil service development program, similar with this come up to the Urban Water and Sewerage Departments (UWSDs') were established. These were operated as (UWSDs) until acknowledged Authorities with fully autonomous (UWSAs') Arusha Urban Water Supply and Sewerage Authority (AUWSA) being among them, by the Minister of Water in harmony with Act. No. 8 of 1997.

1.1.1 Arusha Urban Water Supply and Sewerage Authority

The Arusha Urban Water Supply and Sewerage Authority (AUWSA), is a legally established entity responsible for the overall operation and management of water supply and sewerage services in Arusha City. AUWSA was established under the Water Works Act CAP 272 amendment (Act No. 8 of 1997), now repealed by Water Supply and Sanitation Act No. 12 of 2009 (AUWSA, 2013). It was declared a fully autonomous entity by order of the Minister responsible for Water Affairs in January 1998. AUWSA is not responsible for on-site sanitation system within the City. Arusha City Council (ACC) through its health department is responsible for coordinating sanitation activities within the municipality. The role of Solid waste management in Arusha City is the responsibility of the Health Department and direct under the cleansing Section.

Generally, AUWSA operates, performs and discharges its functions in accordance to but not limited to the following:-

Water Supply and Sanitation Act 2009.

Finance Act, 2001.Public Procurement Act, 2004.

EWURA Act, CAP 414

MoU between MoW/EWURA and AUWSA

Vision Statement

"Water Supply and Sanitation Services in Arusha City delivered in compliance with both National and International Standards".

Mission Statement

"To provide quality water and sanitation *services* efficiently and effectively using available resources and technologies for sustainable development in Arusha City".

Arusha is supplied with water from three different sources namely springs, river and boreholes. The spring sources include Olesha - Masama springs along Themi river located 4 km north of the Municipality and Ngarendolu springs located within the Municipality as well as Nduruma river (Shayo, 2008). There are 12 deep wells (boreholes) located in the northern part of the Municipality (Arumeru District) and three boreholes located within the Municipal area. The boreholes contribute 31% of the daily water production and the springs and river sources 59% (AUWSA, 2013). The production capacity fluctuates seasonally from an average of 32,000m^3/day in dry season to 44,000m^3/day during the rainy season. The water distribution system comprises of 229km of pipeline with diameters ranging from 32mm ($1^1/_2$") to 700mm (28"), the pipe materials are of very old Cast Iron, Ductile Iron, PVC and Polythene. The system also includes storage reservoirs with a total capacity of 13,500m^3, 25 Break Pressure Tanks, 46 Water Kiosks and 108 standpipes (AUWSA, 2013).

Rapid population growth and urbanization in Tanzania exerts enormous pressure on the delivery of water supply and sanitation services to her citizens (URT 2005). Since Tanzania is not in a position to meet the costs of maintaining and improving water supply and sanitation services from public revenues, this has led to the introduction of a commercial approach to the provision of these services on which they must be paid for, rather than a free right (AUWSA, 2013) Regulation of water supply and sanitation services is particularly important since water entities which provide water supply and sanitation services do not face competitive pressures that would otherwise ensure the quality of service provision to consumers is adequate. In Tanzania, the water development authorities faced a number of challenges like water production which does not meet demand and old infrastructures resulting to water losses that lessen financial capability of the water utilities hence poor services. There are no reliable and standardized methods for accounting for water losses. Leakage management performance was measured in terms of "*unaccounted-for water.*" Since this term had no generally accepted definition, there was wide room for interpretation. The "Unaccounted for water" was typically expressed as a percentage of system input, which is already problematic (WHO/UNICEF, 2006). Water as a basic need has multiple uses including drinking, irrigation and generation of hydro power. In case, the Government fails to manage the water distribution, there will be a conflict in the future. There is a question about rights to use the water, whether water is for irrigation or drinking or power generating purpose. The questions of water user's rights and related issues will be major challenges. The time has come for all us to think in this direction. There is an emerging gap between safe quality water available and water demand in many developing and fast growing economies around the world. The economic, environmental, social and political challenges that this water gap presents to governments are very genuine (Madhav, 2011).

Agriculture is currently responsible for about 70% of annual global freshwater withdrawals and up to 90% in some parts of Asia (James, 2010). Yet Governments across Asia will also need on average 65% more freshwater withdrawals for their industry and energy sectors and household use by 2030 in order for their national economies to grow as forecast and energy sectors as well as for people to have access to water. The significance of freshwater resource to man's survival on earth cannot be over emphasized. It permeates through all aspects of man's life on earth. From its use as drinking water, for food production, for washing for the generation of energy, as means of transport, for the production of industrial products to the maintenance of the integrity and sustainability of the earth's ecological systems. The human body constitutes about fifty to sixty-five per cent of water and water is the most important need of the human body only next to air (Yeboah, 2008). In spite of the significance of the freshwater resource to man's survival on earth, the resource all over the world is rapidly depleting. A series of factors account for the fast decrease of the freshwater resource including population growth, increase agricultural irrigation, pollution, overexploitation, denuding of water catchments areas, urbanization, and industrialization. As the population increases, the demand for water in all aspects of life also increases. It is estimated that water use has been increasing twice as fast as population increase in the 21^{st} century (Yeboah, 2008). There is already surprising reports of the situation of the world's freshwater resource availability and its accessibility to man. It was anticipated that the total water use in the world would rise to 5,000 km^3 per year in 2000. This is against the previous figure of 4,130km^3 per year in 1990 (Aswathanarayana 2001:47). It is already known that about one fifth of the world's population lack access to potable drinking water and that about eighty countries, which comprise about forty per cent of the world's population are already in serious water crisis situation (Aswathanarayana, 2001:47).

1.1.2 Water Quality Management

Sustainable management of quality water resources in the face of rapidly growing population and climate change/variability seems to be the main challenge in all developing countries (Maganga, 2002). There is low capacity for water management in the country which have resulted in various problems: pollution of water sources by both domestic and industrial wastes, deforestation of important catchment areas and subsequent dry up of rivers, lack of water for basic hygiene resulting in high prevalence of water borne diseases, water conflicts between upstream/downstream and across sectors, insufficient water for hydropower generation, food shortage, destruction of aquatic resources, low water use efficiency, high water losses in urban supply network andlow water supply coverage. Water quality refers to the chemical, physical and biological uniqueness of water. It is a measure of the situation of water relative to the necessities of one or more biotic species and or to any human need or purpose. It is most commonly used by reference to a set of standards against which compliance can be assessed. The most common standards used to assess water quality relate to health of ecosystems, safety of human contact and drinking water (WHO, 2011).

Water is generally clear and bright in appearance but occasionally for a short period it may come into slight discoloured or hold particles. This is typically an effect of necessary maintenance on the network of pipes for example repairs of a burst water main carrying water from the treatment plant to homes. On the other hand, when the problem persists it is a sign that the underground supply pipe which brings water from the main in the highway into customers' property is in poor condition or that harmless deposits have accumulated over time in areas of low flow in the local water main (DWI, 2010). The safety of drinking water depends on a number of factors, together with quality of source water, effectiveness of treatment and integrity of the distribution system that transports the water to consumers. At every phase in the production and delivery of drinking water, hazards can potentially compromise the quality of the water. Piped distribution systems may be less vulnerable to pollution than open surface-water catchments; however, if piped systems become contaminated, there may be no treatment processes to reduce risks from the introduced hazards. (Melita,*et al,. 2004).* Environmental protection, including water quality monitoring for compliance, is carried out by the Basin Water Offices (BWOs). About 3,380 water samples were collected and analyzed to assess the water quality from various sources and results showed that 96.6% of samples were of good quality for human consumption. Water pollution control was also undertaken whereby the Ministry of Water continued to assess the quality of sewage effluent before being discharged to water bodies (URT, 2009).

1.1.3 Contamintants that Affects Water Quality

(a) Agricultural Contaminants

These are the factors like agricultural runoffs, fertilizers, cleansers which reach the natural source of water and pollute it through pipe burst. Pesticides used on the crops also eventually seep down and contaminate the ground water.

(b) Microbial Contaminants

These are the contaminants like bacteria, viruses, cysts which comfortably dwell in the old and rusty industrial pipes and infect water passing through these pipes to reach the consumer. There are other contaminants like algae and traces of rust which also contaminate water in similar manner. Table 1.1 shows the microbes and the water-borne diseases they cause.

(c) Industrial Contaminants

The list of contaminants affecting water quality will be incomplete without mentioning industrial wastes dumped directly in rivers. There are various hazardous chemicals which also pollute the ground water by seeping in along with rain water.

(d) Human added Contaminants

Comprise of contaminants which people knowingly/unknowingly pollute the water. One way is additional of chlorine in water by water treatment plant to prevent microbes but this is how knowingly chlorine gets added to the water. The added chlorine subsequently reacts with other organic contaminants to produce toxic or carcinogenic by-products.

(e) Maintaining and Replacing Meters Properly

Functional meters easily audited by the meter readers during their normal rounds. The utility should replace the meters systematically, beginning with the oldest meters and those in the worst situation. Poor maintenance will not only encourage inaccuracy but may shorten the life span of the meter. A scheduled maintenance and replacement programme should be in place to manage this problem. Examining meters frequently enables utilities to detect the need for calibration or replacement, hence builds trust with customers. The negative effect of quality water in an area also affects the economy and the environment of the community. This is due to lack of capacity to adopt proactively to its effects in their area which could be attributed to so many factors including lack of sufficient supportive, infrastructure, government policies addressing this issue, lack of political will, insufficient financial resources, knowledge, training and resistance to change.

(f) Waste Water Pharmacerticals

Another source of contaminants affecting water quality is the unknowing addition of pharmaceutical drugs. After consuming drugs, human body will produce drugs and their metabolites by excretion which will reaches the sewer. Despite treatment by water companies, many drugs and metabolites, reach water bodies and contaminated it.

Table 1.1 Human Disease Caused by Polluted Water

DESEASE	PATHOGEN	SYMPTOM	CAUSES
Amebiasis	Entamoeba histolytica parasite	Diarrhea, stomach pain, and stomach cramping	Fecal matter of an infected person (usually ingested from a pool or an infected water supply)
Cholera	Vibrio cholerae bacteria	Watery diarrhea, vomiting, and leg cramps	Contaminated drinking water, rivers and coastal waters
Hepatitis A	Hepatitis A virus	Fever, fatigue, stomach pain, nausea, dark urine, jaundice	Ready-to-eat foods, fruit and juice, milk products, shellfish, salads, vegetables, sandwiches, water
Salmonellosis	Salmonella bacteria	Abdominal pain, headache, fever, nausea, diarrhoea, chills, cramps	Poultry, eggs, meat, meat products, milk, smoked fish, protein foods, juice
E. Coli 0157:H7	Escherichia coli bacteria	Diarrhoea (may be bloody), abdominal pain, nausea, vomiting, fever, etc	Undercooked ground beef, imported cheeses, unpasteurized milk or juice, cider, alfalfa sprouts

Source: Arusha Regional Hospital Medical Reports, 2012/2013

1.1.4 Non Revenue Water

The global volume of non-revenue water (NRW) is surprising. Each year more than 32 billion m^3 of treated water are lost through leakage from distribution networks. An additional 16 billion m^3 per year are delivered to customers but not paid for because of theft, poor metering, or corruption. A NRW reduction strategy can help to improve the quantity and quality of water supplies, and the burden of collecting water, in water scarce areas (Farley, *et al*, 2010). In Africa, many water utilities operate under the jurisdiction of city, municipal, regional, or central governments. These utilities often employ senior managers and directors with backgrounds in various disciplines beyond the water sector. As a result, senior managers entering these positions have limited knowledge of water supply operations, especially on the vital technical and institutional requirements for effectively managing NRW and water losses (Farley, *et al*, 2010). Facing ever increasing urban populations and growing service areas, many water utilities in Sub-Saharan Africa continue to struggle with providing clean drinking water to their consumers. Common water supply problems in African cities are related to the sources and use of raw water, intermittent supply, and the quality of tap water at the consumer's end.

Every drop of water lost or wasted due to system inefficiencies has a direct financial impact as it increases cost to the communities and to the water utilities, especially in areas where demands exceed supplies. The more water loss a system experiences, the more water has to be produced and ultimately delivered to meet the customer needs. This added expense can cause unexpected fluctuations in a water utility's financial stability (Malek, *et al.*, 2011). One of the major challenges facing water utilities is the high level of water loss in distribution networks (Fig 1). If a large proportion of water that is supplied is lost, meeting consumer demands is much more difficult. Since this water yields no revenue, heavy losses also make it harder to keep water tariffs at a reasonable and affordable level (Lambert, *et al.*, 1999).

This situation is common in many sub-Saharan Africa cities and Tanzania is not exempted. "Non-Revenue Water" (NRW) defined as the difference between the amount of water put into the distribution system and the amount of water billed to consumers averages 35% in the region's cities and can reach much higher levels (Fanner, *et al.*, 2007).

Figure 1.1: Water Leakage Due to Aged Water Supply System

Tanzania as an underdeveloped country have also suffers from the problem of water pipe burst which result to unsafe water to human and loss of treated water through leakage. Although water quality and the availability of water supply in Urban Water Authorities in Tanzania is not a new phenomenon, some communities like people of Arusha City experienced negative effects of potential water quality deterioration of drinking water caused by leakage leading to organic compounds contaminating treated water from the intake throughout the distribution system. Water in contact with plastic pipes, surface coatings or other materials can be affected by migration of components that make the water quality unacceptable with respect to aesthetic or health. This study will focus on the effects of water pipe leaks on water quality and non revenue water which cause or threaten the life of people economically, environmentally, socially and politically in Arusha City the case study of Arusha Urban Water Supply and Sewerage Authority (AUWSA). Water quality and the NRW are the big challenges to the water industry in general and it openly affects the level of income realized from water billings, service level and consumer satisfaction to meet the water demand from consumers which in turn affects service sustainability in water sector. The existence of NRW is contributed by a number of reasons, depending on the technological development level and its purpose in the industry. Some of the developed countries have managed to control the level of NRW to the lower level like Singapore with 5% and Netherlands with 6%, while the developing countries including Tanzania has an average of 35.2% of NRW for regional UWSAs (UWSAs Annual reports 2008/2009 to 2011/2012). In Tanzania, the suggested level is 20% or below as per the regulator's, Energy and Water Utilities Regularogy Authority (EWURA) current Key Performance Indicators (KPI), but none of the water Authorities has ever met that level.

1.1.5 Water Resource Managment

Water resource management and potentially polluting human activity in the catchment will influence water quality downstream and in aquifers. This will have an impact on the treatment steps required to ensure safe water, and preventive action may be preferable to upgrading treatment (WHO, 2011). The influence of land use on water quality should be assessed as part of water resource management. This assessment is not normally undertaken by health authorities or drinking-water supply agencies alone and should take into concern various forms of recreation, urban or rural residential development, herbicides, extraction activities, road construction, application of fertilizers, pesticides and other chemicals, construction or modification of waterways maintenance and use (WHO, 2011). Water was seen in the past as an endless product and this led to the ignorance of issues like water loss in the management of water utilities in most countries. On the other hand, water, and for that matter freshwater resource is free natural resource to man, its availability to man at any particular point in time, place and space is limited hence, the necessity for what is called water management (Baumann, *et. al.,* 1997:2). Water loss from supply networks is a common crisis requiring a supervision plan which can be normally applied. Raising such a plan requires a problem solving approach, first categorize the difficulty and its causes and then use suitable tools to deal with the problem and to decrease or eliminate it (Farley and Traw, 2003). In the developing countries, one of the major issues affecting water utilities is the considerable difference between the amount of water put into the distribution system and the amount of water billed to consumers, non revenue water (Philippe, 2006).

Physical water losses can occur along the entire distribution system, from storage reservoirs and the primary network to the smallest service connections. When people think about leakage, they normally think of big and spectacular pipe bursts. These often cause a lot of damage but are insignificant in volume compared to all the other leaks that do not come to the surface. Normally around 90% of water that is physically lost from leaks cannot be seen on the surface. These leaks might eventually become visible after many years, but until then, large volumes of water are lost every year. Sometimes, undetected leaks can be quite large, such as those that run directly into a sewer or a drain. Therefore, a water utility that does not practice a policy of efficient and intensive active leakage control will always have a high level of leakage, except if the infrastructure is new and/or in excellent condition. Water supply utilities are basically charged with the responsibility of producing adequate, clean, and safe water and the distribution of the same at affordable cost to customers within their areas of jurisdiction. The utilities charge their customers according to the approved tariff by the Regulator i.e. Energy and Water Utilities Regulatory Authority (EWURA).In practice, there is an interrelated chain of water loss from the production stage, the sales stage and the billing stage whereby the quantity of water at all these stages do not tally at all. Pursuant to this observation, it can be noted that there is a deviation between the quantities of water billed from the quantity of water produced. The difference between these two quantities is known as Non Revenue Water (NRW). Although it is widely acknowledged that NRW levels in developing countries are often high, actual figures are hard to pin down and Tanzania is no exception. Most water utilities do not have adequate monitoring systems for assessing water losses, and many countries lack national reporting systems that collect and consolidate information on water utility performance. Sometimes the water loss is linked with illegal connection and not leakage. The result is that data on NRW is usually not readily available and even when data is available, it is not always reliable (National Audit Office, 2012) .

No business can survive for long if it loses a significant portion of its marketable product, but that is exactly what is happening with many water utilities. High levels of NRW eventually lead to low levels of efficiency. When a utility's product (treated water) is lost, water collection, treatment and distribution costs increase, water sales decrease, and substantial capital expenditure programs are often promoted to meet the ever-increasing demand. In short, the utility enters into a vicious cycle that does not address the core problem. A combination of proper balance of government oversight and private sector initiative can provide an enabling environment and the right incentives to help reduce NRW, with immediate operational and financial benefits. This approach has the potential to bring rapid improvements for a public water utility, in terms of both increased cash flows and more water available to serve the population, by efficiently harnessing the know-how of the private sector (Lambert, 2001). This could in turn generate enough momentum to push for the institutional and governance reforms that are necessary to establish sustainable water utilities so that they can more effectively serve the need of the growing population in developing countries. The main objective of a water utility is to satisfy customer demand. A high level of NRW has a severe and direct impact on the ability of utilities to meet this objective and therefore has a negative impact on customers. In water systems characterized by unsatisfied demand and limited coverage, a high level of NRW is often the main reason why the system cannot be improved. In many cases, the population is then forced to use alternative water sources, which are often of poor quality and high in cost. High physical losses often lead to intermittent supply, either because of limited raw water availability or because of water rationing, which may be needed to reduce supply hours (and therefore hours of water leakage) per day (Farley, 2008).

Efforts to reduce Non Revenue Water (NRW) involve different approaches and options. Among them is the Water Balance Concept whereby the main goal is to ensure that the deviation between water produced and water billed is kept to the minimum and the preferable level is 20%. According to the International Water Association, the definition of Non Revenue Water is the difference between system input volumes and billed authorized consumption i.e. **NRW = SYSTEM INPUT VOLUME - BILLED AUTHORISED CONSUMPTION** and it consists of the major components as shown in table 1.2. This is a particular problem in Tanzania, where consumers have expressed anger that a precious and scarce resource is being wasted, whilst they are paying for inefficient services from water utilities. The combination of physical leaks, plus water taken from the system is, unfortunately, a feature of many systems. From the consumers' point of view, those who have illegal connections or have estimated actual consumption below real consumption are cheating the system (IWA, 2006).

Table 1.2: The Water Balance Components

<table>
<tr><td rowspan="9">System input volume m^3/year</td><td rowspan="2">Authorised consumption m^3/year</td><td rowspan="2">Billed authorised consumption m^3/year</td><td>Billed metered consumption including water exported m^3/year</td><td rowspan="2">Revenue water m^3/year</td></tr>
<tr><td>billed unmetered consumption m^3/year</td></tr>
<tr><td rowspan="7">Water losses m^3/year</td><td rowspan="2">Unbilled authorised consumption m^3/year</td><td>Unauthorised consumption m^3/year</td><td rowspan="7">Non Revenue Water m^3/year</td></tr>
<tr><td>Unbilled unmetered consumption m^3/year</td></tr>
<tr><td rowspan="2">Apparent losses</td><td>Unauthorised consumption m^3/year</td></tr>
<tr><td>Metering inaccuracies m^3/year</td></tr>
<tr><td rowspan="3">Real losses m^3/yeart</td><td>Leakages in transmissions and distribution mains m^3/year</td></tr>
<tr><td>Leakages and overflow from storage tanks m^3/year</td></tr>
<tr><td>Leakages on service connections up to point of metering m^3/year</td></tr>
</table>

Source: IWA Standard Water Balance

The mechanism of the water balance can be measured, estimated, or calculated using a number of techniques. Ideally, all of this important machinery will be measured, but this is often not the case. Sometimes even key data, such as the total system input, are not really known, so determining water balances is usually inexact at the outset. However, it is always worth trying to set up a water balance, even if main fundamentals are based on estimates. By doing this, it will be possible to produce a catalogue of necessary actions that are needed to improve the accuracy of the water balance. While the benefits of minimizing NRW are well known, decades of effort have not delivered much improvement in the developing countries. While there are many explanations and excuses, much of the failure is due to underestimating the technical difficulties and complexity of NRW management, along with the potential benefits of taking action. On the other hand, if utility leaders are not sufficiently informed about the level, causes and cost of NRW, along with the potential for improvement, they will not be able to convince their owners to provide funding for NRW management activities. Reducing physical losses will not only help postpone capital investments for developing new water sources, it will also help reduce a utility's operational costs like electricity bill. Water delivered to customers' taps has a large amount of embedded energy. The research outcomes will convince managers of water utilities with still high (or unknown) levels of water losses that the introduction of these new concepts will be an important first step towards more efficiency. This research therefore, aimed at assessing the impact of leakage to non quality water and non revenue water in Arusha city, the case study of the Arusha Urban Water Supply and Sewerage Authority (AUWSA). NRW is a good indicator for water utility performance; high levels of NRW typically indicate a poorly managed water utility. In addition, published NRW data are often problematic, suspicious, inaccurate, or provide only partial information.

1.2 Statement of Research Problem

Worldwide, water demand is increasing and income are diminishing, while the little water produced is not the same to the water billed, in observation of this, it has been thought essential to come across the causes of this water losses leading to a significant percentage of NRW. All regional UWSAs in Tanzania every year lose more than 70 million m^3 per year of treated water which is equivalent to more than 40 Billion Tanzania Shillings. Saving just half of that amount UWSAs would supply water to an addition of 810,185 people without any further investment (UWSA's annual reports, 2003). Non Revenue Water (NRW) remains the main vital indicator which determines how optimalyl the water produced is used. High Non Revenue Water (NRW) denies the Arusha Urban Water Supply and Sewerage Authority's income which diminishes consistent water supply in sufficient quantities to the customer. If abandoned, NRW may impose increased water production cost which inturn will, increase NRW.

A lack of understanding of the magnitude and sources of NRW is one of the main reasons for insufficient NRW reduction efforts around the world. Only by quantifying NRW and its components and calculating appropriate performance indicators can the NRW situation be properly understood, cost estimates be made, and a fair contract model be developed (Lambert, 2001). It is also of utmost importance to have good pressure and supply time data, as those have a fundamental impact on leakage levels and its reduction/increase potential. Contrary to common belief, a large portion of water stolen from public utilities does not come from poor, marginal urban areas, but rather from large industrial customers and those with political influence and enough resources to bribe utility staff and management. Allowing illegal connections and such fraudulent behavior is unfair for those in the population who do pay their bills, especially the poor, and works against promoting a culture of good governance. Most of illegal connections is due to unplanned population which has overloaded the infrastructure such that water pressures are low and sewers frequently block and overflow (Kindom, 2009). Maintenance of distribution systems is very difficult because the high densities and congested nature of the backyard shack development makes access for maintenance very difficult or impossible in places. The continued expansion of public water distribution systems in Arusha Municipality has resulted in thousands of additional service connections annually. Connection or arrangement of piping or appurtenances through which backflow of nonpotable water could flow into the public drinking water supply (Melita, ,*et al*,. 2004). Therefore, cross connection control remains a critical link in protecting public health by maintaining the quality of drinking water from the source, through the distribution system and to the customers. Drinking water quality will be jeopardized without a persistent effort in cross connection control, regardless of efforts to protect the source of supply and improved treatment techniques (Melita, et *al*,. 2004).

It was the intention of this study to determine the knowledge and understanding of NRW for Arusha Urban Water Supply Authority management in relation to poor management system, equity and quality of potable water supply in rapid growth of city like Arusha City. AUWSA is intending to develop strategy for management of non revenue water (NRW) so as to gain a better understanding of the reasons for NRW and the factors which influence its components. The techniques and procedures was developed and tailored to the specific characteristics of the network and local influencing factors, to tackle each of the components in order of priority. This diagnostic approach, followed by the practical implementation of solutions which are practicable and achievable, now can be applied to any water company, anywhere in the world, to develop a strategy for NRW management.

1.3 Significance of the Study

Many water authorities in Tanzania face related difficulties in decreasing non revenue water and this problem of Non Revenue Water had been practiced since declaration of the Water Authorities as fully autonomous entities in January 1998. The data for the quantity of water which is not accounted for are accessible from 2006/2007 when EWURA introduced to all water authorities the reporting system called Maji Information System (MajIs). This study has analyzed the factors contributing to Non Revenue Water (NRW) for the water industry in Tanzania with a case of Arusha Urban Water Supply and Sewerage Authority. For sustainability of any company like AUWSA the economic efficiency is a key to priotize. The common indicators of the economic efficiency of water and sewerage utilities are billing efficiency, the level of non revenue water and labour productivity. On the basis of these indicators the economic efficiency of urban service provision in the water sector in Tanzania is low and AUWSA is not exception. On the issue of billing efficiency, the Government of Tanzania data indicated that urban water utilities have relatively high levels of billing efficiency (never below 70% while for AUWSA is around 90%) (EWURA, 2012/2013).

The average level of non revenue water among the 20 regional water utilities was 45% in fiscal year 2006-2007 and for AUWSA now is around 53%. Data reported by the Ministry of Water and Irrigation in 2009 show that non-revenue water in urban areas varies between 55% in Dar es Salaam and 25% in Tanga and in Arusha according to AUWSA is 53%. It is estimated that non-revenue water is higher in small and district towns (AUWSA, 2013). On average, there were 10 staff members per 1000 water connections in the large water utilities as of 2007. The lowest number in Tanzanian UWSSAs is 6 employees per 1000 connections, obtained in Tanga, Mbeya and Arusha. This study was able to assess the rate and importance of each factor mentioned above, along with taking advantage of an efficient management system, will reduce non-revenue water loss resulting in an efficient water production system. So far, many studies have been carried out on assessment of water losses and non-revenue water in different parts of the world but not in Arusha Municipality.

1.4 Research Objectives

1.4.1 General Objective

The general objective of this research was to assess the causes of Non-Revenue Water (NRW) in Arusha City.

1.4.2 Specific Objectives

The specific objectives were:-

i. To examine the quality of water in the distribution system in Arusha City.

ii. To determine the effects of motivation factor to AUWSA employees and customers on the overall management of Non- revenue water aspect.

iii. To examine how internal and external customers can contribute to the reduction of Non Revenue Water.

1.5 Limitations

The main limitation faced by the researcher in data collection was that most of the personnel interviewed at management level were not willing to give the reality of what transpires and were not willing to accept challenges and my questionnaires were considered as a threat and not an opportunity to be improved upon. In view of this, it took the researcher unnecessarily long time to get the required information. Not totally much has been extended to extent of my research requirement and objectives. Most of the literature obtained has talked much on what is known and if talked about my area of study it has been so brief. Also there has been so little written on the contribution to control of water losses from water customers.

1.6 Research Questions

i. Do the quality of water consumed in Arusha City is within the acceptable Standards?

ii. Do the motivation to employees and customers contributes to reduction of Non Revenue Water?

iii. Do the age of water supply system has an effect on reducing the percentage of NRW?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Until early 1990s, there were no reliable and standardized methods for accounting for water losses. Leakage management performance was measured in terms of "*unaccounted-for water*." Since this term had no generally accepted definition, there was wide room for interpretation. Unaccounted-for water was typically expressed as a percentage of system input, which is already problematic. Given this situation, utility performance could not be measured or compared, realistic targets could not be defined, and performance against targets could not be tracked reliably. While these circumstances still exists in many countries, significant progress has been made to address these past shortcomings. Over the last 20 years, a number of organizations from around the world have developed a group of tools and methodologies to help utilities evaluate and manage water losses in an effective manner (Frauendorfer, *et al.*, 2010).

The Non revenue Water has been defined as an umbrella term that refers equally to water that is actually lost in the course of physical leakages composing technical losses and to water that is not paid for due to illegal connections, nonpayment of bills or other reasons composing commercial losses. It is the difference between the volume of water put into a water distribution system and the volume that is billed to customers. NRW or Unaccounted-for water is the difference between water produced (metered at the treatment facility) and metered use (i.e., sales plus non-revenue producing metered water). Non Revenue Water can be expressed in millions of gallons per day (mgd) but is usually discussed as a percentage of water production (Lahlou, 2001). Also Non Revenue Water (NRW) can be defined as the total amount of water flowing into the water supply network from a water treatment plant (The system input volume) minus the total amount of water that industrial and domestic consumers are authorized to use (The authorized consumption) (Farley, *et al*., 2008). This is water that has been produced and is lost before it reaches the customer. Such losses may be caused through leaking and burst pipes, illegal connections (Fig 2.1) and metering inaccuracies. The imperative to effectively manage NRW is further heightened due to a rapidly growing and urbanized global population and the impacts of climate change which together put greater demand on the scarce and finite water resources. Non-Revenue Water (NRW) are those components of System Input which are not billed and do not produce revenue. NRW is equal to unbilled authorized consumption plus physical and commercial losses (Liemberger, 2010).

Figure 2.1 Multiple Illegal Connections with Massive Leakage

The researcher's definition for NRW which is adopted and shall be referred to in the entire study work is; "Non Revenue Water (NRW) is the difference between the water produced and pumped into the network system and the total water billed to consumers from the full amount produced and it is calculated in cubic meters". NRW denies AUWSA the necessary income required for sustainable operation and maintenance of the system coupled with unreliable water supply to the consumers. In the long run, if unchecked may require increased water production cost which in turn, raise the NRW.

2.2 Status of Non Revenue Water in Different Countries

In Tanzania, water authorities faced a number of challenges like water production which does not meet demand and old infrastructures resulting to water losses that lessen financial capability of the water utilities hence poor services. There are no reliable and standardized methods for accounting for water losses. Leakage management performance was measured in terms of "*unaccounted-for water".* Since this term had no generally accepted definition, there was wide room for interpretation. Unaccounted-for water was typically expressed as a percentage of system input, which is already problematic (WHO/UNICEF, 2006).

Non-Revenue Water gives negative impact on the quality of the utility's water supply services. It reflects the problem of instability of water supply infrastructure. Damaged pipes network, water supply interruption to the customers and quality of treated water supplied are among the subjects that need to be given consideration in ensuring high quality of water supply service (Malek, *et al*., 2011). Given this situation, utility performance could not be measured or compared, realistic targets could not be defined, and performance against targets could not be tracked reliably. Continued non-revenue water (NRW) limits the financial resources available to tackle these challenges facing water utilities (Malcolm, 2008).

In Tanzania especially in Arusha municipality, often consumer are blamed for high levels of NRW, especially due to illegal connections. On the other hand, these are poor people and the poor are the one significantly affected by high water losses. While theft of water in low-income communities is certainly a reality in Arusha Municipality its impact must be put in the proper perspective. The volume of water that is illegally consumed by a poor household is normally quite small, because of the lack of washing machines, flush toilets, garden irrigation, etc. Furthermore, this low level of consumption would nearly always be in the lowest tariff category (Domestic). Therefore, the financial impact is even less than the volumetric impact. Experience in many countries shows that water theft by higher income households, commercial and industrial users can be much more of a problem (AUWSA Profile 2013).

The NRW is a big challenge to the water industry in general and it openly affects the level of income realized from water billings, service level and consumer satisfaction to meet the water demand from consumers which in turn affects service sustainability in water sector. The existence of NRW is contributed by a number of reasons, depending on the technological development level and its purpose in the industry. Some of the developed countries have managed to control the level of NRW to the lower level like Singapore with 5% and Vitens in the Netherlands with 6% and below, while the developing countries including Tanzania with an average of 35.2% of NRW for regional UWSAs (UWSAs Annual reports 2008/2009 to 2011/2012). In Tanzania, for instance the suggested level is 20% or below as per the regulator's (EWURA) current Key Performance Indicators (KPI), but none of the water Authorities has ever met that level.

In Uganda, Non-Revenue Water increased from 21% in 2009/10 to 24% in 2011/12 (Government of Uganda, 2012). This was mainly attributed to the aging infrastructure in a number of towns, some of which have exceeded their design life and are in need of major rehabilitation and/or replacement. As measured in 2008, wetlands in Uganda cover approximately 10.9% of the land surface area, down from 15.6% km^2 in 1994. There is a continuing overall decline in wetlands with Lake Victoria and Kyoga drainage basins having been affected most. This is basically attributed to encroachment for growth of urban centres, settlement or industrial developments and extension of agricultural land. (Government of Uganda, 2012).

2.3 Potential Factors Leading to Low Non-Revenue Water

2.3.1 Motivation

Motivation is the set of processes that determine the choices people make about their behaviours. Motivation is the ability of indoctrinating the personnel with a unity of purpose and maintaining a continuing, harmonious relationship among all people (Armstrong, 2009). Motivation efforts must be directed towards improving AUWSA operations. To be effective, however, they must also be designed to show benefits to the employees. Lack of motivation in return affects AUWSA performance. A number of symptoms may point to low morale: employees being involved in illegal connections, by pass connections, tempering meters, improper maintenance of meters and corrupt practices during the meter readings and billing process and hence leading to high Non-Revenue Water. The Asian developing countries face challenges in reducing NRW, such as aging infrastructure, financial constraints, and poor governance. However water utilities can draw on their motivated and hard working staff as a key strategy to improve NRW (Malcolm, *et al.*, 2008).

In dealing with the reduction of NRW, staff salaries in Cambodia were increased substantially during the reform process. For example, a staff member at a managerial position who was paid 20 USD in 1993 received 200 USD in 2008. Profits are shared with employees in water utilities. The utility also evaluates its employees four times a year and can provide financial incentives, substantial training as well as disciplinary actions such as delays in salary increases or even salary deductions (Das *et al*, 2010).

2.3.2 Unauthorised Water Consumption

Some customers try to reduce their water bills by using a meter bypass, which is an extra pipe installed before the meter. This bypass pipe is often hidden and very difficult to detect. This type of unauthorised consumption is frequently committed by customers in all categories (domestic, industrial, parastatal and commercial premises), where only a small amount of water goes through the meter and the rest through the bypass pipe. This necessitates the utility to undertake customer surveys and leakage step tests to determine where the missing flow occurs (Farley, *et a*l., 2008).

2.3.3 Leakage and Overflows from the Utility's Reservoirs and Storage Tanks

Leakage and overflows from reservoirs and storage tanks are easily quantified. Utility managers should observe overflows then estimate the average duration and flow rate of the events. Most overflows occur at night when demands are low and therefore it is essential to undertake regular nightly observations of each reservoir. These observations can be undertaken either physical or by installing a data logger which will then record reservoir levels automatically at preset intervals. Leakage from tanks is calculated using a drop test where the utility closes all inflow and outflow valves, measures the rate of water level drop, and then calculates the volume of water lost. (Farley, *et a*l., 2008).

2.3.4 Water Meter Accuracy

Water meter accuracy depends on its type, age and quality of water. Water meter sizing is very important as the accuracy is expressed as a percentage of the flow range. If water meters are oversized there will be an unnecessary loss of accuracy on the actual flow rate (Farley & Trow, 2003). Improper meter installation leads to inaccurate data and billing errors. For example in the Fig. 2.2 below Meter Readers will find it difficult to determine which meter belongs to which property.

Figure 2.2 Multiple Connections

Source: Farley, 2008

Meter calibration error and data error losses can be thought of as accounting losses. This quantity of water is not lost from the system and generates no revenues but if not included in loss calculations can produce misleading water loss estimates (Fanner, 2009). These errors arise from service meter calibration errors, meter reading errors, data handling and billing errors and billing period variances. These quantities may be reduced through administrative action. When performing financial calculations related to apparent losses, the water is priced at the retail rate since it should have been charged at that rate. Recovering apparent losses will not reduce physical system leakage but it will recover lost revenue. Calibrating or replacing old meters or enforcing water theft policies can substantially reduce apparent losses (AWWA, 2009).

2.3.5 Leakage due to the Age of Infrastructure

In Africa some of the Urban Water Services Corporations (UWSC) are understaffed and depend on expatriate technical advisors. Recent internal restructuring has distracted UWSC from the need to make urgent decision about infrastructure upgrading and expansion (David, 1996). Based on case studies of utility reforms in East African cities Brown (2007) suggests that private sector participation can lay the foundation for reducing NRW (Silver, 2011).For the majority of water supply systems, leakage is something which cannot be eliminated completely. There will at all times be a level of leakage which has to be tolerated and which has to be managed (Farley and Trow 2003). High leakage together with high failure rate is one of the characteristics of deteriorated pipelines. Reconstruction of the water supply network is therefore an essential part of an integrated water loss management plan, especially after exhaustion of other leakage reduction methods. An economical evaluation of the reconstruction strategy depends on the cost of leaking water and the reconstruction efficiency. The hydraulic model helps to set the right priorities and optimize the reconstruction procedure. For the previous three financial years (2009/2010 to 2011/2012), it is extremely clear that there is no single UWSA in

Tanzania which does not have a problem with NRW control management. In view of this observed crisis, the researcher has analysed what could be the other unidentified reasons for NRW. Table 2.1 shows the Non Revenue Water for the past three financial years in defferent water utilities in Tanzania.

Table 2.1: NRW Percentage for the Previous Three Financial Years

UWSA	2009/2010	2010/2011	2011/2012
Arusha	33.92	35.12	40.01
Dodoma	42.7	40.54	37.3
Iringa	41.2	33.14	56.2
Mbeya	37.9	31.43	34.5
Morogoro	39.1	33.1	40.2
Moshi	34.5	35.8	39.7
Mtwara	33	31.4	35.5
Musoma	42	46.97	47.2
Mwanza	48.7	46.36	42.8
Shinyanga	32.2	33.1	36.7
Songea	40	37.4	40.7
Tabora	38.9	38.2	41.2
Tanga	34	31.8	39.9
Bukoba	51.2	47.13	47.1
Kigoma	57.5	33.66	33.6
Singida	34	37	39.2
Sumbawanga	42.1	39.35	38.5
Babati	41.2	39.55	39.2
Lindi	40.8	35.21	36.2

Source: UWSAs Annual Reports

Non-Revenue Water in the various UWSAs range from 33.00 - 57.50% with most UWSAs in the range between 30-51%. These are really high levels of water losses that have a reflective effect on revenue collection and the financial capability of water supply utilities. In due course no UWSA could economically sustain water supply with such high levels of water losses. Non-Revenue Water includes two different elements: physical water losses and commercial water losses in the form of informal resale of water between customers (UWSAs Annual Report, 2009/2010 – 2011/2012).

2.4 Environmental Effects of Water Leakage

Pipe leakage in Tanzania is perceived to be a major preoblem by many water authorities, both from an environmental point of view as well as the associated costs that are incured to overdesign of newtwork systems and the treatment of potable water that is lost due to leakage (Stewart *et al*, 1999). In many water distribution systems a significant percentage of water is lost while in transit from treatment plant to consumers. In the case of older network systems the percentage of lost water could be as high as 50% (AWWA, 1990). Although Non Revenue Water is usually attributed to several causes inlcuding leakage, metering errors and theft, leakage is the major cause. Water leakage is a costly problem not only in terms of wasting a precious natural resource but also in economic terms (Stewart *et al*, 1999).

Non-Revenue Water is highly synonymous to leakage problems. Leakage in the pipe distribution system not only cause financial loss to the water utilities as well as the country, but, it also brings other connected losses such as destructing the soil structure in the surrounding area of the leakage area, which indirectly cause the slope failure. Among other things that could put in danger the environment due to Non-Revenue Water problems are water ponding on the metalled road which damages the structure and road components (Malek, *et al*, 2011). Little attention has been given to the environmental aspects of leakage from water major and the main focus has been on damage to property and the infrastructure. In the area of environmental effects, most attention has been applied to sewerage pipes. Overflows do cause environmental impacts and they vary in significance from location to location (Stewart *et al*, 1999). In reality, water was perceived as non-limited resources because water availability was sufficient to cover the necessity for various sectors such as agriculture and environment. Progressively due to the increased water use, misuse of water resources, increased population and other natural and human induced changes water has become scarce resource, over Africa. Conflicts are inevitable in the societies because of competing inteests between or among various water users, such as commercial farms, small farmers and livestock keepers. The natural environment has yet to be recognized as an important water user and at present receives hardly any consideration in an already over-allocated resource (EAC, 2011).

2.5 Water and Environment

The environment is under threat from natural and man-made drivers of change including; urbanization, rapid population growth, agricultural expansion, informal settlement development, industrialization and the impacts of climate variability among others. This has left environmental management with a number of issues and challenges. However, the most crucial issue that has emerged over the years is that of weak governance at all levels, coupled with the increased demand for natural resources and the development pressure in the country. This also covers the components of wetland resources management, forestry, environmental support services and weather (Thampapillai, 2002). Water scarcity has attracted the attention of Africa and the international community and is considered one of the major environmental issues of the twenty-first century. On 22 March 2001, the United

Nations commemorated World Day for Water and reported that demands for freshwater had already exceeded supplies by 17% and that over the next 25 years, two thirds of the world's population will experience severe water shortages. The message for that day was: "Concrete efforts are necessary to provide clean drinking water and improve health as well as to increase awareness world-wide of the problems and of the solutions". This year's (2014) message was: Water and Energy. Water and energy are closely interlinked and interdependent. In addition, the World Resources Institute in Washington DC has warned that the world's freshwater systems are in peril. It predicts that by 2025 about a billion people or nearly 50% of the world's population will face water scarcity (WWDR, 2014).

2.6 Climate Change and Water Resource

Water resources is the total range of natural water present on earth and that of potential use to human being. Water resource may occur in form of liquid, vapour or solid, (Oxford Dictionary 2000). All regions of the world show an overall net negative impact of climate change on water resources and fresh water ecosystems. Moreover, the future effect of climate change in Africa and other parts of the world will depend on friends in both climatic and non-climatic factors. Bergkamp, *et al.* (2003) further discuss that the evaluation of these impacts is challenging because water availability, quality and stream flow are sensitive to changes in temperature and precipitation. However, there are some other important factor includin increased demand of water caused by population growth, change of economy, development of new technologies and change in water shed characteristics and water management decisions. Apart from the typical impacts on water resource management, climate change introduces an additional element of uncertainty about the future water resources management. Globally implementation of additional measures, such as water conservation, uses of market to allocate water and the application of appropriate management practice will have an important role to play in determining the impacts of climate change on water resources, (IPCC 2007). The ultimate goal for NRW reduction should be selected with the consideration of cost implications or whether is attainable. Identifying NRW in monetary terms essential in order to setup the preliminary NRW goal and it requires a relationship between the cost of water being lost and the cost of undertaking NRW reduction activities (Wyatt, 2010). The global volume of Non-Revenue Water (NRW) is shocking. Each year more than 32 billion m^3 of treated water are lost through leakage from distribution networks. An additional 16 billion m^3 per year are delivered to customers but not invoiced because of theft, poor metering or corruption. (Lahlou, 2001).

2.7 Definition of Key Terms

Non Revenue Water or Unaccounted-for water is the difference between water produced (metered at the treatment facility) and metered use (i.e., sales plus non-revenue producing metered water). Non Revenue Water can be expressed in millions of gallons per day (mgd) but is usually discussed as a percentage of water production (Lahlou, 2001). Also Non Revenue Water (NRW) can be defined as is equal to the total amount of water flowing into the water supply network from a water treatment plant (The system input volume) minus the total amount of water that industrial and domestic consumers are authorized to use (The Authorized consumption) (Farley, *et al*., 2008). Non revenue water (NRW) is water that has been produced and is lost before it reaches the customer. Such losses may be caused through leaking and burst pipes, illegal connections and metering inaccuracies. The imperative to effectively manage NRW is further heightened due to a rapidly growing and urbanized global population and the impacts of climate change which together put greater demand on the scarce and finite water resources. Furthermore, reducing levels of NRW can greatly contribute to the attainment of MDG target 7 that is to reduce the proportion of people without access to safe drinking water (IWA).

2.8 Components of Non-Revenue Water and Water Balance

The early stage of assessing Non-Revenue Water is to make a water balance within the system in order to understand how much water is actually used and paid for but also how much water is lost and how it is lost. Water balance are widely used by the water utilities but the diversity of formats and evaluations of the losses prevented international comparisons between water utilities (Lambert, 2003). Non-Revenue Water comprises three components: physical (Real) losses, Commercial (apparent) losses, and unbilled authorized consumption (ADB, 2006).

Table 2.2: Components of Non Revenue Water

<table>
<tr><td rowspan="9">System Input Volume (m^3/year)</td><td rowspan="2">Authorized onsumption (m^3/year)</td><td rowspan="2">Billed Authorized onsumption (m^3/year)</td><td>Billed metered consumption (m^3/year)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed unmetered consumption (m^3/year)</td></tr>
<tr><td rowspan="7">Water Losses (m^3/year)</td><td rowspan="2">Unbilled Authorized Consumption (m^3/year)</td><td>Unbilled metered consumption (m^3/year)</td><td rowspan="7">Non Revenue Water</td></tr>
<tr><td>Unbilled unmetered consumption (m^3/year)</td></tr>
<tr><td rowspan="2">Commercial Losses (m^3/year) (Apparent losses)</td><td>Unauthorized consumption (m^3/year)</td></tr>
<tr><td>Customer meter inaccuracies and data handling errors (m^3/year)</td></tr>
<tr><td rowspan="3">Physical Losses (m^3/year) (Real losses)</td><td>Leakages and overflows from the utilities storage tanks (m^3/year)</td></tr>
<tr><td>Leakages on transmission and distribution mains (m^3/year)</td></tr>
<tr><td>Leakages on services connections up to the customers (m^3/year)</td></tr>
</table>

Source: International Water Association, 2006

Table 2.2 above shows two basic components of Non Revenue Water which is Authorized consumption and water Losses. In calculating them there are number of steps which must be followed as summarized below:

i. The system input volume is measured by using measuring devices (Bulk water Meters) at the sources.

ii. Authorized consumption is obtained by calculating the billed metered consumption and then the volume of non revenue water is calculated by deducting Authorized consumption (Non-Revenue Water) from system input volume.

iii. Define unbilled metered consumption and unbilled unmetered consumption to get total unbilled authorized consumption.

iv. Add volumes of billed metered consumption and billed unmetered consumption to obtain the sum of the authorized consumption.

v. Calculate the water losses which are the differences between system input volume and authorized consumption.

vi. Define and assess the components of authorized consumption and metering inaccuracies by appropiate available means and measures to obtain the total commercial losses (apparent losses).

vii. Calculate the physical losses (real losses) which are water losses less commercial losses.

viii. Define kneely and assess components using best available means like night flow analysis, bust frequency, flow rate duraton calculations modelling, then sum them together and cross check with volume of real losses which was derivered in step –vii.

Commercial losses sometimes called apparent losses include water that is consumed but not paid for the use (Malcolm, 2008). In most cases, water has passed through the meters but is not recorded accurately. In many countries commercial losses is higher than physical losses and commercial losses has high value because reducing commercial losses increase revenue while reducing physical losses reduce the production costs. Commercial losses comprise unauthorized consumption and metering inaccuracies. It is estimated that in Developing countries 50 – 65% of NRW is due to commercial losses (World Bank, 2011; Global Water Partnership, 2011). Unauthorized consumption means illegal use, and this could be sole illegal connections, illegal connections to properties that also have legal connections i.e. residents in street divert water for a short time from their illegal to their legal connections, illegal connections for the purpose of selling water. Metering inaccuracies can include malfunctioning water meters, estimated water consumption (when meters are not working) and misreading water meters. Further meter reading errors can be caused due to negligence, aging meters or due to corruption during the exercise of reading the meters and billing customers. Meter readers may read the meters incorrectly or make the simple errors, such as placing the decimal in wrong place also dirty dial, faulty meter and jammed meters can cause the reading errors.

Meter by-passing is an illegal practice in which in some cases customers are trying to reduce consumption by installing water by pass which is an additional pipe connected around the meter (Fig. 2.3). This additional pipe is hidden in the ground and it is difficult to detect. In this type of connection the small amount of water is allowed to pass through water meter and the rest pass through the bypass pipe as the result the amount of water to be paid will be less.

Figure 2.3: Meter by-pass

Meter readers are responsibile to report any observed problems and the responsible section should take immediately action to remedy the problem. If the remedy action is too slow, the meter readers may become demoralized and they may stop reporting the problem. Physical losses sometimes is called real losses or leakages has three components. These are leakages occurring in transimission or distribution mains (lines); leakage and overflow from utility storage, water reservoirs; and leakages occurring on service connections up to the customer’s meter (Malcolm, 2008; Loland, 2010). The leakages occurring in transmission, water reservoirs, distribution mains and overflow are easily visible to internal and external customers and they are quickly repaired compared to the leakage which occurred on service connections to the customer’s meter.

Unbilled Authorized Consumption can be categorized in two groups which are unbilled metered consumption and unbilled unmetered consumption. Unbilled consumption can includes water used for fire figting, water used by the water utility for operational purposes (eg flashing of the water system) and water provided for free to certain consumer groups (eg refugees camps, Orphans, urban poor people and employees of the water utility). That is to say that the unbilled authorized consumption reflects the public policy decision to allocate without monentary compesation.

2.9 Strategies to Reduce and Manage Non-Revenue Water (NRW)

Many tools have been developed on how to reduce and manage Non Revenue water. Table 2.1 give an overview of those tools required to be used for reducing and managing of Non Revenue water (NRW).

Table 2.3: Tasks and Tools for Developing NRW Reduction Strategy

S/No	Questions	Task
1	How much is being lost? - Measure compontents	Water Balance - Improved estimation/measured techniques - Meter calibration policy - Meter checks - Identify improvements to recording procedures
2	Where is being lost from? - Quantify leakage	Network Audit - Leakage studies (Reservioirs, transmission mains, distribution networks) - Operational/customer investigation.
3	Why is it being lost? - Conducting network and operational audit	Review of network operating practices - Investigate: historical reasons:- poor practices, quality management procedures, poor materials/infrastructure, local/political influences and cultural/social/financial factors
4	How to improve performance? Design a strategy and action plans	Upgrading and strategy development - Update records systems - Introduce zoning - Introduce leakage monitoring - Address causes of apparent losses - Initiate leak detection/repair policy - Design short-medium-long-term action plans
5	How to maintain the strategy?	Policy change, training and O&M - Training: improve awareness, increase motivation, transfer skills and introduce best practice/technology - O&M: community involvement, water conservation and demand management programmes, action plan recommendations and O&M procedures

Source: Farley and Liembergerger, 2005

2.9.1 Leakage Control

Not all the water that leaves a water treatment plant reaches the consumer. A significant amount as much as 50%, or even more is lost through leakages. All pipe materials deteriorate with age, and all connections are potential sources of leaks. A common feature of water distribution networks in developing countries is the high number of unauthorized connections to the network. These cause many problems, including loss of pressure and contamination of the supply, and contribute sigificantly to leakage.

There are many electronic methods of leakage control used in developed countries. Most of these are expensive and inappropriate for developing countries. A common feature of water supply networks in low and middle income areas is that they do not supply water 24 hours a day. Sometimes, the rationale is that by limiting the hours of supply, then the consumption can be limited, but the reverse if often true (WHO, 2001). When supply is limited, many people store water as a safeguard, and when supply is resumed they waste the stored water. Also, as the supply is limited and there are many illegal connections, the pressure of the water is often very low. In such circumstances, people tend to connect their own small booster pump to their connection to the main and draw out what water they can. This reduces the pressure in the main further and sucks out all the available water and adds to the possibility of further leakage (IWA 2007). Leakage detection and control in many developing countries is usually done as a response when a leak is reported. However, leakage detection should be a routine preventive function of a water utility as the water lost is a waste of a valuable commodity which is limited in its availability, and of money (in the effort spent in treating and distributing the water which is wasted, and in the loss of the potential revenue associated with the lost water (IWA, 2007)). For real effectiveness leakage monitoring and control must be a regular activities and not based on incident response as is often the case in developing countries.

2.9.2 Control Pressure

When we think of controlling pressure we most frequently think of holding pressure at a near constant value in some type of a distribution system. Most commonly this is accomplished by reducing a high supply pressure down to a lower pressure where it is more practical to handle. If the upstream or supply pressure is constant and if the demand downstream is uniform then some type of a fixed restriction such as an orifice or perhaps a manual valve that is throttled in a partially open position, will effectively reduce the pressure. Frequently, there are supply pressures that are relatively constant but only rarely are distribution system encountered where the demand is consistent and uniform. The back pressure or pressure sustaining valve can also be called a pressure relief valve. It can be used to control pressure in a system where it is installed on a tee so that it can relieve from the system any pressure in excess of a present value. The same automatic valve utilized in a relief capacity can be used to maintain a constant pressure in a booster pump system. This is timely and appropriate to relate these theories of NRW management and actuality considered for NRW management in AUWSAs.

2.10 Consequences of NRW in Tanzania Water Authorities

The issues related to high NRW rates are consumers paying for inefficiencies of water utilities, a precious and scarce resources being wasted and unnecessary investments in production. Another important consideration is that high Non-Revenue Water rates equate to poor governance, which results in low utility staff morale. From the consumers' point of view, those who have illegal connections or have estimated actual consumption below real consumption are cheating those who pay for water. Fig. 2.4 shows the NRW levels for the past three years (2009/2010 – 2011/2012).

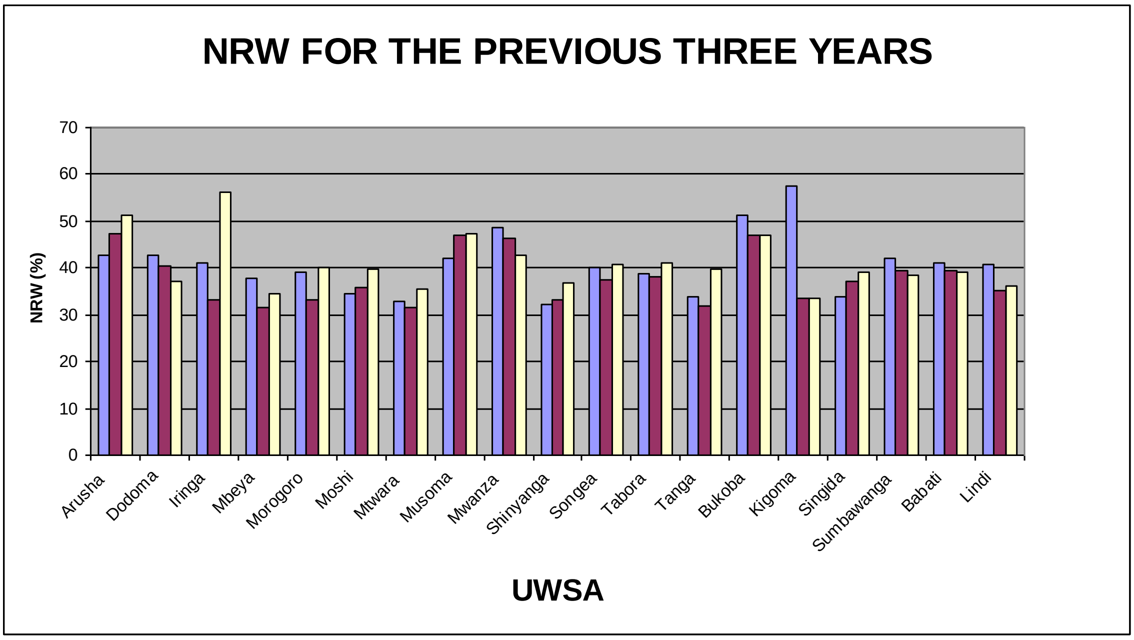


Figure 2.4: NRW Levels for the Previous Three Financial Years

Source: UWSA's Annual Reports – Shirt

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Scope of the Study

This research was carried out in Arusha City, Arusha Urban Water Supply and Sewerage Authority (AUWSA). Arusha City is located between 2^o and 6^o South as well as longitude 34.5^o and 38^o East. The City is also loated on the southern slopes of Mount Meru lying at a height between 1160m to 1450m above sea level. It lies on the Great North road at the center between Cairo and Cape Town. Arusha City is an industrial, international trading, tourism and conference centre. Arusha City Council has a population of 416,442 (199,524 male and 216,918 female) (NBS, 2012). However, despite various efforts made to improve water services and to reduce Non-Revenue Water in Arusha has been no improvement or no significant change in reduction of Non-Revenue Water in AUWSA.

3.2. Research Design

A case study is one of the research designs that are deeply rooted in the phenomenological paradigm. The purpose of the research design is to provide the most valid and accurate answers to the research problem being investigated. It is therefore very important to match the research design with the research problem. Moreover, it is possible to conduct such a study with a single case, a position that suited a study well. In order to analyze the effects of leakage in water quality and quantity, challenges of reducing Non-Revenue Water; taking the case of Arusha Water Supply and Sewerage Authority, a case study was the appropriate strategy. The rationale for this selection is guided by the fact that a case study is not a methodological choice, but a choice of what is to be studied.

A case study captures the essence of the phenomenon and enables the extraction of data, which is rich in both explanation and analysis. This study was guided more by the specificities rather than the generalities; in this regard AUWSA was more specific legitimate area of inquiry. The contention that “the more the object of the study is specific, unique and bounded system, is not to represent the world but to represent the case”: in this light, this study represents the effects of leakage in water quality and quantity, challenges of reducing Non-Revenue Water in Tanzania Water Supply and Sewerage Authorities; taking the case of AUWSA not otherwise.

3.3 Sampling Technique

Purposive sampling was employed in this study, attempts were made to interview and questionnaires were given out by randomly selecting AUWSA customers and staff. Purposive sampling was used to select sample respondents. The reason for applying purposive sampling was that, the technique is employed with belief that the respondents deliver the best and unique information in order to satisfy the research objectives.

3.4 Sampling Frame

In carrying out this research, a total of 140 respondents were used to represent a large population. Questionnaires were distributed to some of AUWSA employees (Management team, Assistants/Supervisors, Technicians/Meter Readers, Normal staff) and customers of different categories (Domestic, Commercial, Industrial and Parastatal). The choice of these units of inquiry is made basing on their involvement, knowledge, experience and number of years stayed in AUWSA. Out of 140 people 21 (15%) were interviewed and 119 (85%) responded through questionnaire as shown in table 3.1.

Table 3.1: Sampling Frame

Unity of Inquiry	Sample Size (Actual Number of Respondents by)			Percent (%)
AUWSA Employees	**Questionnaires**	**Interviewed**	**Total**	
Management team	6	0	6	100
Assistants/Supervisors	6	0	6	100
Technicians/Meter Readers	10	5	15	100
Normal staff	35	8	43	100
Domestic	46	6	52	87
Parastatal	6	2	8	80
Institutions	5	0	5	100
Industrial	5	0	5	100
Total	**119**	**21**	**140**	**89**

3.5 Methods of Data Collection

In determining the data collection methods to be employed in this study the following methods were used:

3.5.1 Questionnaire

This method was used to collect information due to its strength of permitting a wider coverage of respondents with minimum expenses in money, time and effort. The questionnaire facilitates greater coverage that yield greater validity through large and more representative sample. By using this method the study attained consistency and uniformity in the manner questions were posed. Also this method gave respondents a high degree of confidence and a sense of privacy, and allowed them to provide information at their time and pace. Questionnaire was distributed to AUWSA employees (Management team, Assistants/Supervisors, Technicians/Meter Readers, Normal staff) and customers of different categories (Domestic, Commercial, Industrial and Parastatal).

3.5.2 Observation

This method was used in order to get first hand information. The researcher used sight and hearing, and recorded and interpreted information obtained. The researcher participated in various informal discussions of services provided by AUWSAs, leakages handling and the problem of water pipes systems took place in Technical staff meetings. This technique helped to collect information concerning attitudes, perception, leakages, water quality, illegal connections and water pipes as well as the meter functioning. To verify and complement the findings revealed from interviews and questionnaires, observation was used to get an insight into the water pipes systems, and water tanks.

3.5.3 Documentary Review

Documentary research is a rich source of information. Most of the data were derived from documents like AUWSA profile, pamphlets, discussion papers, monthly, quarterly, and annual reports. The documentary analysis also revealed the customers complaints, illegal connections and leakages reports.

3.5.4 Interview

Structured and unstructured interview were conducted to a sample of Arusha Urban Water Supply and Sewerage Authority employees and other external customers. In this connection, various questions were asked in a sequential order and the respondents given the chance to present their views freely. This method was used to collect data on the quality of water in the distribution system in Arusha City, effects of motivation factor to AUWSA employees and customers on the overall management of Non- revenue water aspect, how internal and external customers can contribute to the reduction of Non Revenue Water and other factors contributed to Non-Revenue Water.

3.6 Methods of Data Analysis

The primary data, both qualitative and quantitative were gathered by using the questionnaires, observation, interviews and secondary data obtained through documentary review. The decision on data analysis approaches and techniques was made during the research design stage. The questionnaire consisted of closed ended items and open-ended items. The raw data from questionnaires were analyzed by using content analysis. The data analysis exercise began with the coding process whereby a total of 140 results were coded accordingly. Some of the data collected were rearranged into statistics to ease the analysis and interpretation analysis. The raw data from semi-structured interview were gathered by note taking techniques. The interview manuscripts from each respondent were carefully studied and examined to identify important responses in terms of interesting statements, opinions and comments.

3.7 Qualitative Data Analysis

The study collected this type of information from various respondents and analyzed. The qualitative data provided the non numerical information about the perception of employee's with regards to the effects of leakages on water quality and Non Revenue Water in Arusha Urban Water Supply and Sewerage Authority.

3.8 Metric Data Analysis

This research gathered quantitative information and analysed by using SPSS and MS excell on the number of leakages, number of illegal connections, amount of water produced and losses.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter addresses on how this study was conducted with regards to information collection and presentation. It further describes the whole research design and data gathering methods applied to achieve the objectives and aim of the study. Furthermore, it will provide information regarding secondary data collection, questionnaire administration, observation and interviews conducted to both customers and AUWSA staff for the purpose of this research.

4.2 Unintended Water Losses

For many years, the most widely used performance indicators in the World and Tanzania is not exception for Non-Revenue Water and Real (Physical) losses have been percentages loss. Water produced and delivered to the distribution system is intended to be sold to the customer not lost from the distribution system without authorization (Trow and Pearson, 2010). Although all customers may be metered in a given utility, a fairly sizable portion of the water most utilities produced does not pass through customer meters. Unmetered water includes unauthorized uses, losses from leakages, malfunctioning distribution system controls, thefts and inaccurate meters (Lahlou, 2001). NRW is a measure of a utility's efficiency in terms of both operational performance and financial performance. Managers, policy makers, regulatory agencies, and financing institutions use NRW performance indicators to rank the utility's performance against industry standards and other water utilities (Farley, 2008).

Many states recorded a high NRW level exceeding 40.0%. These include Bucharest – Romania (46.0%), Adana – Turkey (69.0%), Diyarbakir – Turkey (51.0%), Guayaquil – Ecuador (73.0%), Hyderabad – India (50.0%), Delhi – India (53.0%), Jakarta – Indonesia (51.0%), Manila West (53.0%) and Kayseri – Turkey (45.0%) and Sofia – Bulgaria (62.0%). These states are also recording high physical loss which is more than 20.00% (SWAN, 2011).

In Kenya high levels of Non-Revenue Water are detrimental to the financial viability of a water utility and may also strongly affect water availability and continuity of service. The latest report of Kenya's Water Sector Regulator (WASREB) shows an average NRW percentage of 44% for the Water Services Providers (WSPs) in Kenya (VEI, 2013). The involved stakeholders, including the majority of the WSPs united under Water Services Providers Association (WASPA), WASREB and the Ministry of Water and Irrigation are currently increasing their efforts to make a leap in performance improvement. Support in reducing NRW of chosen Water Services Providers in East Africa by introducing collective learning amongst peer WSPs and strengthen their capacity to implement the necessary performance improvements (Butterworth, *et al*, 2001).

In Uganda, according to the National Water and Sewerage Corporation (NWSC), the average share of non revenue water (NRW) in all operating areas of NWSC was 33% in 2010/11. While in Kampala it was 39%, in the other 21 towns it averaged 17%. These values are about the same as in 2006/07 (World Bank, 2010). NWSC explains the high share of NRW in Kampala as being due to the poor condition of the existing infrastructure. To improve the network and thus reduce NRW in Kampala, the

Kampala Network Rehabilitation Project had been launched in 2002. In 2002-2003, NRW had been 45% in Kampala (EUWI Africa, 2011). The effects resulting from the NWR are loss of revenue, poor service delivery, massive water loss, decrease in billing, diminished commercial viability of the Authority, reduction in revenue collection, increase in cost of production, customer complaints on services cost increases, less motivated staff, services not reliable, water rationing and reduction in investment, Hence, all these affect the commercial sustainability of the Authority if proper measures are not put in place to address NRW

4.2.1 AUWSA's Non Revenue Water for the Past Four Years 2009/2010 2012/2013

According to AUWSAs Annual reports, 2009/2010 – 2012/2013, the Non-Revenue Water in Arusha Urban Water Supply and Sewerage Authority during the financial year of 2009/2010 to 2012/2013 indicated as follows: for the financial year 2009/2010 NRW was about 34%; 2010/2011 NRW was about 35%; 2011/2012 was about 40% and for financial year 2012/2013 NRW was 38%. Figure 4.1 ,depicts the NRW trend for four years in Arusha Urban Water Supply and Sewerage Authority. For the four years the Non Revenue Water were between 34% to 40% of which is above the maximum recommended NRW of 20% as per Energy and Water Utilities Regulatory Authority key performance indicator (AUWSA Annual Reports 2009/2010 – 2012/2013). The percentage of NRW fall when the amount of water produced is low due to minimal rain during the year and rise when the amount of water increased at production points, this has a relation with pressure in the system at high pressure the number of leakages is high due to old aged pipes.

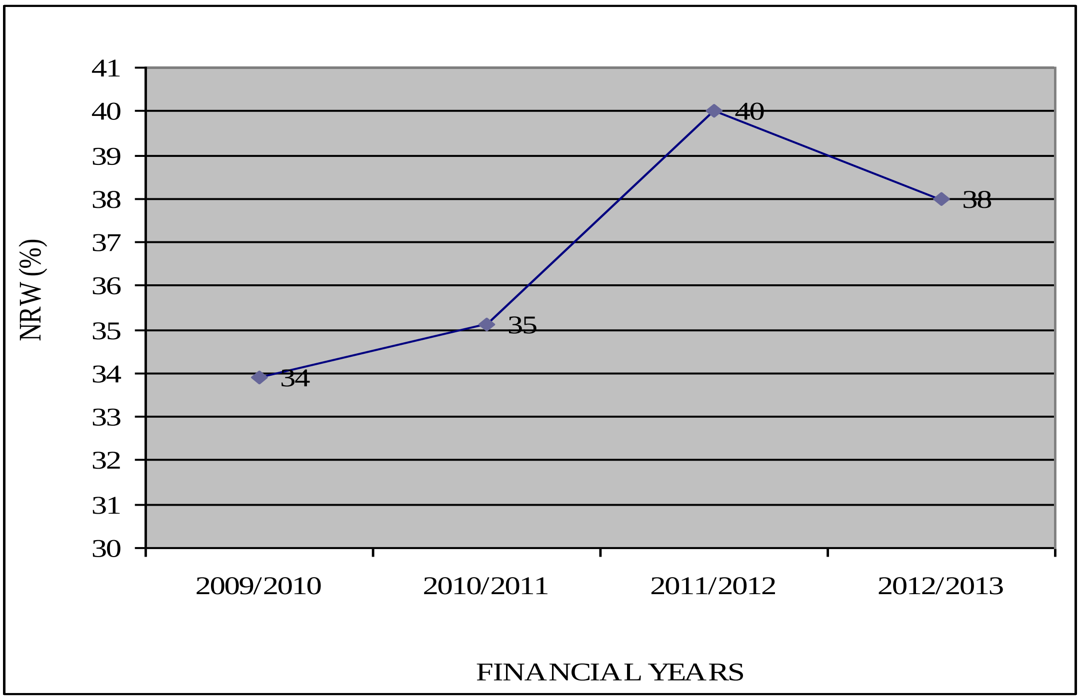


Figure 4.1: AUWSA's Non Revenue Water for the Past Four Years 2009/2010 – 2012/2013

Source: AUWSAs Annual reports, 2009/2010 – 2012/2013

4.2.2 Water Leakage

It is known that when there are water leakage there are also water losses and when water is lost there are losers, who are:-

- The AUWSA for not collecting the expected revenue.
- The water customers for not receiving adequate water volume allocated to them.

With this knowledge, the water customers are willing to cooperate with the AUWSA in the control of the water loss if they are given the opportunity to do so. Issues of water loss and infrastructure are almost universal. In the UK, leaks result in yearly losses of 3.4 billion liters of water (Butterworth, 2001). The average leak rate in Latin American cities is 35% and in China, more than 400 cities have reported losses of 20 percent (IBM, 2013). Infrastructure supervision is one of the mechanisms of leakage decrease management strategies. The general situation of mains, service pipes, service reservoirs and other fittings of a water system is the most influential factor that affects the level of leakage in any water network (National Audit Office, 2012). Real Losses sometimes called “Physical losses” or “leakage” are the annual volumes lost through all types of leaks on mains lines, bursts and overflows storage tanks and service connections up to the customer’s meters. Leakages from transmission and distribution mains are usually large events so they are reported quickly by the public. They can cause serious damage unless they are repaired quickly. Old and poorly constructed pipelines, inadequate corrosion protection, poorly maintained valves, mechanical break and high pressure (Fig. 4.2) are some of the factors contributing to leakage. Utilities can no longer tolerate inefficiencies in water distribution systems and the resulting loss of revenue associated with underground water system leakage. Increases in pumping, treatment and operational costs make these losses prohibitive. To combat water loss, many utilities are developing methods to detect, locate, and correct leaks (Lahlou, 2001).

Figure 4.2: Water Leakage due to High Water Pressure

Water produced and delivered to the distribution system is intended to be sold to the customer not lost or siphoned from the distribution system without authorization. Siphoning to the distribution in the leakage is risk to consumers as this may contaminate the water supply. During the interview made some of the customers indicated the blockage of the meters. One customer said

"I called them to service my meter and they pick a plastic which blocks the water flow"

This shows the high level of contamination production of negative pressure transients creates the opportunity for backsiphonage or backpressure of non-potable water from domestic, industrial or institutional piping into the distribution system. It seems not only that plastic enters, but probably with other visible impurities, bacteria and many others contaminants depending on the site. The public health significance of interruption from a pressure transient depends on the number and the effective size of orifices (leaks), the type and amount of contaminant external to the distribution system, the frequency, duration, and magnitude of the pressure temporary event, and the population exposed. Another NRW based on causes can be classified into physical and non physical losses. In case of the study area, physical water losses may account for nearly a half of the NRW. They are mainly those of leakage particularly from old deteriorated pipes and fittings installed in 1960s and from PVC service mains branching saddles and connections installed using PVC pipes which are vulnerable to heavy loads and damage. Table 4.1 shows the data collected for AUWSA's monthly water produced (m^3), Non revenue water (m^3) and the percentage of NRW in each month. According to Energy Water Utility Regulatory Authority (EWURA) the maximum recommended Non Revenue Water, key performance indicator for all water Authorities in Tanzania is less than 20%. According to Table 4.1 the highest NRW was detected in May to August (Ranges from 44 – 49%) and the smallest NRW was detected in the months September and October (Ranges from 32 – 37%). The table also shows that as the amount of water produced increased during the rain seasons (May to August) the amount of Non Revenue water is also increased and when the amount of water produced decreases the amount of Non revenue is also decreases which indicate that when the amount of water in the pipes increase the pressure in the water pipes where the old pipes bust especially the old cast iron pipes which results the water lost to increases.

Table 4.1: AUWSA's Water produced (m^3), Water Billed andNon Revenue water (m^3) for FY 2012/2013

Month	Water Produced (m^3)	Water Billed (m^3)	NRW (m^3)	% NRW
Jun-12	1,409,916.00	730,042.90	679,873.10	48
Jul-12	1,262,233.46	707,703.00	554,530.46	44
Aug-12	1,308,695.26	719,585.00	589,110.26	45
Sep-12	1,111,554.01	705,415.00	406,139.01	37
Oct-12	1,076,912.50	731,778.00	345,134.50	32
Nov-12	1,102,687.75	659,130.93	443,556.82	40
Dec-12	1,109,730.61	715,056.00	394,674.61	36
Jan-13	1,146,470.50	700,500.00	445,970.50	39
Feb-13	1,060,352.90	659,990.00	400,362.90	38
Mar-13	1,053,396.30	647,895.00	405,501.30	38
Apr-13	1,132,537.82	696,573.20	435,964.62	38
May-13	1,352,095.00	688,292.00	663,803.00	49
Total/Year	**14,126,582.11**	**8,361,961.03**	**5,764,621.08**	**Average 41**

Source: AUWSAs Monthly Reports, 2012/2013

When we require respondents to identify the main causes of Non-Revenue Water in Arusha Urban Water Supply and Sewerage Authority, the results for respondents are as shown on the figure 4.3.

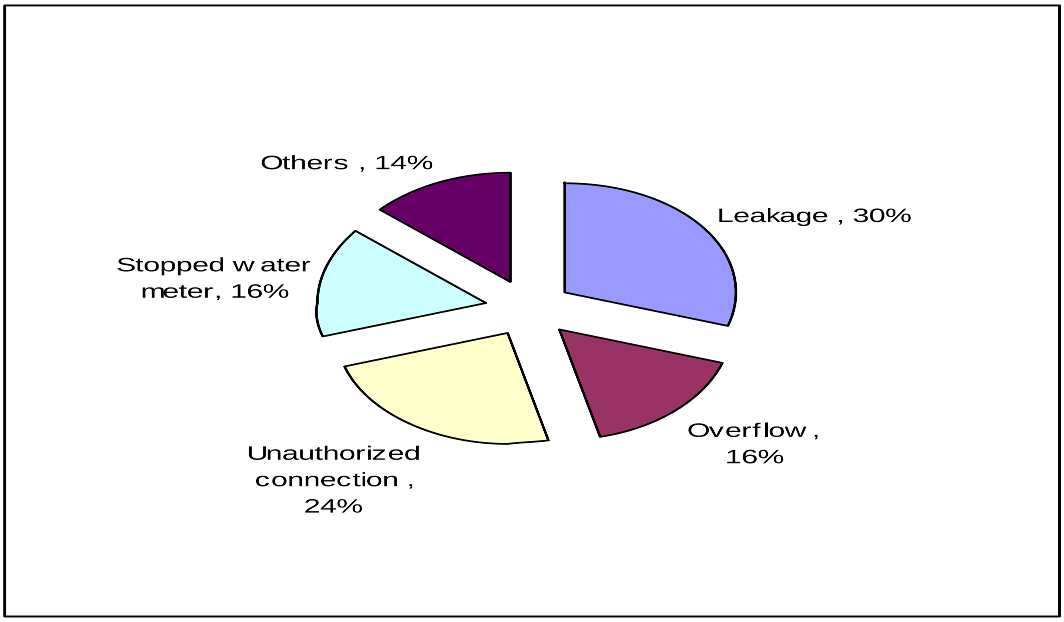


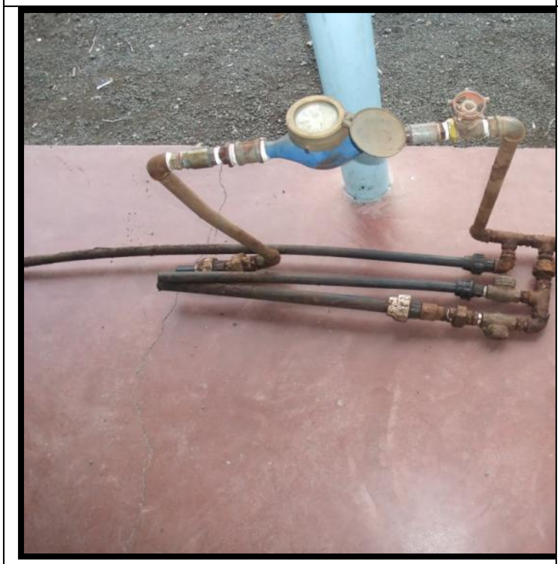
Figure 4.3: Respondents Perception on Causes of Non Revenue Water in AUWSAs Water System

Source: Field Survey Data, 2013

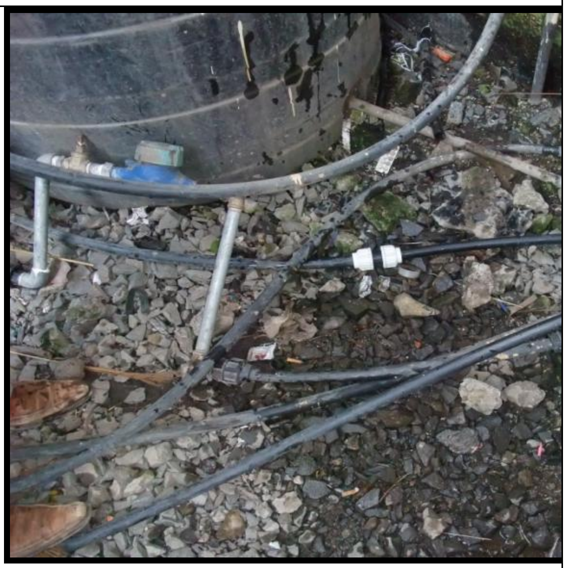
Figure 4.2 above revealed that, 24% of respondents pointed out that the main causes of Non Revenue Water in Arusha Water Supply and Sewerage Authority was caused by unauthorized connections (illegal and by pass); 30% of repondents pointed out that NRW in AUWSA was caused by leakages from water system (transmission mains, Distribution mains, Utility's reservoirs, service connections); 16% of respondents mentioned that the causes of water losses caused by stopped/unfunction water maters (Bulk and customer water meters), whilst 14% respondents enumerated that Non revenue water was caused by other reasons like corruption and bribery among meter readers, wrong data capturing, improper customers records, water meter reversal, wrong water meter installations and unread water meters) and 16% of respondents mentioned that NRW was caused by Overflow from storage tanks and break pressure tanks. Figure 4.4 photograpically illustrates different causes of NRW in AUWSA.

Illegal Connections

Meter By-pass



Meter By-pass



Meter By-pass

Customer Line Tempered

Meter Stolen

Figure 4.4: Some causes of Water Losses

According to ADB, (2010), many water utilities in Asia perform reactive leakage control, meaning that they repair only those leaks that are visible. This is clearly not enough since 90% of the leaks are frequently undetected on the surface. As a result, it takes too long, often many years, until the utility is even aware that there is a leak. In view of the fact that awareness time largely determines the volume of water lost from a pipe burst, utilities need a strategy to reduce awareness time (Frauendorfer, *et al.,* 2010). Apart from being wasteful, leakage has a harmful effects on several aspects of the operations of a well run water supply system (Farley and Trow, 2003:50). It increases cost of production, increases the capacity requirement (treatment plant and mains size) of the water distribution system (Butler and Memon, 2006:149), and can reduce the confidence of customers in the water utility. In Australia, Canada and Portugal, the number of main bursts is higher, which might imply that the underground network is in a worse situation than that in England and Wales. Differences in both soil type and the age of a network might contribute to relative performance.

The Australian Water Companies also have particular problems with root interruption (GAWP, 2011). According to Malek, *et al*., 2011, in Malaysia the national NRW level is 36.63% caused mainly by leakage through pipe burst. The NRW reduction programme will give a return (net benefit-NPV) of RM147.32 million in 5 years time. Water supply service level nationwide could be improved if the implementation of holistic non revenue water reduction programme could be expedited.

4.2.3 The effects of old aged water pipes systems on non-revenue water

Table 4.1 shows the trend of AUWSA's monthly water produced (m^3), amount of water billed and Non revenue water (m^3). When the amount of water produced increase the pressure in the water pipes also increased which causes the old pipes to bust especially the old cast iron pipes which results the the water lost to increases. Figure 4.5 represents respondents perception on how old aged water system contributes to the Non Revenue Water in AUWSAs Water system.

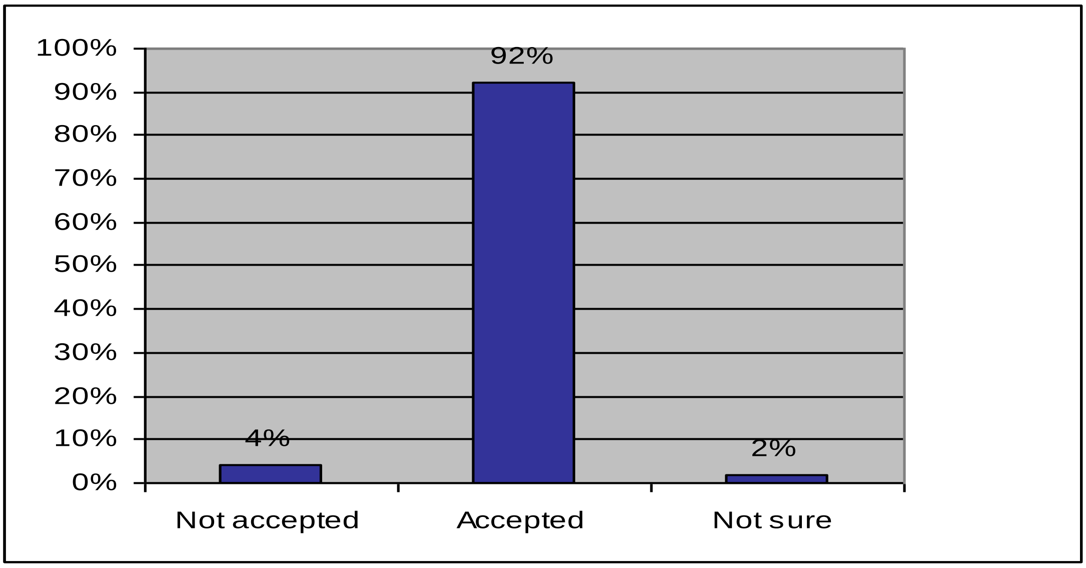


Figure 4.5: Perception on Age of Water System Effect on Non Revenue Water

Source: Field Survey Data, 2013

Respondents were asked to responds to the question if aged water pipes system have any effect to NRW. About 92% agreed while 4% disagreed and 2% were not sure. Respondents who agreed explained that, all water leakages from every water systems were because of old water supply systems (Figure 4.6). During Focus Group discussion respondents indicated that:

"We have very aged water pipes, storage tanks, transmission mains, distribution mains and services connections".

Furthermore, according to documentary review it was revealed that, leakage from transmission or distribution mains, leakage from services connections up to the point of metering were the main causes of NRW in AUWSA (AUWSA's Annual Report, 2012/2013).

Figure 4.5: Old Piped System Increase Leakage of Water Supply

Ageing infrastructure is a rather a common problem for the water industry in the USA and Germany causing high NRW(OFWAT, 2007). The American Society of Civil Engineers (ASCE) reported in March 2005 that drinking water infrastructure spent in the USA was currently running at less than 10% of the national requirement (OFWAT, 2007). Old pipes lead to high NRW in Malaysia and replacing them involved high cost with very return period. It is expected that lifespan of water pipes in Malaysia is 70 years. However, due to environmental factors and surrounding development factors, the pipe strength may have decreased (Malek, *et al*., 2011).

Based on a detailed survey by Falkman, (2012), the average age of water mains in the US and Canada is 47 years old. Of all water mains, 47% are between 20 and 50 years old, and 22% are more than 50 years old. The average expected life of pipe being put in the ground today is 79 years. Non-corrosive materials such as PVC have an estimated life of more than 110 years; however, installation practices affect the actual life that can be achieved. Aging pipes are often decomposed and subject to leaks and breaks that increase water loss. In addition, because average supply pressure is 77 psi with pressure fluctuations less than of 20 psi, pressure events can contribute to water main breaks for pipes that have internal corrosion (tuberculation) or have areas that are weakened by decay. Pressure is an important component of pipe design and material selection. Figure 4.6. shows water leakage.

Figure 4.6: Water Leakage Due to High Pressure

4.3 Lack of Motivation to AUWSAs' Employees and Customers

Motivation efforts must be directed towards improving AUWSA operations. To be effective, however, they must also be designed to show benefits to the employees. Lack of motivation in return affects AUWSA performance. A number of symptoms may point to low morale: employees being involved in illegal connections,by pass connections, tempering meters, improper maintenance of meters and corrupt practices during the meter readings and billing process and hence leading to high Non-Revenue Water. Respondents were required to point out whether motivation to AUWSAs' employees and customers may enhance them to reduce NRW as well as lack of motivation may cause high NRW. Data gathered from interviews revealed that, many respondents identified that reducing NRW is not only looked on technicality such as illegal connections but should be looked on human needs. Therefore they pointed out that, AUWASAs' employees need genuine incentives to do their duties and replace the incentives they have made for themselves through illegal connections and other corruptions. When respondents asked why there was no motivation in AUWSAs' employees and customers they pointed several reasons (Figure 4.7). These were lack of recognition of their performance, low remuneration, no long term trainings, no other rewards, motivation was not given at the right time, leakages reports were not repondend quickly.

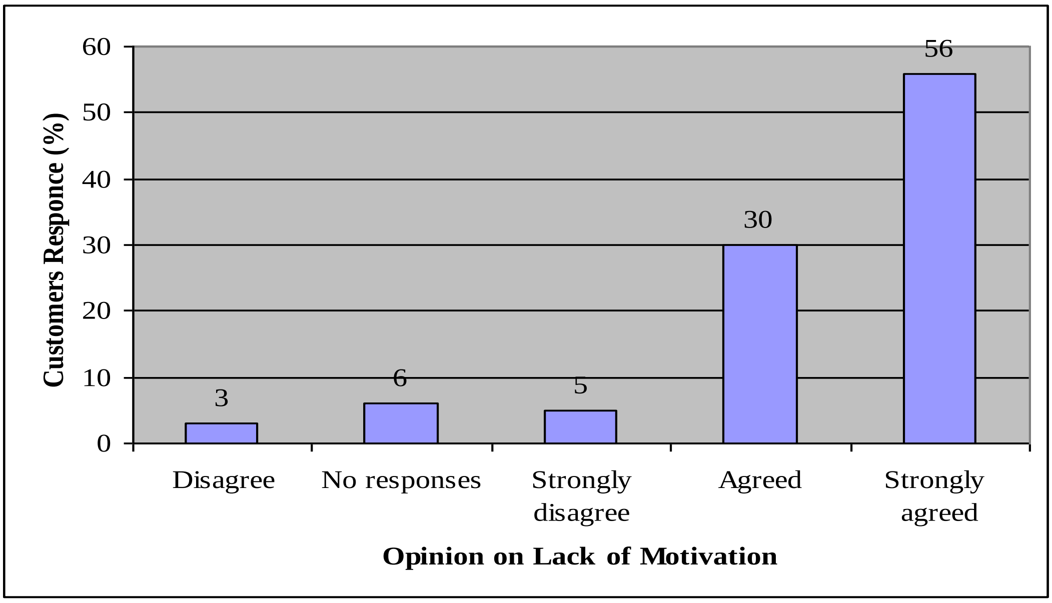


Figure 4.7: Respondence on Effect of Motivation on Increasing NRW

Motivation is important because even at the most basic level, it costs more to replace staff than to keep them. Staff liked to feel needed and respected and keeping them happy means they will stay with the business for much longer Ensuring staff are motivated and stay that way is an important part of running a business (Deci, *et al.*, 2000). Planned acknowledgment of employee efforts not only drives their loyalty, but may also create a positive impact on the financial development of the company.

By using suitable recognition methods, chief financial officers can increase the performance of their employees permanently at the same time safeguarding the company's overall development (Pfeil, 2013). One financial manager in Europe said:

"Our employees should be happy to have a job in our company."

Nevertheless, encouraging attitudes and motivation between employees for the most part affects the impressions of shareholders, customers and suppliers. Whether working as a treasurer, controller, purchaser or receptionist, each employee represents your company, even in their private lives (Gambrell, *et al.*, (2008).

4.4 Unauthorized Connection

Illegal water connection is not a simple matter and has many consequences. It is everybody's concern not only by AUWSA but the customers as well since it has many effects. The illegal connection detection and apprehension program is one of the undertakings of AUWSA to curb losses under its Non-Revenue Water (NRW) reduction plan. Illegal connections also result in water wastage and revenue loss on the part of AUWSA. Consequently, this could also lead to opportunity loss since expansion projects could be delayed due to lack of funds. These projects include mainline extension and improvement to accommodate additional new service connections and to increase water pressure so that more can enjoy 24-hour water supply (WBI, 2010). While meter under-registration is more of a technical problem, water theft is a political and social issue. Reducing this commercial losses is neither technically difficult nor costly, but it requires making difficult and unpleasant managerial decisions that may be politically unpopular. The reason is that illegal connections are nearly always wrongly related with only the urban poor and informal settlements. However, water theft by high-income households and commercial users, sometimes even large corporations, often accounts for great volumes of water lost and even higher losses of revenue (ADB, 2010). Figures 4.8 shows some of commercial premises found with water theft in Arusha City during NRW reduction campaign in the ongoing financial year 2013/2014:

Figure 4.8 Unauthorized Water Connection in some Customers' Pemises

4.4.1 Criminal Aspect of Illegal Connection

According to AUWSA illegal connection is a criminal offense (AUWSA Profile 2013). Any form of unauthorized acquisition of water through illegal re-connect disconnected lines, water meter tampering, illegal removal of water meters and direct tapping constitute a criminal act. However, AUWSA does not have any written document concerning criminal offense when customers using water illegally. This is not mentioned in neither AUWSA Client Service Charter nor in the Application for Water Supply Form. Illegal connections can pose threat to human health. One of its effects is water contamination and the occurrence of water-borne diseases that affect human health that if unabated, could lead to death. To ensure that water is clean and safe, AUWSA regularly conducts water sampling and does physical and microbiological tests. Figure 4.9 shows a number of unauthorized connections in AUWSA for the past four years.

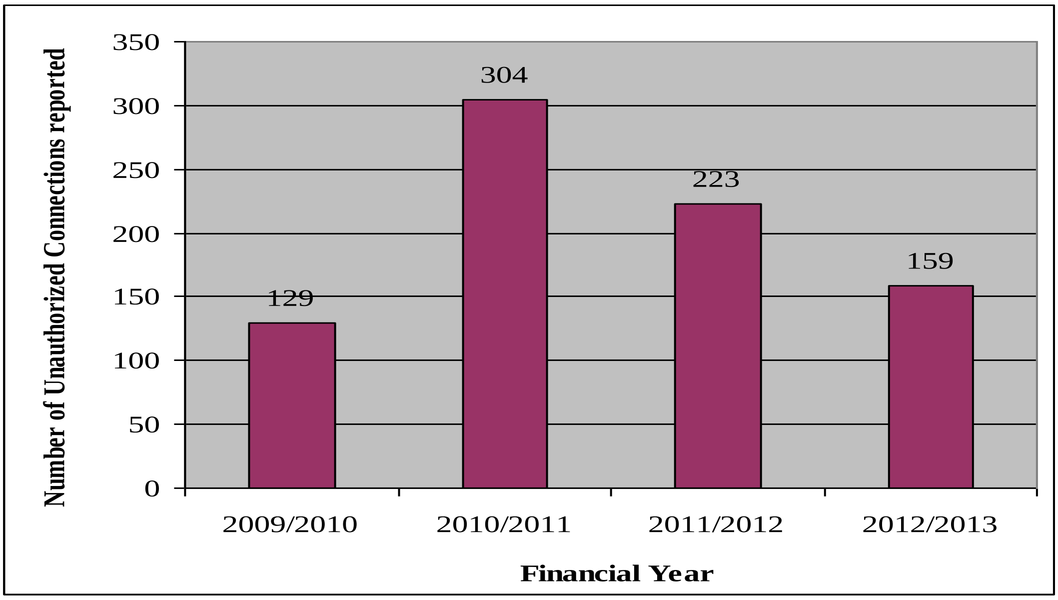


Figure 4.9: Number of AUWSA's Unauthorized Connection eported in Four Years

Source: AUWSAs Annual reports

According to Figure 4.9 the number of unauthorized connections increased from 129 during financial year 2009/2010 to 304, during financial year 2010/2011 followed by a decrease, to 223 (27%) number of unauthorized connections reported in 2011/2012. During the financial year 2012/2013 the number of unauthorized connections reported went down to 159. This decrease was due to the increase of cash reward given to good samaritans whom were reported the unauthorized connections. The amount given to good samaritans incentives was increased from Tshs 10,000/= (FY 2007/2008) to Tshs 40,000/= (FY 2008/2009) per information reported. Therefore this confirm that well motivated customers (external and internal) contribute in reduction of Non Revenue Water. Figure 4.10 shows illegal water connections in as obseved elsewhere (Salleh, 2002).

Figure 4.10 Illegal Connections

An investigation into illegal consumption in Kampala (George, 2011), implicated a significant number of the corporation's staff involved in helping customers to carry out illegal consumption in form of meter bypasses, meter tempering/reversal and under-reading. In addition, the corporation uses a set of forgiveness calls for both its employees and customers to, willingly, disclose illegal consumption. In one of the branches where illegal consumption was uncontrolled, more than 20% of the customer accounts were voluntarily surrendered as suspected illegal connections by staff (George, 2011).

4.5 Contribution of Water Meters to Non Revenue Water

It have been known Non-Revenue Water in Arusha Water Supply and Sewerage Authority occur mostly through tempered with meters, aging and improperly maintained meters, wrongly installed meters(Miya, 2013), slow running meters, broken meters, and make and size of the meters. Futhermore, there were administrative errors, some of which arecaused by corrupt practices during the meter reading and billing process (AUWSA Profile, 2013).

The AUWSA has achieved universal metering by hundred percent since, 2004 and this is one of its cornerstone in reducing its NRW to the current level (AUWSA Annual Reports). The first step in addressing the NRW is putting measuring devices in all sources and customer's points so that the production is measured against the meter readings from all customers. Meter readers must provide accurate readings as this will immediately affect the NRW calculation. This need to be enhanced by using modern way of data captures using mini computer data loggers (Figure 4.11).

Figure 4.11 Using of Data Logger Instrument

The typical method of data handling and billing requires a meter reader to visit each property and read the customer meter. The data is then recorded into to the data logger, taken back to the office, given to the billing department, and uploaded into the billing system. A bill is then printed and sent to the customer. In this scenario, a variety of errors may occur at the different stages; the meter reader may enter incorrect data or the billing department transfers incorrect data into the billing system. (The measuring devices meter for both water source and customer point is as shown in Figure 4.12) .

Figure 4.12: Meter System for Customers and Water Sources

When respondents from AUWASAs' employees and AUWSA customers were asked to identify whether water meters contributed to Non-Revenue Water, (questionnaire, interviews and observation) it was revealed that, water meters contributed for Non Revenue Water the response were as indicated in Figure 4.13.

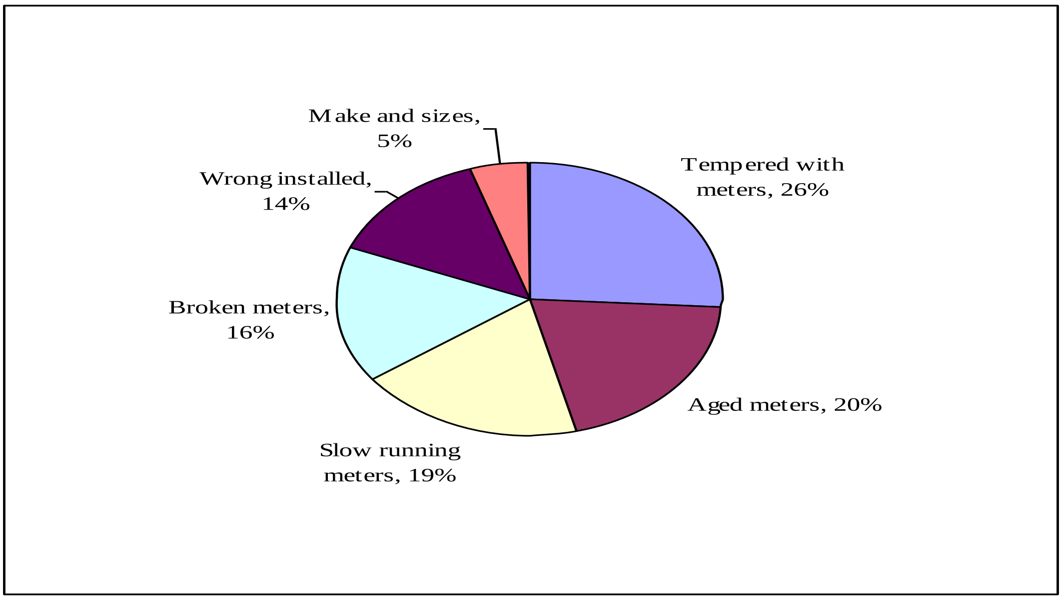


Figure 4.13: AUWSAs' Employees Response on Meters Contrivution to NRW

Source: Field Survey Data, 2013/2014

Moreover some types of meters used in the network are sensitive to flow velocities and when water supply increases and fills overhead domestic tanks, the small flows pass without being registered in the domestic meters, which cumulatively leads to increased NRW (Mutikanga, et al., 2011)**.**

According to Malcolm, *et al*., (2008), sometimes, due to inadequate water treatment or old pipe bust, trashes or sediments can be siphoned to water systems. The sediments and trashes can build up on the internal parts of meters, especially mechanical meters. The buildup of sediment affects the meter's accuracy by increasing friction losses, which causes the meter to run more slowly and thus under register consumption. Figure 4.14 shows how sediments cause meter inaccurancy.

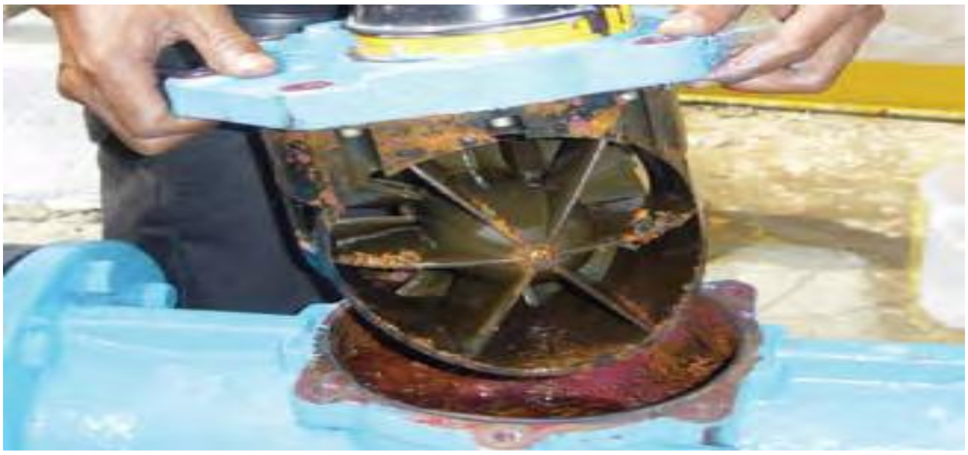


Figure 4.14 Sedimentation is a Major Source of Meter Recording Inaccuracy:

Source: Farley, (2008)

Also during conducting this research, respondents from AUWSAs' employees and AUWSA customers were required to pinpoint whether they ever detect dirt water coming from your tap (Questionnaire (B) item number 14). The responses showed that water from the taps is seen dirty (muddy) when there is a burst or broken pipe which creates a leakage somewhere in the network allowing mud to get into the network. Some times mud is seen in the taps when there is a new water connection made somewhere in the neighbourhood. The Figure 4.15 shows the customer respondents on dirty water from the taps:

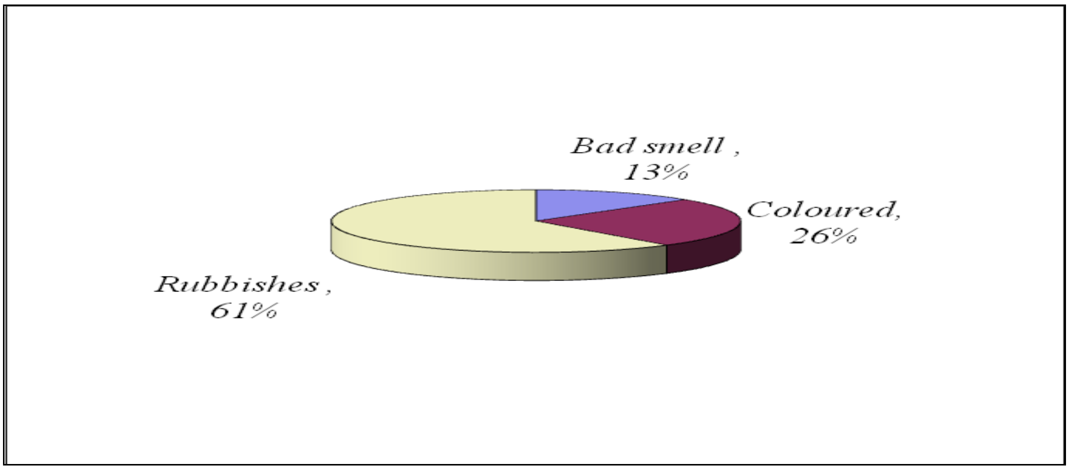


Figure 4.15: Dirty Water From The Taps

The incidences were most likely attributable to unsafe water sources and it is necessary to note that 50 of them were within the municipality (Bwire, 2004). It is probable that the cases can be accredited to the lack of clean water and supplies (storage containers, pipelines, and standpipes), which forced residents to use unreliable and unsanitary sources.

4.5.1 Poor Water Management and Pollution

Water pollution is the contamination of water bodies (e.g. lakes, rivers, ocean, aquifers and ground water). Water pollution occurs when pollutants are directly or indirectly discharged into water. Waterborne diseases are caused by pathogenic microorganisms that most commonly are transmitted in contaminated fresh water. Infection commonly results during bathing, washing, drinking, in the preparation of food, or the consumption of food thus infected. Various forms of waterborne diarrheal disease probably are the most prominent examples and this is not exception to Arusha City. In the study conducted at village of Olorien, located within the municipality. It was revealed that water sampled was highly contaminated by bacteria E. coli and other pathogens (Table 4.2).

Table 4.2: Analysis of House Hold Water Samples

N	% with T. C.	% with F. C.	% with E-Coli	TDS (ppm)	Cl- (ppm)
100	76	42	33	217	6.9

Source: Hartstone, et al., (2006)

The findings from this study helped to confirm the observation that water used by consumers in Arusha Urban water Supply & Authority (AUWSA) is unsafe as a result of source pollution which may be too siphoned of contaminated water in the water supply system. The blockage of meter system (Figure 4.14) is evident that trashes and contaminated water is returned to the water supply system.

4.6 New Customer Connections System

The new customer connection system is computerised and once a distance from customer premises to the main distribution line is established, the system calculates the cost estimates the customer is to pay for being connected with the services. Upon payment, the customer is allocated with the account number and entered into the database ready for metering and billing. The new water connection application process is as shown in Figure 4.16:

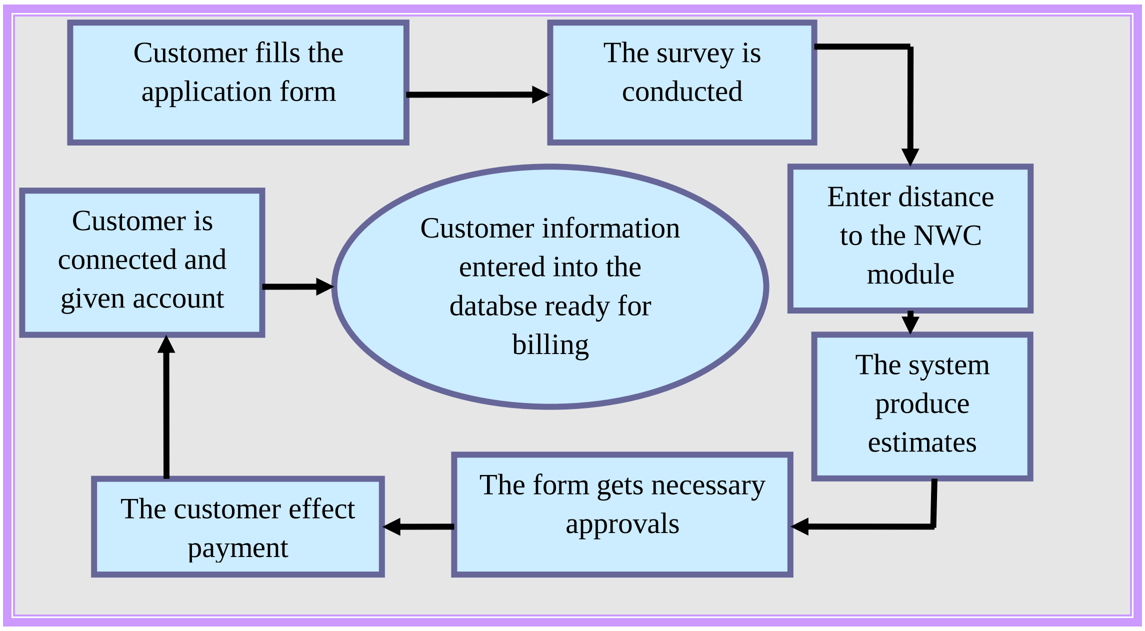


Figure 4.16: New Water Connection Process

However, the actual customer line construction still has some problems and the inherited structure from former water department, which indirectly contribute to the NRW due to age. This is partly the result of national water policy, which requires the connection to have a maximum lengthy of 400 meters which is so long while international standard is 10 meter only. The results of this policy are a lot of spaghetti and poor connection as shown in figure 4.17.

Spaghetti connections

Poor connections

Figure 4.17: AUWSA Spaghetti and Poor Connections

4.7 Other Factors Contributing to NRW

As pointed out before, Non-Revenue Water is caused by several factors. Further, findings came up with other factors or reasons among which are Political influence, inadequate technical skills, poor operations and maintenance, poor workmanship and poor material during construction of water networks.

4.7.1 Political Influence

During design stage of a project, decision makers who are mostly Politicians /Council (Especially for LGAs) whereby implementation of any project has to be endorsed by the Councillors, the cost for procurement of materials can be reduced due to limited financial resources to an extent that the designers/Engineers are forced to buy poor quality materials to meet the interest of politicians who for LGAs are also the Employers of experts.

4.7.2 Inadequate Technical Skills

Due to the fast changing technology for input materials, some of the already available technical staff might not catch up with this situation. Recruitment of adequately trained staff is a challenge to most organizations. Likewise , training of the available staff. This is due to lack of funds whereby in many cases priority for funds allocation goes to core business of the organization. For instance, for Water Utilities; water production and Wastewater disposal activities. Ultimately, the inadequate technical staff can not meet the high demand of O&M activities for a large infrastructure i.e the available personnels can not meet the workload leading to backlog of unattended leakages.

4.7.3 Poor Operations and Maintenance

This is a result of both inadequate technical skills and lack of funds for procurement of proper inputs or materials leading to leakages.

4.7.4 Poor Workmanship

This is a result inadequate technical staff to implement operation and maintenance activities effectively using proper materials resulting into leakages.

4.7.5 Poor Materials and Fittings

Materials for Project implementation and Operation and Maintenance are all procured under the guidance of PPA 2011 and its associated Regulations of 2013. If procurement procedures are not adhered to due to various reasons, then the ultimate consequence lands at procurement of poor quality materials which leads to rampant pipe burst and thus NRW. Figure 4.18 shows the responces from respondents using questionnaire and interviews which required the respondents to enumerate other factors which cause NRW in AUWSA.

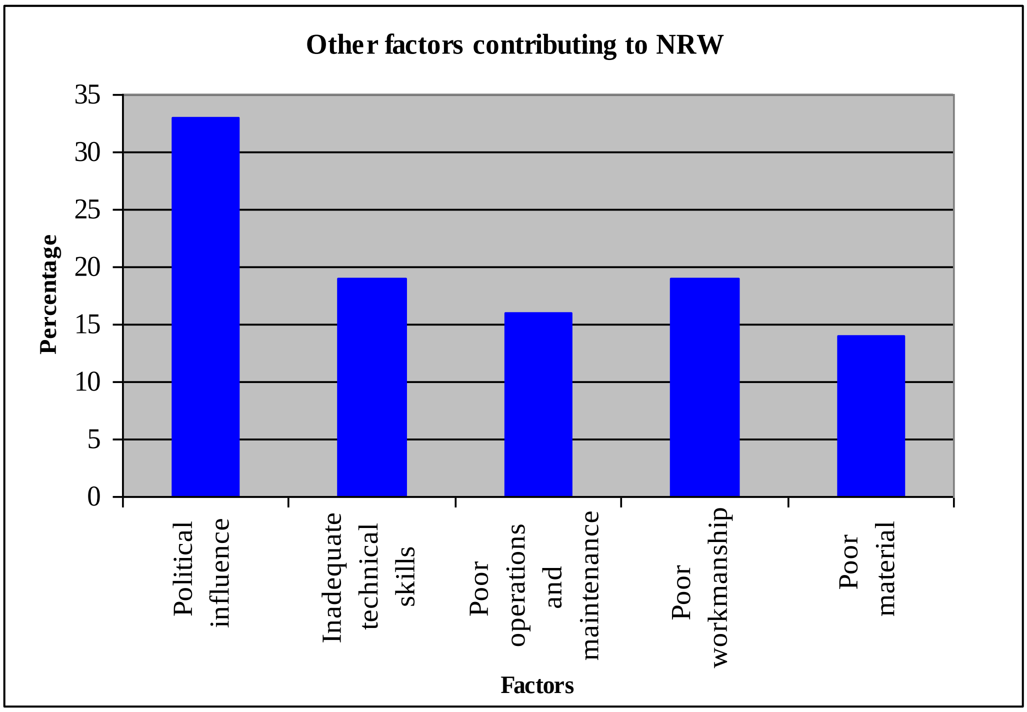


Figure 4.18: Peoples' Perception on other Factors Causing NRW in AUWSA

Source: Field Data 2013/2014

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The chapter provides conlusion and recommendations of the entire findings on assessment of effects of water pipe leaks on water quality and hence lead to non revenue water.

5.2 Conclusion

It is the opinion of the researcher that key issues discussed in this study will put AUWSA in the position to make the right decisions in respect of proper level of investment for addressing the NRW issues. In addition, AUWSA will be able to come up with a proper financial plan and NRW reduction Strategy action plan both of which are both the outcome of this study. This will enable AUWSA to allocate adequate funds or solicit for funds from local and external Financial Institutions to finance the NRW Reduction Strategy for AUWSA.

Much has been written elsowhere about the water challenges faced. The study aimed to find out the negative effects of pipe burst on water quantity and quality in Arusha City so as to provide the most valid and acurate answers to solve the probolem. It was recognised both the positive and negative aspects of water. Water is essential for human, animal and plant life. The findings improved that water supports productive activites such as agriculture, generation of hydropower, industries, fishing, transport, to mention the few. This researcher initially thought that the water customers are not very much aware of the importance of prevention of water losses and also thought that they are also not cooperative to the AUWSA’s effort in prevention of NRW. It has been proved that the problem is not the customers, but the AUWSA in that they don't carry out enough sensitization seminars to inform water customers of what is expected from the customers. Further more if ever the seminars are carried out, very few customers are involved and only during the annual week of "Water Supply". The AUWSA also leave the cost of giving notice to AUWSA to water customers on water loss which is very unfair to the customers because they pay for the service rendered to them. The customers have shown that they are willing to cooperate if they will be facilitated and informed of new technological development for good service rendering. The failure by the AUWSA management to hold and control water spillage during new water connections, repairs and maintenance has a contribution to the non revenue water. It has been proved that there is a lot of water lost during new water connections, repairs and network maintenance because no single AUWSA has any system or gadget to prevent water loss/spillage. This lost water has a contribution to non revenue water because it has been measured during production and pumped into the network but not billed to water customers.

AUWSA should encourage water customers to have roof tanks to serve the purpose of water supply when there is no water supply from the main service line. The best alternative would have been to control and minimize water loss in the network so as to increase water supply to the customers. The water lost in the network is very huge; it is enough to cover the water short fall to customers. The disadvantage of encouraging water customers to have roof tanks is that, these roof tanks affect the operation of water meters by changing the flow rate of the water and make the water meter to under read, hence causing non revenue water. Inefficiencies in data capturing and processing at the billing unit has a contribution to the non revenue water. The water data of customers is not entered properly and in time in the billing system. A customer is connected as new customer, but the information is passed to the billing unit and processed after 2 to 3 months. The new customer consumes the water legally but unbilled because of delay in entering his/her particulars in the billing system. In some cases, a customer is reconnected, but the information is not passed to the billing unit in time, water is consumed, measured but not billed during the required period. This deficiency in data handling and information processing has a contribution to the non revenue water.

AUWSA is putting very little effort in information dissemination and also water customers are not motivated enough to bring up information to the Authority voluntarily. It has been nobserved that the AUWSA put very little effort in information and knowledge sharing with water customers. The customers are willing to accept information and knowledge, but they are not given the opportunity. Therefore the customers may lack some knowledge of water loss prevention just because they are not given the information and knowledge, hence water loss goes on contributing to non revenue water.

5.3 Recommendation

Here the researcher is recommending to the AUWSA's Management that if the following recommendations can be taken into action, the non-revenue water can be reduced to acceptable standard of NRW and water quality. Consequently, there will be no need to look for new water sources because the revenue shall be raised just by controlling the water loss and reducing non-revenue water.

5.3.1 Raising Awareness Knowledge to Staff

Reduction of NRW requires a combined effort from management and staff throughout the utility. However, the number of staff with a good knowledge of NRW is usually limited to engineering or others working at an operational knowledge level. Everyone, from the Chief Executive Officer to the meter readers and crew, should understand the importance of NRW and how it affects their daily duties and the utility efficiency. After awareness programmes are conducted in each community, all staff should work to ensure that customer confidence in the utility‘s services is maintained. A key element in this is open communication. For example, the public should be able to easily contact the utility to report burst pipes, leakages, or other concerns. The utility should create a system to receive information or complaints from customers, and then to distribute it to the relevant operational units so action is taken quickly.

The AUWSA’s staff need to understand NRW and how the NRW reduction programme will improve the organisation. In certain cases, savings from the NRW reduction programme may be shared with the staff through bonuses or other incentives. All staff, from senior management to the crew, should understand the NRW reduction strategy and their role in achieving the NRW target. The team must repair burst pipes as quickly as possible so that water losses and water supply disruptions are minimal. Fast repairs increase the utility’s efficiency and promote customers’ willingness to pay their water bill.

5.3.2 Water Customer Sensitisation

Here the researcher was trying to find out how much the water customers are sensitized by the AUWSA on the water loss on the supply network. It was discovered that AUWSA conduct very few water customer awareness meeting and the few meetings are conducted to very few customers during the National Annual Water Week starting from 16^{th} to 22^{nd} March of every year. It is during this week you will see posters and some invitation for seminar on water conservation and water sources preservation. The water customers appear to be willing to read the advertisements and follow-up seminars on water, but they are not given enough opportunity to read and attend.

5.3.3 Willingness to Report

It was discovered that customers are willing to report any defects or pipe burst noted, but reporting physically or by phone is very expensive to the customers because sometimes they have to walk all the way from their homes to AUWSA for reporting without any compensation or if they are to use phones, they have to bear the costs. It has been discovered that these short comings discourage the water customers to cooperate because they bear extra costs or burden for the interest of AUWSA.

Also water customers say sometimes they are discouraged to report because sometimes they have to report several times the same issue before the problem is attended. In view of this, they say why they should waste their time if the AUWSA don’t take the matters reported very serious.

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