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Factors Influencing Water Supply's Non-revenue Water: A Case of Webuye Water Supply Scheme

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Abstract: **Through this study, the problem of non-revenue water which remains a global challenge for water supply utilities had to be explained in scientific research. The study's objectives were; To assess the extent to which meter registration inaccuracy influence non-revenue water at Webuye water supply scheme. To establish how unmetered consumption influence non-revenue water at Webuye water supply scheme. To examine how illegal consumption influence non-revenue water at Webuye water supply scheme. To evaluate the influence of water tariff on non-revenue water at Webuye water supply scheme. Hypothesis for the study were; There is no significant relationship between meter registration inaccuracy and non-revenue water at Webuye water supply scheme. There is no significant relationship between unmetered consumption and non-revenue water at Webuye water supply scheme. There is no significant relationship between illegal consumption and non-revenue water at Webuye water supply scheme. There is no significant relationship between water tariff and non-revenue water at Webuye water supply scheme. The study employed ex-post facto descriptive survey research methodology and it targeted a population of 1658 registered water consumers. The sample size was 183 consumer connections and 183 consumer water meters. Both primary and secondary data were utilized in the study. The study established that there were significant positive relationships between meter registration inaccuracy, unmetered consumption, illegal consumption and non-revenue water while there was no significant relationship between water tariff and non-revenue water at Webuye water supply scheme.**

Keywords: **Non-revenue water, Water tariff, Unmetered consumption, Illegal consumption, Meter registration inaccuracy, Water balance.**

I. INTRODUCTION

Background of the Study:

The efficient and sustainable supply of high quality water to commercial, industrial and domestic users, at an acceptable pressure and with the minimum loss through leakage is a key objective for all water supply and distribution utilities. Globally, water demand is rising and resources are diminishing. It is expected that by 2030, 47 percent of the world population will live in regions with severe water stress. The growing pressure on water has led this resource to be considered scarce and must therefore be managed efficiently. 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 [1].

The World Bank has estimated the total cost of NRW to utilities worldwide at US$14 billion per year. Reducing by half the current levels of losses in developing countries, where relative losses are highest, could generate an estimated US$ 2.9 billion in cash and serve an additional 90 million people further investment. It takes on a new dimension in developing countries, where poor infrastructure is the major source of high water losses. Yet not all losses are the result of poor

infrastructure and leaking pipes. 'Apparent' losses from the network, and excessive use or misuse of water, are often the result of local customs, combined with low tariff structures or inadequate metering policies [2]. According to WASREB (2012), Non-revenue water is the difference between amount of water produced for distribution and the amount of water billed to consumers. NRW constitutes of real losses (physical) through leaks, bursts, reservoir overflows, apparent losses (commercial) through illegal connections, water theft, metering inaccuracies and unbilled authorized consumption [3].

Non-revenue water is typically measured as the volume of water "lost" as a share of net water produced. However, it is sometimes also expressed as the volume of water "lost" per km of water distribution network per day or volume of water "lost" per connection per day. The non-revenue water levels of some selected countries expressed in percentage terms are; Singapore 5, Denmark 6, Germany (2005) 7, Netherlands 6, Japan (2007) 7, Mexico (2004) 51, Philippines (2009) 16, England (2005) 19, France (2005) 26, Zambia (2009) 45, Tunisia (2004) 18, Nigeria 42, Uganda (2009) 22 and Kenya (2012) 45 [4]. In kenya, the NRW levels for various water utilities (urban water service providers) expressed in percentage of water produced for financial year 2011/2012 were Nairobi 44, Eldoret 27, Nyeri 26, Kisumu 49, Nzoia 52, Embu 41, Kitui 68, Mandera 37, Murang'a 44, Isiolo 48, kirinyaga 78 and Sibo 60 [3].

In the financial year 2010/2011, only 67 percent of the large Water Services Providers (WSPs) were more likely to be viable while 39 percent of the small WSPs were more likely to be viable, with the less viable WSPs being associated with high amounts of NRW as compared to the more likely viable ones. The average NRW as a percentage of total water injected into the distribution system was 45 percent translating to financial losses of Ksh 9.5 billion annually. The factors influencing NRW levels resulting to high financial losses and low viability of Kenyan WSPs is the subject of this research report with the case of Webuye Water Supply Scheme [3].

Statement of the Problem:

The implementation of Water Act 2002 led to privatization of the water sector in Kenya resulting to the formation of Water Service Providers (WSPs) aiming to improve on the quality of water and sanitation services that were being offered to the citizens, thus the WSPs were expected to be self sustaining through generation of revenues from services they offered. Contrary to the above expectation, the situation where infrastructure for water service providers is in place but not viable is being experienced in Kenya even after having implemented the Water Act 2002 for more than ten years. It is reported that 41percent of the existing pumping scheme WSPs in Kenya are not viable, with non-revenue water (NRW) being considered to be one of the major causes of the non viability of WSPs in Kenya [3]. Only 67 percent of the large WSPs were more likely to be viable while 39 percent of the small WSPs were more likely to be viable, with the less viable WSPs being associated with high amounts of NRW as compared to the more likely viable ones. The national average NRW is 45 percent translating to financial losses of Ksh 9.5 billion annually.

Focusing on Webuye water supply scheme of Nzoia Water Services Company (NZOWASCO), the scheme is reported to record the highest NRW of 56 percent compared to the other three schemes managed under NZOWASCO cluster. The NRW levels for Kitale, Bungoma and Kimilili schemes of Nzoia water Services Company limited are 42 percent, 40 percent and 44 percent respectively. As a result of the high NRW levels, Webuye water scheme is reported to have attained the lowest cost coverage estimated at 65 percent as compared to Kitale, Bungoma and Kimilili whose cost coverage are 123 percent, 104 percent and 101 percent respectively [5]. If the above trend of NRW for Webuye water supply scheme continues, it is feared that the schemes cost coverage will further drop leading to deterioration of infrastructure in place hence poor quality service offer.

Based on the above observations, there was need of carrying out research on the factors influencing the high NRW levels at Webuye water scheme with the aim of developing and implementing a NRW reduction strategy based on the findings of the study, hence leading to the topic of this research report "factors influencing water supply's non-revenue water: a case of Webuye Water Supply Scheme".

Research Objective:

The general objective of the study was to establish factors influencing Non-revenue Water at Webuye water supply scheme.

Specific Objectives:

The specific objectives of this study were;

1. To assess the extent to which meter registration inaccuracy influence non-revenue water at Webuye water supply scheme.
2. To establish how unmetered consumption influence non-revenue water at Webuye water supply scheme.
3. To examine how illegal consumption influence non-revenue water at Webuye water supply scheme.
4. To evaluate the influence of water tariff on non-revenue water at Webuye water supply scheme.

Research Hypothesis:

The study sought to ascertain the following hypothesis;

(a) H_{01}: There is no significant relationship between meter registration inaccuracy and non-revenue water at Webuye water supply scheme.

(b) H_{02}: There is no significant relationship between unmetered consumption and non-revenue water at Webuye water supply scheme.

(c) H_{03}: There is no significant relationship between illegal consumption and non-revenue water at Webuye water supply scheme.

(d) H_{04}: There is no significant relationship between water tariff and non-revenue water at Webuye water supply scheme.

Significance of the Study:

It is hoped that the findings of this study will be important for the following reasons;

The water utility management team will be able to use the recommendations of the report to develop a NRW reduction strategy giving priority to the critical factors hence being able to tackle the real issues instead of trial and error. Through implementation of NRW reduction strategy based on the study findings, reducing the NRW to the levels of financial sustainability of the water utility, will lead to increase of both financial resources and the water available to utilities which will guarantee provision of services that will meet the current and future needs for the lowest costs possible [1]. The findings of the study will be used by other scholars and researchers to carry out more research in the related fields.

2. LITERATURE REVIEW

The Concept of Non-revenue Water (NRW):

Non-revenue water is the difference between water produced and the amount of water sold to all customers for a water supply system. Formula (1) provides an expression of NRW in percentage terms [6].

$$\text{NRW} = \left(\frac{(\text{Water Produced m}^3 - \text{Water Billed m}^3)}{\text{Water Produced m}^3}\right) \text{X}100 \qquad \text{…….. formula (1)}$$

There are two main components of water losses, technical and commercial. The first of them lies on physical failures on the distribution system (pipe leaks), being some of them easily identified and corrected. On the other hand, there is a commercial component that is in part linked to lack of measuring (faulty meters that inaccurately register consumption). This is the water used but not paid for. The commercial component of NRW is also associated with illegal connections established by users stealing water or taking it without any legal means to measure it or simply by shifting connections in order to lower consumption measurement. NRW is typically measured as the volume of water "lost" as a share of net water produced. However, it is sometimes also expressed as the volume of water “lost” per km of water distribution network per day or volume of water “lost” per connection per day.

Influence of Meter Registration Inaccuracy on Non-revenue Water:

Meter under-registration means that, the meter only reads portion of the water that passes through it and therefore, the consumer is only billed for that portion. Meter under-registration in water utilities is associated with; meter wear and tear, incorrect meter installation practice, lack of meter maintenance or calibration and incorrect meter sizing [7], [8].

Water meter inaccuracies are considered to be the most significant and hardest to quantify. Water meter errors are amplified in networks subjected to water scarcity, where users adopt private storage tanks to cope with the intermittent water supply [9]. According to a study carried out to analyse water meter age and the private storage tank effect on meter

performance in Palermo (Italy), it demonstrated that the impact on apparent losses from the meter starting flow rapidly increased with meter age. Private water tanks, usually fed by a float valve, overstate meter under-registration, producing additional apparent losses between 15 percent and 40 percent for the users analysed in the study [10].

'Calculating the optimum level of apparent losses due to water meter inaccuracies' research, it was concluded that 'the higher the amount of volume used at low flows (which increased the degradation rate of the weighted error since meters degraded in first place at low flows) the higher the optimum level of water meter error and the higher the consumption volume of the users the lower the V parameter (ratio of meter cost to the product of yearly consumption and water price) and the lower the optimum level of water meter error [11].

It is was widely acknowledged that mechanical water meter's metrology become more and more inaccurate during their operating life due to 'wear and tear' of the measuring components [11], [12], [13], [14].

Influence of Unmetered Consumption on Non-revenue Water:

In 1998, it was found out that some of the non-revenue water for city of Sequim was due to irrigating unmetered city parks, including Silberhorn Ball fields, Carrie Blake park and buildings, the high school football field bathrooms, fire hydrant flushing, fire department training, and water trucks used for dust control and street cleaning etc.

The city carried out an aggressive maintenance, reconstruction and meter replacement program over a short period of approximately 6 years. Within that timeframe, the non-revenue water reduced from 30 percent down to approximately 9 percent. The city installed new meters throughout the system and added meters in those places that had no meters such as Carrie Blake park and Dr Standard park. The reduced use of unmetered potable water from fire hydrants for dust control, street washing, vehicle washing and landscape watering also provided a great reduction in the non-revenue water [15].

A survey carried out in 2010 on small scale water providers in Kenya indicated that, in Nairobi the unreliability of water supply could be reduced dramatically by controlling the high rates of non-revenue water. In 2009, 40 percent of the water that entered Nairobi City Water and Sewerage company's network was recorded as "non-revenue water" [16]. This figure measured not only water lost through leaks caused by the decay of infrastructure, but also water diverted through illegal connections, inaccurate metering of water use, and inefficient revenue collection due to low metering ratios and weak billing capacities.

Influence of Illegal Consumption on Non-revenue Water:

Illegal consumption is also known as unauthorized water usage. This may include illegal water withdrawal from hydrants, illegal connections, illegal reconnections and bypasses to consumption meters. Reduction of illegal consumption reduces non-revenue water [17]. Illegal consumption is categorized into;

Meter by pass, where the consumer is a legal customer with a meter. The customer has an alternative pipe taping water before the meter. Illegal Connection where by the consumer is not a customer to the water supply system consumer data base. He / she simply connect himself / herself to the network without the knowledge of the water supply operator. Fetching water at a point before the meter - the customer consumes water that is not metered by closing the stop cork, removing the meter then connects a horse pipe to the network and fetches water. After fetching water, the meter is reinstalled in its normal position. Meter reversal, this is a situation where by customers install meters in reverse order so that they count backwards to desired readings. When satisfied they turn the meters to the correct position. Meter reversal may entail reversing the meter readings manually [18].

Water theft (illegal consumption) 'is probably the easiest to conceptualise although sometimes may be very difficult to eliminate' [7]. A part from loss of water to the water supply system, illegal consumption also played a major role in limiting the water system's ability to increase its level of service. Illegal consumption or water theft is where someone deliberately bypasses the water meter to get water for a period of time. Some of the causes for water theft were; water scarcity, poor management, lack of awareness, inappropriate tariff system and refusal to allow individuals to have house connection [19]. Several factors accounted for the difficulties for water utility staff to try to stamp out illegal connections in a water system. Some of the factors were;

The assumption that water was a basic human need and therefore should not be charged for. The involvement of politicians who try to win public support at the expense of sustainability.

Influence of Water Tariff on Non-revenue Water:

By 2006, the prevailing water tariffs for Asian cities were generally below the actual cost of water supply. The existing tariff structure needed to be rationalized to address cost recovery principles. The full cost recovery (FCR) for water services primarily covered all costs associated with operating, maintaining and financing the capital cost of expansion of the municipality's water system. The concept implied that revenues from water sales, primarily through tariffs, were equal to or exceeded the amount required to cover all costs related to obtaining, processing and distributing water to the corporation's consumers. Clearly, achieving full cost recovery could be an important determinant of a utility's ability to improve on operational efficiency and expand service / infrastructure. Attainment of full cost recovery enabled water utilities to reduce non-revenue water levels by;

Both maintaining and hiring of competent staff hence having a competent and motivated human resource for developing and implementing non-revenue water reduction strategies. Keeping well maintained water infrastructure including measuring devices hence reducing on both physical and apparent losses. Embracing modern technologies for managing non-revenue water among them including pressure management, geographical information systems (GIS) and intelligence metering [20].

The Water Balance Concept:

This is the 'big picture' of the water loses contribution of various components of a water system [1], In the United States, water balance is also called a 'water audit'. The International Water Association (IWA) developed a standard international water balance structure, a concept that has been adopted by national associations in many countries across the world (Table1).

TABLE 1. Standard IWA water balance structure showing NRW components

<table>
<tr><td rowspan="8">System Input Volume</td><td rowspan="3">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed metered consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed unmetered consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled metered consumption</td><td rowspan="6">Non-Revenue Water</td></tr>
<tr><td>Unbilled unmetered consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized consumption</td></tr>
<tr><td>Metering inaccuracies and data handling errors</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on transmission and/or distribution mains</td></tr>
<tr><td>Leakage and overflows at utility's storage tanks</td></tr>
<tr><td>Leakage on service connections up to point of customer metering</td></tr>
</table>

Source: Farley, 2005.

Conceptual Framework:

The study had two main variables; factors influencing (independent) and non-revenue water (dependent). The independent variable was broken into sub-variables namely; meter registration inaccuracies, unmetered consumption, illegal consumption and water tariff. The factors were assumed to have effect on the day to day provision of water services hence influenced the level of Non-revenue Water at Webuye water supply scheme. The indicator for measuring the level of NRW was the percentage ratio of the volume of water unbilled to the volume of water injected into the distribution system or percentage volume of water "lost" as a share of net water produced. The relationship between these variables is shown in the conceptual framework of the study, Fig.1.

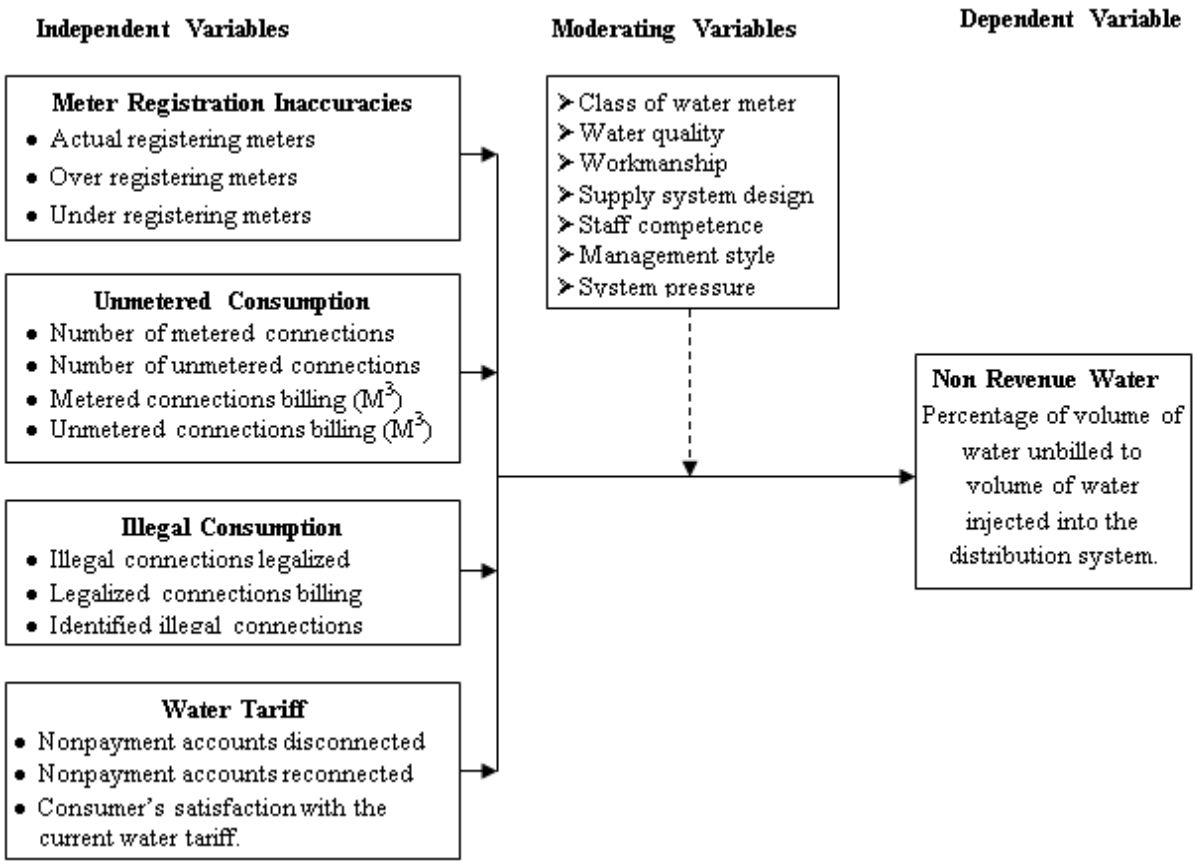

Fig. 1. Perceived Conceptual Framework

3. RESEARCH METHODOLOGY

Research Design:

This researcher employed ex-post facto descriptive survey research methodology with both quantitative and qualitative research designs for this study. This is a survey research design used to determine reasons or causes for the current status of the phenomenon under study. As a result of the cause-and-effect relationships, this research design does not permit the manipulation of the variables [21]. This research design was adopted for the study because the cause (independent variables) was studied after they had exerted their effect on the dependent variable. Therefore, the researcher proceeded to investigate the independent variables in retrospect for their effect and possible relationship with the dependent variable. The study was concerned with ascertaining the influence of the identified factors on Non-revenue Water levels at Webuye water supply scheme.

Target Population:

This study targeted a population of all the registered 1658 water consumer connections of Webuye water supply scheme as at 30th June 2012. The composition (categories) of all the registered water consumer connections was 1540 domestic, 60 institutional, 51 commercial and 7 kiosks. Out of the 1658 registered water consumer connections, 1038 were billed based on actual meter readings and the rest (620) were estimated [5].

Sample Size and Sampling procedure:

To determine the sample sizes for the registered water consumer connections, the researcher applied Yamane's formula [22] at 93 percent confidence level.

Thus,

$$n = \frac{N}{1 + N(e)^2}$$

------ formula (2)

Where n = required responses.

N = sample size.

e^2 = precision level.

Thus the targeted sample size for registered water consumer connections was 183. A sample of 10 percent to 20 percent is acceptable, thus from a population of 1658, the researcher worked with a sample of 183 respondents representing 11.03 percent of the total population, this was to avoid the biasness associated with small samples which tend not to be representative [23].

The sampling techniques adopted for the research were; First, stratified sampling was applied whereby the researcher classified the respondents in four main strata (domestic, institutional, commercial and kiosks). This was to increase efficiency because it was important to treat homogenous parts of the population as populations in their own rights as a result of the population not being homogeneous. Second, systematic sampling was applied to the domestic stratum, whereby the targeted respondents were grouped into 70 groups each consisting of 22 respondents, after which the 3rd and 8th members from each group were selected to form a sample of 140. Third step involved carrying out random sampling on both institutional and commercial targeted respondents, out of which 20 institutional and 16 commercial were selected. Fourth, all the 7 kiosks targeted respondents were selected as they constituted only 0.42 percent of the targeted population.

Data Collection Instruments:

The core of the study was formed by both primary and secondary data that was collected from the field and from the company records respectively. Primary data was collected through questionnaires and field observations while secondary data was obtained through document review. The questionnaire was arranged into four sections; section one dealt with general information, section two focused on unmetered consumption, section three dealt with illegal consumption and section four captured information on water tariff. The questionnaire was administered through the support of four NZOWASCO metering officers from Webuye scheme. The document review was used to afford the researcher the opportunity to access the past characteristics of connected active water service users over a given period, illegal consumption cases filed and the corresponding non-revenue water levels, while field observations enabled the researcher to gain first hand information of the consumer meters registration accuracy.

Validity of Research Instrument:

This research adopted the content validity technique to measure the validity of instruments that were to be used. In constructing the instruments, simple English language that the respondents easily understood was used. Content validity of the instrument was established in two stages. First, the researcher critically considered each item in the instrument to see if it contained a real representation of the desired content and if it could measure what it was supposed to measure after considering the constructs to be measured. Secondly, the instrument was presented to two research experts then to the supervisor who evaluated the applicability and appropriateness of the content, clarity and adequacy of the of the instrument construction from a research perspective. They indicated by tick or cross for every item in the questionnaire if it would measure what it was expected to measure or not. The recommendations of the research experts and the supervisor were considered and incorporated in the final instrument.

Instrument Reliability:

This is the degree to which a research instrument yields constant results or data after repeated trials [24]. It is concerned with the internal properties of a measure and indicates the accuracy or precision of the research instrument. The reliability of a test refers to the ability of that test to consistently yield the same results when repeated measurements are taken of the same individual under the same conditions [25].

Pre-testing through piloting involved administering the research instruments to 10 respondents from Bungoma water supply scheme which was outside the study area at two separate times (two weeks interval) to determine the instruments' reliability. A Pearson product moment formula (3) was used to calculate the reliability of the instrument by calculating the correlation coefficient to establish the relationship between the two sets of scores.

$$r = \frac{\sum xy - n\bar{x}\bar{y}}{\sqrt{\sum x^2 - n(\bar{x})^2}\sqrt{\sum y^2 - n(\bar{y})^2}}$$ ---------- formula (3)

Where r = Correlation coefficient

n = Paired sample size,

When $r = 1$, a perfect positive correlation exists between the variables,

$r = 0$, no linear correlation exists between the variables,

$r = -1$, a perfect negative correlation exists between the variables.

A correlation coefficient (r) of +0.68 was obtained from the calculation. A correlation coefficient of at least 0.5 is considered high enough for the instrument to be used for the study [26]. Thus the instrument (questionnaire) was used for the study.

4. CONCLUSION

The study established that non-revenue water at Webuye water supply scheme was significantly influenced by water meter registration inaccuracies, unmetered consumption and illegal consumption while water tariff did not significantly influence non-revenue water at the same scheme.

The factor that had the highest influence on non-revenue water was meter registration inaccuracy (rho = 872, p = 0.000). There was a strong positive correlation between meter registration inaccuracy and non-revenue water. Increase in meter registration inaccuracy lead to increase in non-revenue water almost at the same proportion. Unmetered consumption had the second highest influence on non-revenue water with a correlation coefficient of 0.733 and p-value of 0.000. There was a strong positive correlation between unmetered consumption and non-revenue water. Increase in unmetered consumption lead to increase in non-revenue water. Illegal consumption had the third highest influence on non-revenue water with a correlation coefficient of 0.460 and p-value of 0.000. There was a moderate positive correlation between illegal consumption and non-revenue water. Water tariff had the least influence on non-revenue water with a correlation coefficient of –0.278 with p-value of 0.189.

5. RECOMMENDATIONS

Based on the findings of this study, that non-revenue water at Webuye water supply scheme was significantly influenced by water meter registration inaccuracies, unmetered consumption and illegal consumption while water tariff did not significantly influence non-revenue water at the same scheme, it is recommended that the management of Nzoia water Services Company need to develop and implement a NRW reduction strategy at Webuye water supply scheme which should include meter registration accuracy enhancement and aged water meters replacement program besides replacing all class ‘B’ water meters with class ‘C’ ones. The company should also adopt use of magnetic water meters as they are more durable and have higher accuracy as compared to displacement water meters and multi-jet velocity water meters the company is using.

There is need for NZOWASCO to meter all unmetered consumer connections and carry out regular servicing and calibration of consumer water meters at Webuye water supply scheme. The company should carry out periodic customer base audit by reconciling office consumer database with field connections. NZOWASCO should sensitize its staff on influence of illegal consumption on the sustainability of the company and its reflection on the integrity of the staffs.

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