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Analysis of Distribution and Availability of Drinking Water, in Kigali City of Rwanda

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Abstract

This study assessed the relationship between water production, distribution and its availability to consumers in Kigali city of Rwanda. The researcher applied the secondary data collected from the Water and Sanitation Authority (WASAC) Limited and Nzove Water treatment Plant. These data included water produced and distributed (supplied), and water received (consumed) by consumers. The results indicated that between 2014 and 2018, a total of 97,881,591 m^3 was supplied, 64,242,628 m^3 was billed (reached customers), which led to a loss of 33,638,963 m^3. In addition, across six (6) branches fed by the Nzove WTP, 4,203 cases were recorded due to water inaccessibility, 5,339 cases resulted from water leakage and 7,146 cases were registered as request for information which also can be of water shortage. This was attributed to poor distribution system like old pipeline, damage of distribution system caused by ongoing construction and urbanization activities. Furthermore, the water loss prediction revealed that in 2018, the loss will increase from 65,760, 277 m^3 up to 147,960,624.5 m^3 in 2030. For successful water distribution, regular monitoring water accessibility among customers would help to ensure that the supplied water reaches its beneficiaries. In addition, involvement of the local community in managing the distribution system and efficient information exchange system for reporting supply related shortfalls would be useful in water management.

Keywords

Kigali City, Nzove Water Treatment Plant, Water Availability, Water Distribution

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1. Introduction

There are globally, 2.1 billion people lacking access to safely managed drinking water services and it is estimated that by 2050, global water demand could be up to 30% higher than today [1]. Since currently, around 1.9 billion people live in potentially severely water-scarce zones and estimates indicate that by 2050, the figure could rise to around 3 billion people. In Rwanda, with a steady growing population, especially in Kigali City where the population growth rate for 2025 is expected to be 4.1 to 5.8%, water supply in the city has not been able to keep up with the rapid pace of population growth. As a result, due to insufficient amount of water supply and water outages, the daily average water supply time is 8 hours, which is extremely short [2, 3].

Consequently, Kigali City has been forced to perform constant water restrictions and suspend the water supply to some areas. In addition, each water treatment plant has a fixed water supply area, and no interconnecting water supply network has been developed to cover for shortages in another water supply area. This expresses that a planned and efficient water supply is not possible while the existing pipe lines were laid in the 1970s or earlier and have significantly aged hence hampering effective water distribution [4].

Environmental degradation in Rwanda has undermined the country's capacity for water supply due to the decline of ecosystem and their water purification role. Hence, the cost of water purification in wet season increases due to high

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turbidity levels and the water quantity decreases during dry seasons [5]. High water treatment costs are incurred on turbidity reduction during water treatment at Nzove water treatment plant. These costs are spent on items such as; chemicals, structures and maintenance [6]. Data from the plant indicate that around 577,605,093 RWF are spent each year with the monthly average cost of 48,133,757 RWF with the greater part of this budget spent in rainy seasons [7].

Kigali city is one of areas facing water scarcity partly due to under production where current water production is 64,000 m^3 while the demand is estimated at 90,000 m^3 per day [8]. This has led to water rationing by WASAC to city suburbs leaving many city dwellers in frustration as taps go dry for days. The national water utility in Rwanda, WASAC provides water to Kigali City and all urban centers of Rwanda through its 18 water treatment plants, including Nzove Water Treatment Plant [9]. The policy aims mainly to ensure water availability in Kigali city and secondary cities. However, there still scarcity of water among residents of Kigali city and rationing leaves many city dwellers in frustration as taps go dry for days on end.

Moreover, the report of the Office of the Auditor General highlighted leakages on transmission and distribution means which expresses that leakages and overflows at utility storage tanks as well as leakages on service connections up to point of customer metering cause water loss which contributes to water scarcity [8]. Hence, it is on basis of the above water scarcity problem in Kigali city that this study seeks to evaluate the influence of water production on its availability in the City. The objectives of this study were to (1) examine the effectiveness of Nzove WTP water production, distribution and availability among consumers, and (2) determine the challenges of water production and availability and propose relevant policies to ensure water availability and minimize water loss during distribution. The results of this study could serve as guiding tool to policy makers on how to manage the available water sources and ensure response to the growing water need.

2. Methodology

2.1. Study Area Profile

The current study was conducted at the Nzove Water Treatment Plant (WTP). The Nzove WTP is located in Kanyinya Sector, Nyarugenge district in Kigali city of Rwanda. The main customers of this WTP are located in Kacyiru sector of Gasabo distirict, Kagarama sector of Kicukiro district and Kanyinya sector of Nyarugenge district [10]

The Nzove WTP operates under WASAC and is currently the biggest and newest WTP that supplies 41 percent of Kigali's water needs. Nzove supplies water to 25 sectors of Kigali city and Kamonyi district in the southern province of Rwanda. In the Nzove water supply system, there are 6 pump stations which are Nzove, Ruyenzi, Kigali (Karama), Kanyinya, Kicukiro and Kimisange. These pump stations supply water to areas where it cannot be sent directly from Nzove water pumping station. There are 30 reservoirs on the water supply network [7].

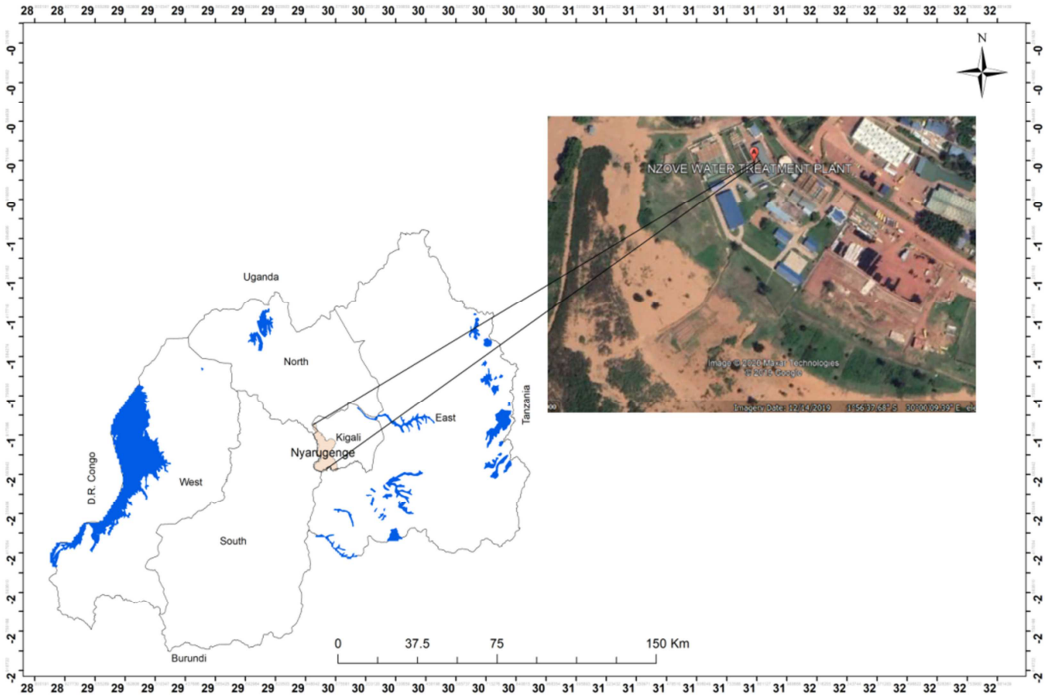

Figure 1. Map indicating the location of Nzove Water Treatment Plan.

2.2. Data Collection

Based on the objectives of this study, the authors only employed the secondary data. These data were collected from the Water and Sanitation Authority (WASAC) Limited. This study specifically considered the Nzove Water Treatment Plant and considered a period of study covering four budget years, namely 2014-2015, 2015-2016, 2016-2017 and 2017-2018. The followings were the types of data collected for this study.

1. The amount of water produced and supplied by the treatment plant
2. The amount of water billed by the water treatment customers
3. The claims made by consumers either as lack of water or water loss during the distribution process

The unity of water was the cubic meters (m^3). Thereafter, the authors analyzed the correlation between water loss and claims received by the treatment plant across the period considered. This helped to reveal the extent to which the supplied water is not reaching the customers and this was based on to propose appropriate water management policies.

As indicated above, this study only employed the secondary data collected from the Nzove water treatment plant. These data were analyzed and enriched by further discussion with similar related studies. Such studies included the reports of WASAC Ltd., WTP offices and Ministry of Infrastructure (MININFRA) website and other researches related to water production, distribution and availability across different parts of the world.

2.3. Data Analysis

After data collection, Tables were made to reveal changes in the quantity of supplied and billed water. The results were presented into tables by referring to each budget year considered in order to differentiate the supplied and billed water along with indicating the lost water in the considered period of study.

Furthermore, the authors predicted water loss from 2018 to 2030 in order to help policy makers to better understand the status of water distribution and access to consumers in the coming years. The data were analyzed and presented into tables by using Microsoft Excel.

3. Results

This section presented the analysis and interpretation of the data which were collected to facilitate the evaluation of water production and its availability in Kigali City. The analyzed and presented data were related to the water supplied, water billed by customers and water claims.

3.1. Supplied and Billed water between 2014-2018

Table 1. Water balance (m^3) in the period 2014-2015.

2014-2015	Supplied	Billed	Balance
July 2014	1,934,226	1,280,455	653,771
Aug 2014	1,859,593	1,290,667	568,926
Sep 2014	1,798,274	1,196,205	602,069
Oct 2014	1,830,937	1,200,079	630,858
Nov 2014	1,772,809	1,227,087	545,722
Dec 2014	1,838,223	1,391,462	446,761
Jan 2015	1,868,150	1,305,569	562,581
Feb 2015	1,653,162	1,204,520	448,642
Mar 2015	1,815,290	1,153,993	661,297
Apr 2015	1,748,416	1,240,823	507,593
May 2015	1,803,906	1,121,033	682,873
Jun 2015	1,792,486	1,203,771	588,715
Total	21,715,472	14,815,664	6,899,808

The results, as shown in Table 1 indicated that the lost water was 6,899,808 cubic meters. This loss was mainly recorded throughout the dry season mainly in the months of May, June, July and August. However, during this period in most parts of Kigali city, water is very expensive which likely expresses its scarcity yet the treatment plant releases much water.

Table 2. Water balance (m^3) in the period 2015-2016.

2015-2016	Supplied	Billed	Balance
July 2015	1,840,590	1,266,622	573,968
Aug 2015	1,786,883	1,269,687	517,196
Sep 2015	1,681,858	1,219,298	462,560
Oct 2015	1,733,224	1,255,984	477,240
Nov 2015	1,747,816	1,304,830	442,986
Dec 2015	1,788,891	1,286,475	502,416
Jan 2016	1,766,623	1,240,071	526,552
Feb 2016	1,604,753	1,212,566	392,187
Mar 2016	2,114,339	1,312,596	801,743
Apr 2016	2,174,318	1,377,479	796,839
May 2016	2,173,092	1,340,024	833,068
Jun 2016	2,262,931	1,481,901	781,030
Total	22,675,318	15,567,533	7,107,785

The results of the study in Table 2 revealed that the lost water increased up to 7,107,785 cubic meters compared to the period of 2014-2015 where the loss was 6,899,808 cubic meters. This expresses that despite the increased water production, the growing water demand is not satisfied since much of the supplied water is lost on its way. Similarly, as shown for the previous period (Table 1), dry period recorded high water supply and water loss.

Table 3. Water balance (m^3) in the period 2016-2017.

2016-2017	Supplied	Billed	Balance
Jul 2016	2,366,056	1,538,509	827,547
Aug 2016	2,363,714	1,550,058	813,656
Sep 2016	2,233,099	1,471,165	761,934
Oct 2016	2,272,867	1,419,264	853,603
Nov 2016	2,116,926	1,385,679	731,247
Dec 2016	2,188,040	1,422,129	765,911

2016-2017	Supplied	Billed	Balance
Jan 2017	2,239,505	1,484,885	754,620
Feb 2017	2,047,264	1,246,959	800,305
Mar 2017	2,200,022	1,177,468	1,022,554
Apr 2017	2,118,578	1,295,019	823,559
May 2017	2,240,035	1,341,473	898,562
Jun 2017	2,233,460	1,422,982	810,478
Total	26,619,566	16,755,590	9,863,976

The results of this study in Table 3 showed that the balance between the supplied and billed water kept on increasing since 2014 and reached 9,863,978 cubic meters in the period of 2016-2017. This expresses that the current water distribution system is heavily ready to huge water loss which likely can impact on consumer water satisfaction as well the factory's benefits.

Table 4. Water balance (m^3) in the period 2017-2018.

2017-2018	Supplied	Billed	Balance
Jul 2017	2,358,680	1,510,843	847,837
Aug 2017	2,376,386	1,600,843	775,543
Sep 2017	2,195,068	1,473,615	721,453
Oct 2017	2,079,164	1,403,414	675,750
Nov 2017	2,178,763	1,340,409	838,354
Dec 2017	2,284,467	1,302,878	981,589
Jan 2018	2,311,169	1,532,376	778,793
Feb 2018	2,060,830	1,374,943	685,887
Mar 2018	2,291,706	1,367,840	923,866
Apr 2018	2,161,958	1,391,955	770,003
May 2018	2,231,670	1,385,750	845,920
Jun 2018	2,341,374	1,418,975	922,399
Total	26,871,235	17,103,841	9,767,394

The above results in Table 4 indicated that for the period of 2017-2018, the balance between the supplied and billed water was 9,767,394 cubic meters. Nevertheless, similar to previous periods considered by this study (2014-2015, 2015-2016 and 2016-2017), the results indicated that much water is supplied during the dry season but also lost during this season. Therefore, in Kigali city, the more supplied water, the higher lost water.

3.2. Overall Water Loss

The following Table 5 summarized the total loss on water based on the supplied and billed water from Nzove Water Treatment Plant to its customers.

Table 5. Total water lost between 2014 and 2018 (m^3).

Period	Supplied	Billed	Loss	Average
2014-2015	21,715,472	14,815,664	6,899,808	14,307,640
2015-2016	22,675,318	15,567,533	7,107,785	14,891,552
2016-2017	26,619,566	16,755,590	9,863,976	18,241,771
2017-2018	26,871,235	17,103,841	9,767,394	18,319,315
Total	97,881,591	64,242,628	33,638,963	65,760,277

The results in Table 5 revealed that high volume of water (26,871,235 m^3) was supplied in the period of 2017 and 2018. However, much loss compared to the supplied and billed water was registered in the period of 2016 and 2017. It reached 9,863, 976 m^3 whereas the lowest water loss of 6,899,808 m^3 was recorded in the period of 2014-2015.

3.3. Water Related Claims

In order to indicate the extent to which the above water loss (amount of water not reached to customers but provided by the treating plant), the authors analyzed the claims related to water that have been recorded over the considered period of study. More details are provided in the following Table 6. The authors used the recorded water claims that have been received by the Water Sanitation and Corporation (WASAC). However, due to data shortage, only the Corporation was able to provide the claims registered in 2018 which are used by this study as shown in the following Table.

Table 6. Water related claims in 2018.

Branch	No water access	Reported leakage	Request for info
Gikondo	731	1,447	1,146
Remera	1,043	605	1,274
Kanombe	594	695	1,148
Kacyiru	1,010	456	1,533
Nyurugenge	465	1,347	1,582
Nyamirambo	360	789	463
Total	4,203	5,339	7,146

The results of the analysis, as indicated in Table 6 showed that the Gikondo, Remera and Kacyiru branches recorded the majority of claims on water inaccessibility. For the registered water leakages, Gikondo, Nyarugenge, Nyamirambo and Kanombe were the branches with high numbers of 1,447, 1,347, 789 and 695, respectively. Whereas other information related to water that has been received in 2018 registered increasing record at the Nyarugenge, Kacyiru, Remera and Kanombe as well.

It can be observed from the results (Table 6) that the branches with high number of water leakages, no water access and requested info are the same namely the Gikondo, Kanombe, Kacyiru and Nyarugenge branches. These requests can be associated to the recorded water loss in this period (2017-2018, Table 4) which amounted 9,767,394 m^3. Thus, the higher water loss of water, the increase in water associated claims from customers.

3.4. Key Barriers to Distribution of Water at Nzove WTP

For this section, the author considered recent reports on challenges faced by water distribution system in Kigali city including the Nzove water Treatment Plant. The report of the Rwanda Water and Forestry Authority indicated that the location of Kigali city (hilly areas) makes the water distribution difficult and the location of residents from improved water system makes the problem more complicated. It is reported that 63 percent of residents live within 200 m from an improved water distribution system [10]. In addition,

recent studies which considered Nzove WTP as the case study mentioned that burst pipes, poor construction and urbanization activities which undermine water pipelines, poor monitoring and information sharing from the plant managers to communities, and unmetered consumption were the key challenges hindering distribution of water from Nzove WTP. These are associated with inadequate or delay in repairing of the pipelines broken, data handling errors and unauthorized water consumption from unregistered customers which sometimes leads to providing water to wrong consumers [11-13].

3.5. Water Loss Prediction

Moreover, the authors, based on the total annual water loss (Table 6) calculated the average annual water loss and predicted the future water loss per annum. The results (Table 7) indicated that if current water loss continues to be recorded much water will be lost in the coming period. Based on the annual average loss of 16,440,069.5 m^3, it is clear that by 2030, a total of 147,960,624.5 m^3 will be lost.

Table 7. Estimated water loss in the future (m^3).

2014-2014	Loss
Total loss (2014-2018)	65,760,277
Average annual loss	16,440,069.5
Water Loss Prediction	
2018-2023	82,200,346.5
2023-2028	98,640,416.0
2028-2033	115,080,485.5
2033-2028	131,520,555.0
2030	147,960,624.5

4. Discussion

The clean and accessible water is critical to human health, a healthy environment, poverty reduction, sustainable economy and peace and security as well. Globally, over 40 percent does not access on sufficient and clean water [1]. It is predicted that by 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity. This complete inaccessibility to water limits agricultural production which employs about 70 percent of world accessible freshwater and then leads to poverty [14]. The issue of limited or poor access to safe water is highly recorded within developing countries. This is likely accelerated by flooding which pollutes water quality and damages the sources as well.

It is estimated that up to 80% of illnesses in the developing world are linked to inadequate water and sanitation. Water stress and lack of sanitation disproportionately affect women and girls. These factors can alter their health, safety and opportunity to engage in economic activities. It is reported that women and girls are managers of natural resources mainly for household use and small-scale farming activities [1, 14]. They are the one suffering the most in case of water shortage; however, they can act as key change agents in sustainable water management practices if well involved in managing the available water resources.

This study considered the Nzove Water Treatment Plant and assessed its water distribution and accessibility among its customers. The analysis used the supplied and billed water along with claims received in relation to water among customers from different branches billing water generated by the Nzove WTP. The results indicated that the access to water is limited by increasing loss of water during the distribution process among all branches. This leads to water shortage and its associated consequences including not limited to diseases, poor hygiene and sanitation, and poverty as well. The results of the research in Tables 1, 2, 3 and 4 revealed that the balance (lost water) between the supplied and billed water kept on decreasing across the year.

It was noticed that in May of 2014-2015 and that of 2015-2016, high water loss (balance) was recorded at 628,873 m^3 and 833,068 m^3, respectively. Whereas in 2016-2017, increased loss of water was recorded in March, it reached 1,022,554 m^3 and then 981,589 m^3 in December of 2017-2018. Hence, in the period of 2016-2017, much water was lost which implies high supply as well. This expresses that the distribution system at Nzove Water Treatment Plant is somehow poor since all supplied water does not reach the target customers. The above months in which much water loss was recorded are of both dry (May) and rainy (March and December) seasons, respectively. It has been reported that in Kigali city, water becomes more scare in dry season. However, based on the findings of this study (Tables 1, 2, 3 and 4), it can be confirmed that water loss is being recorded throughout the year. This call for strong water distribution system by for example checking the types of water distribution pipes used since the billed water does not reach the customers.

This can be justified by the fact that, as revealed by this research, in 2018, 5,339 cases were recorded due to water leakage and 4,203 cases were related to water inaccessibility (Table 6). Hence, revision of water distribution system can help Nzove Water treatment Plant to maximize its water distribution and access among its customers. The report of the Water Sanitation Corporation [7] indicated that water scarcity problem has persisted in Kigali city largely due to water production and distribution challenges related to water treatment and supply expenses. The report also highlighted that water production and distribution at the Nzove WTP is hampered by heavy production costs particularly over the stretchy 6 months' rainy season running from November to May due to high raw water turbidity. During this period, the amount of treated water produced and supplied by the Nzove

WTP is lowest at the time of highest turbidity at the peak of the two rainy seasons [7]. This can be similar to the findings of this research where much water was lost during rainy season (Tables 1, 2, 3 and 4).

This additionally was marked by the report of the Office of the Auditor General [8] that water scarcity takes for almost 8 days/ month during the rainy season and affects the top consumers like industry, social service facilities such as hospitals and other government installations [8]. In addition, the expansion of Nzove water extension pipeline is 105.4 km. This makes it the longest and news water supply system over the city of Kigali. However, it is reported that the frequency of power failure is high and it is under heavy load. There are no backup power sources in the water treatment plant. The hydraulic pressure fluctuates drastically and it is inferred that a large load is applied with drastic effects on water distribution around the city of Kigali [7]. This has severe impact on the distribution and availability of water across the customers since the supplied water does not reach the beneficiaries.

This is similar to the findings of this study in Table 5, the lost water recorded gradual increase and the period 2016-2017 marked huge loss of 9,863,976 m^3. This loss can be attributed to several factors including poor distribution system, not allocating consumers at the right place and many more. The Office of the Auditor General [8] also found that some water facilities and part of the water distribution network in Kigali City were constructed during the colonial period. Although facilities have been upgraded and new infrastructure constructed over time, pipes in the network are made of materials such as cast iron, galvanized steel, Polyvinyl chloride and Polyethylene which suffer from degradation with passage due to environmental conditions that cause corrosion, normal wear and tear and through effects of leakage within the network.

Furthermore, apart from poor distribution system, poor coordination among stakeholders can be the other reason behind the water loss being recorded at Nzove WTP despite large amount of water produced. Accordingly, as recently reported, for the period 2011-2014, there has been 14 cases of water loss recorded due to damage of water infrastructure resulting from different road construction projects in Kigali City [7, 8]. Thus, sustainable construction and good machinery which can easily detect water pipelines would be one of the alternative solutions to the problem.

5. Conclusion

This study aimed to assess the relationship between water production and distribution and its availability to consumers in Kigali city. The authors considered the case of Nzove Water Treatment Plant (WTP) and employed secondary data provided by the Nzove WTP and Water Sanitation Corporation (WASAC Ltd.), and other related studies conducted at Nzove WTP. The results indicated that between 2014 and 2018, a total of 97,881,591 m^3 was supplied, 64,242,628 m^3 was billed (reached customers), which led to a loss of 33,638,963 m^3. In addition, across six (6) branches fed by the Nzove WTP, 4,203 cases were recorded due to water inaccessibility, 5,339 cases resulted from water leakage and 7,146 cases were registered as request for information which also can be of water shortage. The authors attributed this loss of water to poor distribution system like old pipeline, damage of distribution system caused by ongoing construction activities and community daily activities which causes water leakage since they are not aware of the location of water distribution system. For successful water distribution, the study suggests policy makers to ensure that water distribution system are marked and publicly known, regular monitoring water accessibility among customers would help to ensure that the supplied water reaches its beneficiaries. In addition, involvement of local community in managing the distribution system would be of paramount importance.

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