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Original research article

Assessment of Water Supply System Performance Indicators Based on the Customer Bill-Based Approach

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ABSTRACT

Significant efforts have been undertaken over the last two decades by governmental organizations and local and international non-governmental sectors to improve water supply and sanitation structures; however, there are significant challenges to the town's growth and expansion. Chiro town's population is increasing, and the community is affected by water and excreta-borne diseases as a result of a lack of proper sanitation facilities and a water supply system. In this study, billed data from Chiro Town water supply service enterprise customers have been used to assess the performance of the water distribution network over ten years (2011-2020). The findings show that the Town's water coverage is 62.9%, the water demand is 8,121.6m^3/day, and the computed annual water production is 4,222.3m^3/day. Residents of the town have complained about a lack of access to improved drinking water supplies, low water consumption, and sanitation facilities, particularly in the community of those who live in the town's borders and practice open defecation. For all domestic use, 16.32% and 83.68% of respondents used unprotected and protected water sources, respectively. This study suggested that strong sectoral coordination, community involvement, and sufficient financial resources were required to identify the root causes and provide an efficient water supply system in the study area.

1. Introduction

The Water is required for all living things to survive and is crucial for food production and economic development. Furthermore, as an input to almost all production, including agriculture and industry, it is a driver of long-term growth and poverty alleviation [1]. However, providing adequate water supply and improved sanitation facilities to the rapidly growing cities, particularly in developing-country cities, is a challenge. This compelled numerous international organisations to increase their resolve to address the worldwide problems of water supply consumption and sanitation [2]. Furthermore, one of the United Nations Millennium Development Goals is to provide improved water sources, sanitation, and hygiene. Many international non-governmental organizations focus on increasing the use of improved water sources and sanitation infrastructures for rural and urban communities, such as piped water dwellings, public taps, protected boreholes, rainwater harvesting, and protected springs [3], [4]. WHO-UNICEF and other international organizations have been making substantial efforts for more than a half-century to ensure worldwide access to improved water and sanitation infrastructure by developing global programs and strengthening national institutions. According to the World Health Organisation (WHO), access to these infrastructures is one of the fundamental needs and human rights that are critical for everyone's health [5].

However, providing safe drinking water and adequate sanitation systems to worldwide people, particularly in developing countries such as Africa, remains one of the most difficult challenges [6]. Despite the extensive efforts of the water utilities sector, billions of people continue to lack access to these services [7]. According to the global water supply and sanitation assessment report, nearly 1.1 billion people worldwide lack improved water supply in 2000, with the majority living in Africa and Asia [8]. High water demand and limited sanitation infrastructure pose significant challenges in Ethiopian towns experiencing rapid urbanization [9]–[11]. These challenges are especially difficult for very young and

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elderly who have minimum resistance to suffering diseases [3]. Poor water distribution systems and sanitary facilities injure both rural and urban communities, which has a substantial impact on national and regional development. Residents in most Ethiopian towns, including Mudulla [12], Awaday [13], Ambo [14], Robe [10], Addis Ababa [15], Axum [16], Adama [17], Shambu [18], have complained about water supply systems such as insufficient water quantity, poor distribution, and a lack of water supply coverage. These are due to increased water demand with population growth, and insufficient water production, which has a significant impact on the economic progress of towns and people's health [19], [20]. According to WHO [21] and Dinka [22], the challenges that face the global water utilities sector in the twenty-first century are caused by numerous significant factors such as limited water infrastructures, a lack of reliable estimated total water demands, and a lack of accurate water sources selected by decision-makers. All of these factors can have a significant impact on the performance of existing water distribution systems over their lifetime, which can be accessed through various scenarios [23]. Earlier studies, for example, [17], [24]–[26] noted that water quality deterioration in distribution systems, low pressure, water loss, and low coverage are the factors that challenge water supply utility. Large capital investments are required to plan cost-effective water supply projects to solve the problems associated with a lack of clean water that regularly affects scattered settled communities of cities. As a result, an international water association and various countries' water services have developed indicators to evaluate water supply system performance [24], [27]. The most important indicators to consider when evaluating the performance of a water distribution system are the frequency and problems with water supply interruptions, the comparison of water production and consumption, and the level of community satisfaction with the existing water distribution supply [28]. According to a UNICEF Ethiopia report and an analysis of EDHS data (2000–2011) [29], the country's current water supply system coverage is still very low, with approximately 87 million people (approximately 58%) living without access to safe water supply and 54 million people (approximately 32%) living without improved sanitation. Nonetheless, approximately half of Ethiopia's population (over 65 million people) lacked access to safe drinking water. The situation is worse in Chiro, which is plagued by a lack of treated water supply and improved sanitation facilities, particularly among the community who live on the town's outskirts and practice open defecation. The coverage is extremely low and has a significant impact on the living conditions of town communities. Water losses are also high as a result of ineffective leakage management, leaking pipelines, and pipe breaks. This resulted in inaccurate meters and/or unauthorized consumption, as well as service interruptions. Due to the challenges posed by residents' varying water consumption, the condition of existing water supply systems, including performance supplying systems, the quantity of water, and consumption of specific locations, is required to provide solutions by designing adequate water supply systems that can supply sufficient water for the community. As a result, this study was carried out to assess the performance of Chiro town water supply systems using selected performance indicators based on the town water billing rate.

2. Method

2.1. The Study Area

The Chiro town is located in the eastern part of Ethiopia, specifically in the Oromia regional state. The study area is located between 9°4′ 30" and 10°01'14"N latitude and 40°52'0" to 4109'17"E longitude, with elevations ranging from 1692 to 1896 meters above mean sea level. The town has a total area of approximately 50 hectares. The main asphalt road from Dire Dawa to Addis Abeba City crosses through town. This town is one of the most rapidly developing in the Oromia region and the country. The annual rainfall distribution patterns are nearly identical to the country's central regimes. According to the National Metrological Agency [30], the town's rainy season is primarily from May to August, with maximum and minimum mean monthly rainfall of 167mm and 18mm, respectively. The study area's topography is flat and gently sloping towards the north and south sides. The mountain borders the study area to the north and south. Thousands of rural resident's flock to the town, which serves as a major marketing center. The most important economic activity includes trading, hotel services, and small-scale manufacturing industries, and Chati is the main foreign currency-earning cash crop, which covers a huge area in and surrounding town.

2.2. Data Used for The Study

In this study, data from the town water supply service such as current daily consumption, monthly and annual water produced, number of water meters, and level of connection were used. These data were used to estimate water loss, the status of the water distribution system, the gap between water supply and demand, and community satisfaction with water production. In addition, other information was collected over three weeks in February and March of 2021 via interviews and valid questionnaires. A pre-tested structured questionnaire was developed by Afan Oromo (local language) and translated into English to gather information on the socio-economic characteristics of the respondent, types of household's storage systems and water sources, availability of alternative water supply sources, sustainability factors of the existing services and level of water supply satisfaction both in quantity and quality. A sample size of households (n) was determined using sampling techniques that were developed by Cochran (Eq (1)) [31]–[34].

$$n = \frac{N.Z^2.P.Q}{W^2((N-1)+Z^2.P.Q} \quad (1)$$

Where: n is a sample size of households; N is the total number of households; P is the households variable (50%); Q is non-residential houses = 1-P; Z is 95% confidence interval (1.96), and W is an allowable error (0.05). The average person per housing unit and total population was obtained from the Chiro town administration office is 5. According to the statistical data collected, the average person per housing unit varies across the eleven kebeles; however, we used the mean of all kebeles. The total number of households is 15,784, calculated by dividing the total population by the average number of people in one house. A sample of households with high, medium, and low incomes from each kebele was chosen at a random interval of ten (**Table 1**). Then, various information was collected from households to assess community satisfaction with water sources (quantity), rate of water source quality, water meter functionality, and water distribution infrastructure. The prepared checklist was used in a discussion with water utility personnel.

2.3. *Water Demand Projection*

The quantity of water production, supplied, and total water consumed is computed based on the yearly water billed data. The population in 2015 and 2020 was forecasted using the geometrical growth rate method based on the past existing population (**Table 2**) [35], [36]. This method has been adopted for this study due to the method is mostly applicable to growing towns and cities having a vast scope of expansion, like Chiro [37]. The geometrical growth method is following Eq (2).

$$P_n = P_0(1+r)^n \quad (2)$$

Where; P_n is a forecasted population at n years, P_0 is the initial population, r is the annual growth rate (%), and n is the number of decades.

The total water requirement for a town has been estimated for both domestic and non-domestic purposes. Three steps were taken to identify the water demand-supply gap: (i) determining the level of per capita demand per person, (ii) computing per capita demand by the level of connection, and (iii) calculating overall demand coverage based on the design criteria as following Eq (3) [38], [39]. The percentage of people who have and do not have a house connection is one indicator taken to compare water supply coverage cities (Eq (4)), which is then evaluated based on the quantity, quality, and level of water connection [19], [40].

To estimate water consumption per person, yearly water consumption data of billed reports from 2011 to 2020 were converted to average daily per capita consumption using town population (**Table 3**) [41]. The per capita water demand (liters per person per day) is computed using Eq (5) [42], [43]. The level of water connection is another indicator that may be used to assess the performance of water supply systems; consequently, the number of domestic connections per family has been calculated using data from water connected for domestic and non-domestic purposes, as indicated in Eq (6) [42]. Also, the average family size of 5.5 that was obtained from the census was used.

2.4. *Water Loss Estimation*

The total annual water produced and distributed to the distribution system and the water billed that was aggregated from the individual customer meter readings were used to quantify the total water loss (real losses and apparent losses) for the entire town. The real losses and apparent losses referred to as uncounted for water were expressed as a loss per kilometer length of main pipes calculated by the difference between water produced and water consumed as following Eq (7) [44].

Table 1. The number of different income households and sample size

Income of household	No of households	A sample size of households
High income	2368	57
Medium income	5524	133
Low income	7892	190
Total	15,784	380

Table 2. The projected population of Chiro town (2010-2030)

Year	1995	2000	2005	2010	2015	2020
Growth rate (%)	-	-	-	4.55	4.33	4.15
Population (no)	24,963	38,257	47,830	51,264	63,366	78,347

Table 3. The yearly water consumption of Chiro town

Sub-town	Yearly water consumption data (m^3/year)									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Alagora	57902	67053	73521	72656	66287	64054	81387	84287	81387	136287
AribaHore	41338	45512	61307	75513	55992	74575	55241	63028	66095	77628
ArbaRekete	47395	52182	58916	70916	53586	169809	63337	72336	85143	154455
Medhicho.2	32016	31946	49315	87235	39581	7273	38776	114156	82188	114156
Medhicho .3	58850	64794	71915	71914	64054	122422	78646	78645	154356	78646
Medhicho.9	68643	76058	62624	81914	156802	156802	192521	192520	205699	242760
Chiro	65593	119173	62091	69781	269809	84316	220171	330915	231271	316528
ChiroKella	72975	71537	61157	80081	70720	118312	86830	86829	104522	88830
Nejebas	75801	115773	67784	102384	121648	156802	138439	138448	138439	75341
Wachu	74437	89668	94185	94042	119412	74233	151456	154455	89496	138448
Wedeyiti	76434	85290	78353	96353	88316	53374	104523	104523	86829	104520
Total	671382	818987	741169	902791	1106206	1081972	1211326	1420142	1325425	1527598

(Source: Chiro town water supply service enterprise

$$Production\ (1/person/day) = \frac{Annual\ production\ (m^3)\,.\,1000\ (liter/m^3)}{Population\ number\,.\,365\ day} \tag{3}$$

$$Water\ supply\ coverage = \frac{(Annual\ production\,.\,100\%)}{Annual\ demand} \tag{4}$$

$$Percapital\ consumption\ ((1/c)/d) = \frac{Annual\ consumption\ (m^3)\,.\,1000\ (liter/m^3)}{Population\ number\,.\,365\ day} \tag{5}$$

$$Connection\ per\ family = \frac{Total\ number\ of\ connection}{Number\ of\ population\ of\ the\ town/average\ family\ size} \tag{6}$$

$$Total\ water\ loss\ (\%) = \frac{(Total\ water\ produced - total\ water\ billed).100}{Total\ water\ produced} \tag{7}$$

3. Result and Discussion

3.1. *Water Loss Estimation*

This study assesses the available water sources, their distance from the demand centre, and the use of alternative water sources for Chiro town water distribution. According to the mode of service, 83.68% of the inhabitants get their drinking water from improved sources. From this, 57.63%, 14.21%, and 11.84% of respondents get water for their domestic needs from a private, a public tap, and a neighbour's house water tap, respectively, as shown in **Figure 1**. Because there are no private water taps in their compound and no public water taps in all kebeles of the town, some members of the community have had to rely on alternative water sources to survive. This is consistent with the findings of previous studies; the existing water distribution system has limited coverage [12], [16], [30], [45]. Access to safe drinking water is crucial for improving health, for domestic and recreational uses, and for contributing significantly to poverty reduction. The residents of Chiro town, on the other hand, continue to rely on unimproved water sources such as hand-dug wells, nearby rivers, unprotected springs, and vendors (water stored in small tanks). According to the findings, 16.32% of respondents were forced to use natural water sources for all domestic purposes without regard for treatment. This is due to a lack of safely piped water supply systems in the town, particularly near scattered settled communities; as noted by Daniel et al. [12] and Abdisa and Reddy [13], this may cause waterborne diseases in the town communities. Other studies have found similar results in global cities, such as Dhaka, Bangladesh; Welenchiti, Ethiopia; and Maiduguri, Nigeria; [3], [46], [47].

Furthermore, the researchers observed the study area and determined that the water sources may be contaminated with urban stormwater, agricultural farm chemicals, and other contaminants that can cause illness when consumed, bathed in, or used for other hygiene activities. In addition, we confirmed that the challenges are caused not only by a lack of improved water supply systems, but also by insufficient water quantity with population growth due to urbanisation. There are six functional boreholes in the study area. These boreholes' total current average yield is 94 l/s (see **Table 4**). According to (UN-HABITAT 2012) [48], in towns, the drinking water source may be a public fountain or a standpipe no more than 200 metres away; however, the existing public tap is positioned beyond this distance. This forces the urban community to travel long distances and spend a significant amount of time fetching water [49].

As observed in the field there are four currently existing reservoirs in Chiro town were two old existing and two newly constructed concrete circulars with a capacity of 500m^3, 500m^3, 200m^3, and 100m^3, respectively. Among the 36 water points observed in the study, five are not functioning properly due to water supply insufficiency and problems with monitoring or management. In line with this, responses from the town water supply service enterprise head revealed that the existing water distribution has problems managing a large number of inhabitants. Therefore, households' demand for private connections was very high and increased over time. The capacity of the existing water source was not adequate in its quantity for the town population, because of its shortage of production, lack of awareness of people as the owner of the property, and technical problems. Unequal distribution of pipelines with old systems in some sub-city of the town makes difficult the provision of water supply. In the high density of Chiro town, technical water supply management is a challenge in practice because urbanization typically occurs without any planning. Water supply schemes are among the most important and costly public infrastructures; as a result, continuous operation and maintenance are required to sustain their services, as highlighted by Haider et al. [24]. Furthermore, understanding the existing problems and the factors that can affect the condition of the current water

Table 4. The existing water sources of Chiro town

Source of water	X(UTM)	Y(UTM)	Z(m)	Depth(m)	SWL(m)	Q (l/s)	Status
Chiro WS-BH-1	710846	998572	2228	250	34.4	43.34	Working
Chiro WS-BH-2	710585	998429	2237	120	40.6	25	Working
Maremia–BH	706467	973783	1872	111.7	40	4.26	Working
Millennuium-BH	705805	967174	1865	90	47	6.2	Working
High school-BH	704150	998341	2242	125	48.55	7.7	Working
Nejebas–BH	706987	998418	2221	230	46	7.5	Working
Addis Ketema- BH	706034	998213	1876	121	0	0	Non-function
		Total				**94**	

*SWL is depth to static water level, UTM is Universal Transverse Mercator, and BH is a borehole distribution systems, such as population growth, economic factors, and community involvement, are essential prerequisites criteria for designing a sustainable new water supply scheme in developing-country towns like Chiro [20], [50]. With an increasing population, the current water supply cannot meet all demands; people have suffered as a result of insufficient water production. As a result, until a new water supply is implemented, all stakeholders should be involved in maintenance, cost recovery, and ongoing support of high-quality services to use the existing systems, as noted by previous studies [51] and [52].

3.2. Frequency and Problems of Water Supply Interruptions

Interruptions in drinking-water supply, either from intermittent sources or as a result of inefficiencies in quantity and access to quality drinking water. As a result, the frequency, causes, and effects of water interruptions in the study area were identified in this study. Water interruption has been a critical challenge in Chiro town for the last ten years, affecting residents' lives in a variety of ways. According to the results of selected households, 0.79%, 35%, 42.36%, 9.74%, and 12.1% of total respondents (out of 133 Nos) were getting tap water regularly daily, once every 2 to 3 days, 4 to 5 days per week, only once per week, and difficult to get tap water even once per week, respectively (See **Figure 1**). According to this finding, 99.21% of those interviewed did not get water regularly. Even residents in the town center who have a water tap connected to the main water line frequently face water shortages during the day. Due to the high frequency of interruptions, the town and community faced water scarcity and were forced to buy water from a neighbor and rely on alternative water sources. These were caused by a lack of water quantity produced by the water sector, as well as main breaks and emergency repairs, as discovered by Maziotis [53] and Molinos [45]. As a result, low-income respondents may be impacted by water-related issues. This is consistent with an earlier study by Lopez and Mathers [54], which discovered that 80% of diseases are spreading in Africa due to a lack of clean water, resulting in the deaths of children under the age of five.

Out of 133 interviewed households, 72.1% could not identify the reasons for the continuous water supply interruption, while 27.9% gave various reasons such as an old water supply system, a lack of water supply connection, and poor maintenance. In line with this, they stated that the following major factors contributed to the interruption problems: topography, too old a water supply system, a lack of water due to an imbalance of the demanded and produced water in the town, and electric power interruption. The study area's topography is one factor that causes water interruption; as a result, some areas of low elevation receive water from the pipeline throughout the day.

Some Chiro town's water supply system was built in 1990 (before 20 years) to serve a population of 32,000 people. As a result of its long years of service, the system requires effective maintenance. Because the current population is not the same as the initial population number used at the design stage, the water coverage is inadequate with the increased population. However, as previously highlighted by Jeandron et al. [55] and DiCarlo and Berglund [56], the interruption of water varies from place to place within the country. This shows that the town's residents do not have equal access to water distribution. Hence, while it is difficult to solve the problem all at once, it is preferable to give advance notice and interrupt service by shift or rotation rather than serving some areas continuously while others suffer from continuous water interruption. Water supply shortages are becoming more prevalent in the study area as a result of insufficient water demand from its customers. Furthermore, after a detailed study of the current and future population, urban growth, and availability of community infrastructures such as industrial activities, another water supply scheme for drinking will be required to solve water scarcity. Based on the existing water sources, the town should build additional wells to extract groundwater from underground aquifers. However, future water supply systems should account for future population growth and accurately estimate all types of water demand, as presented in Kharti and Porto [57] and Gleitsmann [58].

The direct human consequences of Chiro town's water supply interruptions are: spending a long time fetching water (mostly by women and children); suffering poor health, particularly children, as a result of direct injury from carrying heavy loads over long queues. Female student absenteeism from school is another issue caused by water interruptions. Furthermore, because the community used an unimproved water source, children became ill as a result of using poor-quality water to maintain adequate hygiene standards. This clearly shows how water interruptions have a significant impact on the day-to-day activities of the urban community. According to the findings of an African Development Fund (ADF) investigation [59], access to water is a precondition for health and livelihood, which is why the MDG target has been identified as sustainable access to affordable drinking water supplies.

This study further stated that improving the supply of water was broadly recognized as a critical component of human rights, social, and economic development.

3.3. Frequency and Problems of Water Supply Interruptions

The current water production of Chiro town depends on the borehole source of gravity and pumping transmission lines with a gravity-fed water distribution system. The computed average annual water production from the compiled customers' billing rate of the last ten years (2011-2020) was 1,541,153.5m^3/year (4,222.31 m^3/day). The consumption rate of water supply shows an increasing trend in the analysis period in Chiro town. The average annual water consumption from the year 2011 to 2020 is 1,080,699.8 m^3/year (2960.8m^3/day) as shown in **Table 5**. Whereas, water consumption increased from 671,382 m^3/year to 1,527,598m^3/year during the same period. The average annual water loss for Chiro town was to be 460,453.7m^3/year. Aside from annual water production and annual demand, Chiro Town's water supply coverage is quite low. According to a recent study in Ethiopian cities such as Addis Ababa City [8], Axum Town [16], Hosanna Town [60], Ambo Town [14], Addis Kidam Town [51], and others, water consumption increases from time to time due to rapid urban development, with these issues affecting the community.

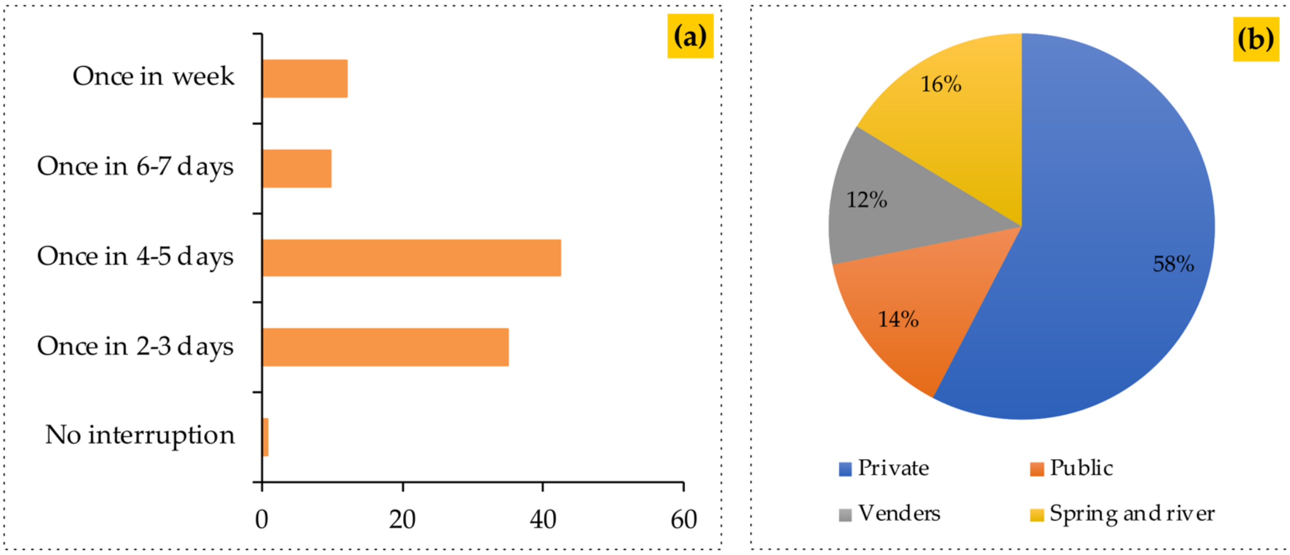

Figure 1. The frequency of water interruptions and the alternative water source that the community is forced to use

Table 5. Annually water production, consumption, and water loss (2011-2020)

Year	Population	Water production (m^3/year)	Water production (l/Person/day)	Billed water consumption (m^3/year)	Water consumption (l/Person/day)	Water loss (m^3/year)	%of water loss
2011	50493	926987	50.3	671382	36.4	255605	27.6
2012	53447	1023715	52.5	818987	42.0	204728	20.0
2013	57695	1196410	56.8	741169	35.2	455241	38.1
2014	60464	1460125	66.2	902791	40.9	557334	38.2
2015	63366	1677138	72.5	1106206	47.8	570932	34.0
2016	66407	1525879	63.0	1081972	44.6	443907	29.1
2017	69594	1778112	70.0	1211326	47.7	566786	31.9
2018	72592	1954160	73.8	1420142	53.6	534018	27.3
2019	75876	1833724	66.2	1325425	47.9	508299	27.7
2020	78347	2035285	71.2	1527598	53.4	507687	24.9
Total		15411535	642.4	10,806,998	449.5	4604537	298.8
Average		1,541,153.5	64.2	1,080,699.8	45.0	460,453.7	29.9

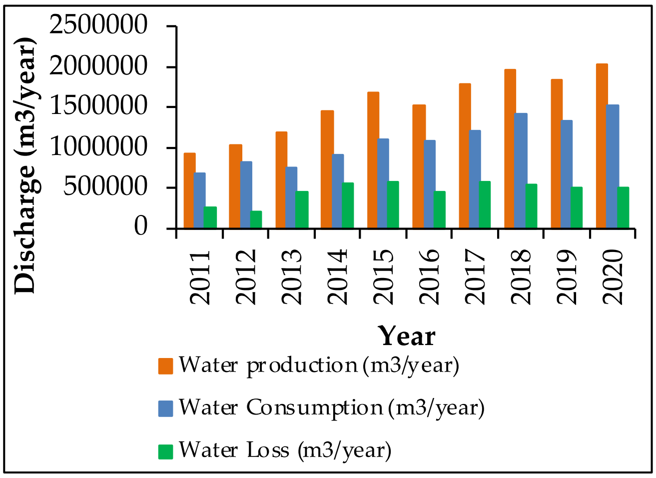

Figure 2. Summarized water production Consumption and Loss (m^3/yr).

As shown in Table 5 and Figure 2, the average water production and per capita water demand were 64.2 and 45 l/Person/day respectively. It is also lower than the per capita water consumption computed for Addis Ababa in 2009 by Kabeto [61]. However, the most important factors that characterize the study area's water supply coverage are higher than the estimated per capita of other Ethiopian towns such as Addis Kidam Town, Adwa Town, and Alibo Town, which are 19.5 l/c/day [62], 28 l/c/day [63], and 30 l/c/day [64], respectively. According to Ethiopia's Ministry of Water, and Energy [65], the minimum per capita for a town with a population of 50,000 to 80,000 people is 60l/c/day. The study area's current per capita water demand is lower than the country standard used for design purposes. This implies that the existing water distribution systems are insufficient to meet all of the required water demands. During the project's implementation in the town, the estimated and used per capita for various demand category activities is 52 l/c/d. It was unrealistic and unacceptable compared with the average estimated in this study.

Moreover, the level of water coverage in the study area is evaluated based on the level of water supply connection per family. The total number of connections or water meters within the town is 8974. Among these, 7718 and 1256 water meters are connected for domestic and non-domestic water purposes respectively. The level of water connection as expressed by the study area water coverage became 62.9%. While more than half of the town's families use tap water, the connection per family in Chiro town is much lower than the maximum level of residential water supply connection [51]. The daily water lost per connection per day was estimated using Eq (8). The overall length of the pipe is 78.2 kilometers, with sizes ranging from 25mm to 300mm. This is used to determine the water loss per kilometer (Eq (9)).

$$Water\ loss = \frac{Annual\ loss\ x\ 1000}{Number\ of\ connection\ x\ 365} = \frac{1261.51x1000}{8974\ x\ 365} = 0.38\ liter/connection/day \quad (8)$$

$$Water\ loss\ per\ km\ of\ pipe = \frac{Annual\ loss\ x\ 1000}{Total\ pipe\ length\ in\ km\ x\ 365} = \frac{1261.51x1000}{78.2\ x\ 365} = 44.19\ liter/km/day \quad (9)$$

3.4. Community Satisfaction Level on The Existing Water Supply System

The level of community satisfaction with the town water supply system was assessed in this study. The percentages of respondents who strongly agree to strongly disagree about their level of satisfaction are shown in Table 6. The cause of customers' dissatisfaction with the water supply system as indicated by 76.8% (191/380) of households strongly agreed it is because the population increased from time to time in the town. Out of 380 selected households 74.9%, 50.3%, and 77.7% of them strongly agreed the existing water supply system was not satisfied due to insufficient water sources, the problems of operation and maintenance, old water distribution system respectively. Likewise, the results of respondents' interviews show that the Chiro town community has been not satisfied by its quantity and the lack of water sector coordination to expand the old project considering recent per capita water demand. The billed data of eleven kebeles of the study area show that there is no continuous supply system in the town due to insufficient water quantity to supply safety for the gradually increased population. Although water quality tests and analyses were not the aims of this study, though, assessing the community's perception of the sources’ quality and quantity satisfaction was an important point. 1.8% of the households rated as very good the quality of the water supply sources, whereas 3.2% rated it as good quality, 4.5% as satisfactory, and 54.8% rated it as strongly unsatisfactory of the quality of the source of water. Similarly, 20.1% of the households responded that the water sources are unprotected. Out of the 380 respondents asked about the financial resource to maintain the water supply system 46.8% responded that insufficient financial resources. The respondents' response about 75.9% of questioned customers is unsatisfied with water coverage. Any stakeholder should be involved in the planning, designing, construction, operation, and maintenance of the water supply project to satisfy the community by providing an adequate supply of safe water that is required for reducing infectious diseases in Chiro town. This means that local community participation, including local financing, has been a hallmark of successful long-term projects.

4. Conclusion

Based on the present study findings, the average daily consumption in the study area is very low when compared to national or international benchmark per capita for water utilization for various domestic purposes. The 2020 average daily per capita of the town was 45 l/person/day and the average losses for ten consecutive years were 460,453.7m^3/year (29.9%). The designed discharge from all sources was 8,121.6m^3/day. However, the average annual water production calculated from the last ten years' billed data collected, is 1,541,153.5m^3/yr (4222.3m^3/day). This demonstrates that the provision of potable water in Chiro town is inefficient due to low water production, implying a large gap between water demand and supply for the residents. This was caused for water interruptions and insufficiencies in the town water supply system. Also, caused community complaints because of rendering unequal water distribution. The community was strongly unsatisfied with the existing water supply distribution system due to a lack of good governance and a lack of financial capacity to operate and maintain. Because the majority of the residents are low-income and spend a large portion of their income on water and health-related problems. As a result, the Chiro town water sector should construct additional wells to address the current issues. According to the study's findings, the challenges identified as causing community complaints are a lack of improved water sources near the town, a lack of technological capacity, poor distribution of water infrastructures, inefficient manpower, insufficient financial resources, and weak sectoral coordination. Therefore, this study suggests that the existing water distribution should be replaced considering the recent and future forecasted per capita to fit community satisfaction. Also, the office should have modified the existing water supply by considering the increased projected population of urban areas by concerning different organizations and permitting enough financial resources.

Table 6. Community satisfaction level on the existing water supply system

S/No	Cases	No of the respondents 380				
		A	B	C	D	E
1	Increase in the number of dwellers	76.8%	16.5%	2.4%	3.2%	1.1%
2	Insufficient water sources	74.9%	20.1%	1.8%	0.3%	2.9%
3	Quality of water sources	54.8%	35.7%	4.5%	3.2%	1.8%
4	Lack of technical skills to handle the problems related to water supply operation and maintenance	50.3%	43.6%	3.2%	1.5%	1.4%
5	Poor water distribution infrastructure	77.7%	16.6%	1.9%	1.3%	2.5%
6	Insufficient financial resource	46.8%	43.9%	4.6%	3.2%	1.5%
7	Water sector coordination	62.3%	29.1%	2.8%	2.6%	3.2%
8	Coverage of pipelines and maintenance problems	75.4%	17.9%	3.2%	2.1%	1.4%
9	Pressure in the water supply system	62.6%	28.6%	3.1%	2.5%	3.2%

*Where; A is Strongly agree, B is Agree, C is Uncertainty, D is Disagree, and E is Strongly disagree

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Author Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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References

[1] W. J. Cosgrove and D. P. Loucks, "Water management: Current and future challenges and research directions," *Water Resources Research*, vol. 51, no. 6, pp. 4823–4839, 2015.

[2] M. A. Montgomery and M. Elimelech, "Water and sanitation in developing countries: including health in the equation," *Environmental science \& technology*, vol. 41, no. 1, pp. 17–24, 2007.

[3] W. D. Girsha, A. M. Adlo, D. A. Garoma, and S. K. Beggi, "Assessment of Water , Sanitation and Hygiene Status of Households in Assessment of Water , Sanitation and Hygiene Status of Households in Welenchiti Town , Boset Woreda , East Shoa Zone , Ethiopia," *Science Journal of Public Health*, vol. 4, no. 6, pp. 435–439, 2016, doi: 10.11648/j.sjph.20160406.13.

[4] K. Amenu, A. Markemann, and A. Valle Zárate, "Water for human and livestock consumption in rural settings of Ethiopia: assessments of quality and health aspects," *Environmental monitoring and assessment*, vol. 185, pp. 9571–9586, 2013.

[5] W. J. W. Supply and S. M. Programme, *Progress on sanitation and drinking water: 2015 update and MDG assessment*. World Health Organization, 2015.

[6] WHO/UNICEF, "Joint Monitoring Programme for Water Supply and Sanitation report," 2014.

[7] U. and WHO, *Progress on Drinking Water and Sanitation, 2012 update*. .

[8] W. B. Desalegn, "Water Supply Coverage and Water Loss in Distribution Systems The case of Addis Ababa Water Supply Coverage and Water Loss in Distribution Systems The case of Addis Ababa.," *MSc thesis, International Institute for Geo-information Science and Earth Observation Enschede, Netherlands*, 2005.

[9] Y. Abatneh, O. Sahu, and S. Yimer, "Purification of drinking water by low cost method in Ethiopia," *Applied Water Science*, vol. 4, pp. 357–362, 2014.

[10] D. Abera, S. Geremew, L. Dejene, D. Irge, and T. Ahmad, "Assessment of physico-chemical quality of borehole and spring water sources supplied to Robe Town , Oromia region , Ethiopia," *Applied Water Science*, vol. 7, no. 1, pp. 155–164, 2017, doi: 10.1007/s13201-016-0502-4.

[11] M. Kassa, "Assessment of Water Supply and Sanitation: The Case of Embacho Embacho Town, Gidan Woreda, Northern Ethiopia Mulatu," *Science, Technology and Arts Research Journal*, vol. 4, no. 2, pp. 259–262, 2015.

[12] T. et al. Daniel, "Assessment of the quality of drinking water supply , and the status of Assessment of the Quality of Drinking Water Supply , and the Status of Sanitation and Hygiene in Mudulla Town , Tembaro Woreda, Southern Ethiopia," *Civil and Environmental Research*, vol. 8, no. 6, pp. 67–78, 2018.

[13] M. Abdisa and R. U. Reddy, "ASSESSMENT OF POTABLE WATER SUPPLY IN AWADAY TOWN IN EHIOPIA," *The International Journal of Science Sciences*, vol. 9, no. 1, pp. 65–72, 2014.

[14] S. Bekeletekle, "An Assessment on the Status of Water Suppy and Sanitation in Ethiopia: a Case of Ambo town," *Journal of Sustainable Development in Africa*, vol. 13, no. 1, pp. 23–43, 2011.

[15] Y. Sileshi, "Water Supply Coverage and Water Loss in Distribution System with Modeling (The Case Study of Addis Ababa).," *MSc Thesis, Addis Ababa University*, 2011.

[16] A. Zewdu, "Assessing Water Supply Coverage and Water Losses from Distribution System for Planning Water Loss Reduction Strategies (Case Study on Axum town , North Ethiopia)," *Civil and Environmental Research*, vol. 6, no. 8, pp. 82–88, 2014.

[17] W. M. Desta, F. F. Feyessa, and S. K. Debela, "Heliyon Modeling and optimization of pressure and water age for evaluation of urban water distribution systems performance," *Heliyon*, vol. 8, no. March, p. e11257, 2022, doi: 10.1016/j.heliyon.2022.e11257.

[18] M. Kassa, "Evaluation of water supply and demand : The case of Shambu town , Western Oromia , Ethiopia," *International Journal of Water Resources and Environmental Engineering*, vol. 9, no. 5, pp. 96–101, 2017, doi: 10.5897/IJWREE2016.0699.

[19] H. Alegre *et al.*, *Performance indicators for water supply services. IWA publishing*. IWA publishing, 2016.

[20] S. M. Yadav, N. P. Singh, K. A. Shah, and J. H. Gamit, "Performance evaluation of water supply services in developing country: A case study of Ahmedabad city," *KSCE Journal of Civil Engineering*, vol. 18, no. 7, pp. 1984–1990, 2014, doi: 10.1007/s12205-014-0306-8.

[21] G. W. Supply and S. Assessment, "Report," *World Health Organization, Geneva, Switzerland. Available from: www. who. int/water_sanitation_health/monitoring/globalassess/en*, 2000.

[22] M. O. Dinka, "Safe drinking water: concepts, benefits, principles and standards," *Water challenges of an urbanizing world*, vol. 163, 2018.

[23] J. Zischg, M. Mair, W. Rauch, and R. Sitzenfrei, "Enabling efficient and sustainable transitions of water distribution systems under network structure uncertainty," *Water*, vol. 9, no. 9, p. 715, 2017.

[24] H. Haider, R. Sadiq, and S. Tesfamariam, "Performance indicators for small- and medium-sized water supply systems : a review," *Environ. Rev.*, vol. 22, no. 1, pp. 1–40, 2014.
[25] W. M. Desta and A. Befkadu, "Customer and model based performance evaluation of water distribution systems: the case of Adama town, Ethiopia," *Iranian (Iranica) Journal of Energy \& Environment*, vol. 11, no. 1, pp. 13–18, 2020.
[26] S. Li and W. Han, "Performance evaluation for urban water supply services in China," *Water Supply*, vol. 20, no. 8, pp. 3511–3516, 2020.
[27] H. Alegre *et al.*, *Performance indicators for water supply services.* IWA publishing, 2016.
[28] R. A. Mesalie, D. Aklog, and M. S. Kifelew, "Failure assessment for drinking water distribution system in the case of Bahir Dar institute of technology, Ethiopia," *Applied Water Science*, vol. 11, no. 8, p. 138, 2021.
[29] S. Seyoum and J. P. Graham, "Equity in access to water supply and sanitation in Ethiopia: An analysis of EDHS data (2000–2011)," *Journal of Water Sanitation and Hygiene for Development*, vol. 6, no. 2, pp. 320–330, 2016, doi: 10.2166/washdev.2016.004.
[30] H. B. Dinsa, "EVALAUTION OF HYDRULIC PERFORMANCE ON CHIRO TOWN WATER SUPPLY DISTRIBUTION SYSTEM USING WATER GEMS. MSc THESIS Arba Minch University," 2021.
[31] W. G. Cochran, "Sampling Techniques (3rd Edn), John Willey \& Sons, New York." USA, 1999.
[32] O. Oyesanmi, "ASSESSING AND MODELING THE DETERMINANTS OF HOUSEHOLD WATER CONSUMPTION IN LOKOJA TOWN , KOGI STATE," *FUDMA Journal of Sciences*, vol. 3, no. 4, pp. 105–114, 2019.
[33] Z. T. Virk *et al.*, "Water availability, consumption and sufficiency in Himalayan towns: a case of Murree and Havellian towns from Indus River Basin, Pakistan," *Water Policy*, vol. 22, no. 1, pp. 1–19, 2019, doi: 10.2166/wp.2019.012.
[34] S. Nanjundeswaraswamy, T. S., & Divakar, "DETERMINATION OF SAMPLE SIZE AND SAMPLING METHODS IN APPLIED RESEARCH," *Proceedings on Engineering*, vol. 3, no. 1, pp. 25–32, 2021, doi: 10.24874/PES03.01.003.
[35] A. K. Chatterjee, *Water Supply, Water Disposal and Environmental Engineering. Khanna publishers, NaiSarak, Delhi-110006*. Khanna Publishers, 2005.
[36] Z. M. Bhagat, S. K., Welde, W., Tesfaye, O., Tung, T. M., Al-Ansari, N., Salih, S. Q., & Yaseen, "Evaluating physical and fiscal water leakage in water distribution system," *Water*, vol. 11, no. 10, pp. 1–14, 2019.
[37] A. Kumar *et al.*, "Design of Water Distribution System Using Epanet," *International Journal of Advanced Research*, vol. 3, no. 1, pp. 789–812, 2015.
[38] R. B. Billings and C. V. Jones, *Forecasting urban water demand*. American Water Works Association, 2011.
[39] J. Jiao and M. Dillivan, "Transit deserts: The gap between demand and supply," *Journal of Public Transportation*, vol. 16, no. 3, pp. 23–39, 2013, doi: 10.5038/2375-0901.16.3.2.
[40] J. A. P. Vilanova, M. R. N., Magalhães Filho, P., & Balestieri, "Performance measurement and indicators for water supply management: Review and international cases," *Renewable and Sustainable Energy Reviews*, vol. 43, pp. 1–12, 2014, doi: 10.1016/j.rser.2014.11.043.
[41] J. Rangaiah, V. Mallikarjuna, and P. Udaya Bhaskar, "Water Demand Analysis for Selected Rural Regions in Visakhapatnam District," *IOP Conference Series: Earth and Environmental Science*, vol. 796, no. 1, 2021, doi: 10.1088/1755-1315/796/1/012045.
[42] Asmelash, "Assessing Water Supply Coverage and Water Losses from Distribution System for Planning Water Loss Reduction Strategies (Case Study on Axum town , North Ethiopia)," *Civil and Environmental Research*, vol. 6, no. 8, pp. 82–88, 2014.
[43] B. Abate, "Assessment of Water Supply and Demand of Boditi Town," *Civil and Environmental Research*, vol. 8, no. 11, pp. 18-28–28, 2016.
[44] M. Farley and S. Trow, *Losses in water distribution networks*. IWA publishing, 2003.
[45] M. Molinos-Senante, A. Maziotis, R. Sala-Garrido, and M. Mocholi-Arce, "Estimating performance and savings of water leakages and unplanned water supply interruptions in drinking water providers," *Resources, Conservation and Recycling*, vol. 186, p. 106538, 2022.
[46] P. Biplob, D. C. Sarker, and R. C. Sarker, "Assessment of Water Supply and Sanitation Facilities for Korail Slum in Dhaka City," *International Journal of Civil & Environmental Engineering*, vol. 11, no. 5, pp. 115–128, 2011.
[47] M. Mustapha, M. Sridhar, A. O. Coker, and M. Mustapha, "Assessment of water supply system from catchment to consumers as framed in WHO water safety plans : A study from Maiduguri water," *Sustainable Environment*, vol. 7, no. 1, pp. 0–14, 2021, doi: 10.1080/27658511.2021.1901389.
[48] Un-Habitat, *Enhancing urban safety and security: Global report on human settlements 2007*. Routledge, 2012.
[49] L. Moretto, "An application of the UN-HABITAT Urban Governance Index (UGI): water supplies in a low-income community of the Caracas Metropolitan Region," *Economics*, pp. 1–12, 2007.
[50] I. Dom, E. R. Oviedo-ocaña, K. Hurtado, and R. P. Hall, "Assessing Sustainability in Rural Water Supply Systems in Developing Countries Using a Novel Tool Based on Multi-Criteria Analysis," *Sustainability (Switzerland)*, vol. 11, p. 5363, 2019.
[51] K. Town, "Evaluation of current and future water demand scenario and hydraulic performance of water distribution systems , a case study for Addis," *Applied Water Science*, vol. 13, no. 2, pp. 1–17, 2023, doi: 10.1007/s13201-022-01843-9.
[52] B. R. Water and D. Systems, "Review of Water Distribution Systems Modelling and Performance Analysis Softwares," *International Conference on Engineering for Sustainable World*, vol. 1378, p. 022067, 2019, doi: 10.1088/1742-6596/1378/2/022067.
[53] A. Maziotis, A. Villegas, M. Molinos-Senante, and R. Sala-Garrido, "Impact of external costs of unplanned supply interruptions on water company efficiency: Evidence from Chile," *Utilities Policy*, vol. 66, p. 101087,

2020.

[54] A. D. Lopez, C. D. Mathers, M. Ezzati, D. T. Jamison, C. J. L. Murray, and others, "Measuring the global burden of disease and risk factors, 1990--2001," *Global burden of disease and risk factors*, vol. 1, pp. 1–14, 2006.

[55] A. Jeandron *et al.*, "Water supply interruptions and suspected cholera incidence: a time-series regression in the Democratic Republic of the Congo," *PLoS medicine*, vol. 12, no. 10, p. e1001893, 2015.

[56] M. F. DiCarlo and E. Z. Berglund, "Using advanced metering infrastructure data to evaluate consumer compliance with water advisories during a water service interruption," *Water Research*, vol. 221, p. 118802, 2022.

[57] K. Khatri, K. Vairavamoorthy, and M. Porto, "Challenges for urban water supply and sanitation in developing countries," in *Water for a Changing World-Developing Local Knowledge and Capacity*, CRC Press, 2008, pp. 93–112.

[58] B. Gleitsmann, "The importance of community involvement in the planning and design phases of rural water supply development projects in the Koro region of Mali, West Africa," Cornell University, 2005.

[59] A. Tadesse, T. Bosona, and G. Gebresenbet, "Rural Water Supply Management and Sustainability: The Case of Adama Area, Ethiopia," *Journal of Water Resource and Protection*, vol. 05, no. 02, pp. 208–221, 2013, doi: 10.4236/jwarp.2013.52022.

[60] A. A. Anore, "Evaluation of Water Supply Distribution System and Hydraulic Performance of Hosanna Town," *International Journal of Research Studies in Science, Engineering and Technology*, vol. 7, no. 6, pp. 18–28, 2020.

[61] S. Kabeto, "Water Supply Coverage and Water Loss inDistribution System with Modeling The Case Study of Addis Ababa. Addis Ababa: MSc Thesis.," Addis Ababa University, 2011.

[62] Y. A. Mekonnen, "Evaluation of current and future water demand scenario and hydraulic performance of water distribution systems, a case study for Addis Kidam Town, Ethiopia," *Applied Water Science*, vol. 13, no. 2, p. 40, 2023.

[63] T. B. Beyene, "HYDRAULIC MODELING OF WATER SUPPLY AND WATER LOSSES IN WATER SUPPLY DISTRIBUTION SYSTEM OF ADWA TOWN, ETHIOPIA. MSc THESIS, ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY," 2020.

[64] F. F. Geleta Ebsa D, "Hydraulic performance Analysis of water supply distribution network using water GEM v8i.," *Drink Water Eng Sci Discuss*, pp. 1–18, 2021, doi: 10.1177/027046768200200107.

[65] D. Adeba, M. L. Kansal, and S. Sen, "Assessment of water scarcity and its impacts on sustainable development in Awash basin, Ethiopia," *Sustainable Water Resources Management*, vol. 1, no. 1, pp. 71–87, 2015, doi: 10.1007/s40899-015-0006-7.