Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **14(3),** 34-47, September **(2025)** *Res. J. Engineering Sci.*

Case study

Sustainable management of drinking water supply systems in lacustrine areas in Benin: the case of the municipality of So-Ava

Arouna YESSOUFOU[*1], Aminou Tachégnon ATINDEKOUN[1,2], Alexis Babylas TOBADA[1], Leslie Abravy ANANFACK[1], Pierre Zannou AYATOGANDJI[2], MouhamedAl-Mourtada BOURE[1], Boladji Abdou Waris YESSOUFOU[2], Nicaise YALO[1], Daouda MAMA[1]
[1]Laboratory of Applied Hydrology, National Water Institute, University of Abomey-Calavi, Benin
[2]Service des Affaires Générales à la Mairie de Sô-Ava, Benin
arouna.yessoufou@gmail.com

Available online at: www.isca.in, www.isca.me
Received 15th July 2025, revised 21st August 2025, accepted 13th September 2025

Abstract

In lacustrine municipalities, surface water is permanently available and abundant, yet its quality is poor. Nevertheless, the population tends to prefer using surface water rather than water intended for Drinking Water Supply (DWS). This raises the issue of abandonment of DWS infrastructure, despite their presence in all districts of the municipality of Sô-Ava. The objective of this research is to contribute to the sustainable management of drinking water supply facilities in lacustrine environments. The study methodology was based on documentary research, field visits, surveys, and direct observation. The findings of this study reveal that the DWS infrastructure in the municipality is quite extensive and includes Village Water Supply Systems (VWSS), Autonomous Water Post (AWP), and Boreholes equipped with Hand Pumps. However, frequent breakdowns are observed in these facilities (non-functional standpipes and taps in 68.64% of VWSS and 41.17% of AWP). This situation explains the low drinking water coverage rate in the municipality, which stands at 28.54%. In addition to breakdowns, four other factors influencing the proper management of these facilities were identified according to respondents: flooding, the reddish coloration of water, the cost of drinking water supply, and the distance between DWS facilities and households. Finally, sustainable management measures for drinking water supply facilities in the municipality were proposed. These sustainable measures address social, economic, and environmental aspects.

Keywords: Drinking water, flooding, coverage rate.

Introduction

Water is an indispensable resource for the survival of all living beings, essential for health, and constitutes a fundamental human right. With rapid population growth and the constant increase in waterborne diseases worldwide, the need for sufficient quantities of quality water is urgent and undeniable[1]. Generally, in developing countries, water supply is provided by treatment units that fail to meet the needs of the entire population[2].

Access to safe drinking water, sanitation, and hygiene at home should not be a privilege reserved for the wealthy living in urban areas. It is a necessity to prevent the transmission of fecal-oral diseases, particularly in developing countries. Despite this, the joint report by the World Health Organization and the United Nations Children's Fund published in 2017 shows that 2.1 billion people, or 30% of the global population, still lack access to safely managed domestic drinking water services, and 4.5 billion, or 60%, lack access to safely managed sanitation services. With the rapid and unplanned growth of African cities, this issue disproportionately affects vulnerable and impoverished populations in disadvantaged neighborhoods[3].

In reality, the main challenge is to minimize health and environmental risks, which also have significant economic consequences[4]. In this same vein, the United Nations Water Conference held at the UN headquarters in New York from March 22 to 24, 2023, emphasized the urgency of accelerating initiatives toward universal access to drinking water and sanitation by 2030. At the closing session, UN Secretary-General António Guterres highlighted: "Water means health, sanitation, hygiene, and disease prevention; it means peace, sustainable development, poverty reduction, support for food systems, job creation, and prosperity[5]."

In Benin, the average coverage of rural water services reached 73% in 2022, according to ANAEPMR. However, the challenge remains much greater in lacustrine areas, particularly in the municipality of Sô-Ava. This lacustrine municipality in southern Benin has abundant water resources but of poor quality[6]. Approximately 65% of its territory is covered by water during the low-water period, making Sô-Ava one of the most remarkable lacustrine areas in the country, where most community activities depend on water. Nevertheless, the constant presence of water does not necessarily translate to access to safe drinking water.

A large portion of the population does not use the existing drinking water supply systems to meet their water needs. Instead, they rely on untreated surface water for domestic use, with all the associated health consequences.

In the past, communities simply relied on flowing water to meet all their domestic needs (drinking, laundry, dishwashing, bathing, cooking, etc.). Today, efforts by various technical and financial partners have provided the municipality with numerous drinking water infrastructures, which were initially a source of pride for the communities. However, this pride is gradually giving way to disappointment, as community expectations are not being met. According to respondents, the water from DWS facilities is perceived as doubtful—both because its taste closely resembles that of surface water (rivers, lakes), especially during floods, and because reddish deposits, described as “mud” by the population, form at the bottom of containers after a few hours at rest.

Thus, in light of these issues, the management of drinking water supply systems remains a major concern, despite their presence in all districts of Sô-Ava. It is therefore necessary to respond to the needs and expectations of the population by ensuring the sustainable management of drinking water supply facilities.

Study area: Geographical and Administrative Context: Located in southern Benin, the municipality of Sô-Ava lies between 6°24' and 6°38' North latitude and between 2°27' and 2°30' East longitude. It covers an area of 218 km². The municipality occupies part of the lower valley of the Ouémé River and the Sô River, from which it derives its name. Sô-Ava is bordered to the north by the municipalities of Zè and Adjohoun; to the south by the municipality of Cotonou; to the east by the lacustrine municipalities of Sô-Ava and Dangbo; and to the west by the municipality of Abomey-Calavi.

The municipality of Sô-Ava is organized into seven (07) districts comprising 69 villages, as presented in Table-1. The geometric and administrative map is shown in Figure-1.

In Sô-Ava, human settlements are mainly concentrated on islets, along waterways, and on the riverbanks. Fishermen and farmers make up more than 70% of the population, while agricultural households represent over 18% of all households.

Climate and Vegetation: The municipality of Sô-Ava is characterized by a subequatorial climate with alternating two rainy seasons and two dry seasons. The main rainy season lasts from March to July, while the shorter one occurs from September to November. The average annual rainfall is approximately 1,200 mm. Temperatures range between a minimum of 22°C and a maximum of 35°C. Relative humidity averages 69% during the dry season (November to March) and 90% during the wet season. A slight influence of the Harmattan wind sweeps Across the area between December and January.

The municipality benefits from a significant hydrographic network covering nearly half of its territory. Favorable to fishing resource exploitation, the river currently faces various pollution problems. These include primarily sedimentation due to severe riverbank erosion, petroleum product trafficking, but especially heavy metal residues (lead and mercury) originating from battery discharges and other wastes (household garbage, biomedical waste, human and animal excreta, etc.) dumped into the river by local populations.

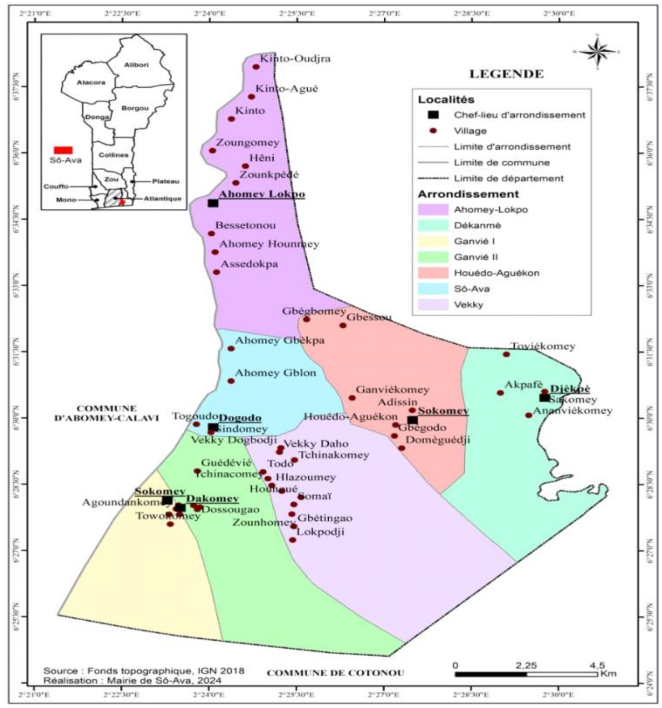

Figure-1: Geographical and administrative location of the municipality of Sô-Ava.

Geology, Hydrography, and Water Resources: The municipality of Sô-Ava lies entirely within the Ouémé Plateau watershed, with its waters draining into Lake Nokoué. Consequently, the municipality has a significant hydrographic network covering more than half of its territory. It is located within two geomorphological units of the country. The coastal edge is mainly occupied by Lake Nokoué, which features lagoonal depressions along its shores. The floodplain of the eastern bank of the Sô River is situated in inland valleys and is primarily characterized by floodplains and marshes. Favorable for the exploitation of fishing resources, the lake currently faces various pollution problems, mainly sedimentation caused by severe erosion of its banks.

Demographic Characteristics: The population of the municipality of Sô-Ava is very dynamic. Estimated at 37,818 inhabitants during the 1979 general population census, it was assessed at 59,148 in 1992, with an intercensal growth rate of 3.25%. The third General Population and Housing Census (RGPH 3) counted 76,315 inhabitants in Sô-Ava in 2002, comprising 38,088 women and 38,227 men, with an annual intercensal growth rate of 2.58% between 1992 and 2002. The 2013 projection estimated the population at 108,766, based on an annual intercensal growth rate of 3.99%. However, the actual population recorded in the 2013 RGPH 4, as shown in Table-2, was 118,547, including 58,527 females and 60,020 males, corresponding to a female percentage of 49.33%. The annual intercensal growth rate was 3.97%.

Housing: The entirety of Lake Nokoué and its villages constitute an important tourist site. Indeed, the stilt houses, canoe transportation, and lacustrine lifestyle attract numerous visitors. The inhabitants of these lake communities take advantage of this tourist influx to engage in the trade of handicrafts. In the lacustrine environment, housing typically consists of stilt houses, mostly built with bamboo and covered with thatch. However, there is an increasing presence of houses constructed with permanent materials, featuring concrete slabs or roofs made of corrugated iron sheets.

Table-1: Administrative organization of Sô-Ava.

Districts	Villages	Number of Villages
Ahomey-Lokpo	Ahomey-lokpo centre, Ahomey-Ounmey, Assedokpa, Bessetonou, Heni, Kinto-Ague, Kinto-Dokpakpa, Kintooudjra, Zoungomey, Zounkpode	10
Dekanme	Anaviecomey, Djekpe, Kpafe, Kpoviecomey, Sakomey	05
Ganvie 1	Agonmekomey, Agoundankomey, Gansougbamey, Gbamey-Tchewa, Gounsoedji, Hindagao, Kpassikomey, Sokomey, Tohokomey, Yokagao	10
Ganvie 2	Agbongamey, Ahouanmongao, Dakomey, Dakomey-Yohonoukon, Dossougao, Gounsoegbamey, Guedevie, Guedevie-Gbegbessa, Have, Kindji, Sinhoungbomey	11
Houedo-Aguekon	Domeguedji, Gblonto, Gbegodo, Gbagbodji, Ganviecomey, Gbegbome Uuekekome, Gbessou, Sokomey	08
Sô-Ava	Ahomey-Domey-Zounmey, Ahomey-Fonsa, Ahomeygbekpa, Ahomey-Gblon, Dogodo, Dokodji, Houndomey, Sindomey	08
Vekky	Aniankomey, Avlezounmey, Dogodo, Eguekomey, Gbetingao, Hlouazounmey, Hounhoue, Kpacomey, Lokpodji, Nonhoueto, So-chanhouetodo, Somaï, Tchinancomey, Totakoun, Vekky-Daho, Vekkydogbodji, Zounhomey	17
Total		69

Table-2: Population distribution by sex and districts[13].

Administrative Division	Total Number of Households	Total Population	Male	Female
Dist: Ahomey-Lokpo	2 035	11 026	5 487	5 539
Dist: Dékanmey	1 276	6 617	3 333	3 284
Dist: Ganvié I	3 361	19 155	9 926	9 229
Dist: Ganvié II	2 926	18 017	9 289	8 728
Dist: Houedo-Aguekon	3 460	20 909	10 513	10 396
Dist: Vekky	5 147	29 476	14 849	14 627
Dist: Sô-Ava	2 151	13 347	6 623	6 724
Commune de Sô-Ava	20 356	118 547	60 020	58 527

Methodology

Sampling of the Surveyed Population: The sampling of the surveyed households was carried out using a simple random sampling method, as it is the most commonly used approach. It is one of the best probabilistic sampling techniques, allowing time efficiency and resource savings. This technique is particularly suitable because it only requires a complete list of the members of the target population and their contact information as a sampling frame. During this survey, several households were interviewed, as shown in Table-3, representing approximately 210 households out of 2,095 selected in the municipality.

Table-3: Distribution of the number of households surveyed.

District	Number of selected households	Samples
Ahomey-Lokpo	300	30
Dekanmey	298	30
Ganvie 1	276	28
Ganvie 2	301	30
Houedo-Aguekon	298	30
Sô-ava	307	31
Vekky	315	31
Total	2095	210

Distribution of Surveyed Individuals: Table-4 presents the number of individuals surveyed within the households. These individuals are categorized by sex and age group. Among them, men were mainly engaged in fishing or farming, while women were predominantly traders or homemakers.

Field Visits: Field visits were conducted in various locations throughout the municipality. These visits enabled the identification of specific sites for field surveys and allowed direct observation of the condition of drinking water supply facilities.

Interviews: These consist of verbal exchanges, guided by questionnaire forms, conducted with key informants in the village.

KAP Surveys (Knowledge, Attitudes, and Practices): These questionnaire-based tools are particularly suited for studying drinking water supply facilities. They enable the collection of both quantitative and qualitative data.

Table-4: Distribution of surveyed individuals by sex and age group.

District	Surveyed	Sex		Age Group
		Male	Female	
Ahomey-lokpo	30	13	17	15 years, 45 years
Dekanmey	30	11	19	13 years, 65 years
Ganvie1	28	14	14	14 years, 52 years
Ganvie2	30	12	18	18 years, 59 years
Houedo-aguekon	28	15	13	17 years, 64 years
Sô-ava	25	08	17	14 years, 58 years
Vekky	31	13	18	15 years, 61 years
Other factors				
MAIRIE	4	3	1	28 years, 57 years
DDEM Atlantique	2	1	1	28 years, 57 years
DGEau	2	1	1	28 years, 57 years
Total	210	91	119	

Direct Observation: Used to gather information on individuals' behavior by observing their daily practices.

Method for Calculating the Coverage Rate: The coverage rate is calculated according to the type of infrastructure, as there are simple and complex facilities. i. For simple facilities, the coverage rate is based on the actual population of each served locality, with a maximum of 250 people per hand pump. ii. For complex facilities (Village Water Supply Systems – VWSS and Autonomous Water Points - AWP), as prescribed in the communal programming guide, the population served by VWSS should be determined based on a specific consumption of 20 liters per day per inhabitant, relative to the average daily production of the VWSS during the dry season. However, during the surveys, it was observed that per capita consumption is lower than the prescribed standard. To avoid underestimating the number of people served, the number of functional taps per standpipe or ramp was taken into account, with a maximum of 250 people per tap, using the following formula: Number of taps × 250/ population. iii. Method of Sampling and In Situ Measurement of Water Parameters: Water sampling at various water points and rivers was carried out on January 15 and 17, 2024, between 6:00 AM and 11:00 AM.

Sampling involved visiting the water infrastructures and rivers with sterile plastic containers to collect water samples while respecting hygiene standards. This allowed sampling from ten (10) drinking water supply facilities and three (03) rivers. These include: AEV of Houedo-Aguekon; AEV of Gbessou; PEA of Gbegbomey; AEV of Ahomey-Lokpo; PEA of Ahomey-Ounmey; AEV of Ahomey-Gbekpa; AEV Emmaüs of Ahomey-Gblon; Artesian borehole of Ganvie 1; AEV of Dakomey/ Ganvie 2; AEV Emmaüs of Sô-Tchanhoué; River water from Ahomey-Lokpo; River water from Kinto; River water from Ahomey-Ounmey. The selected parameters were measured in situ using potentiometric methods, specifically with a multiparameter device (Laqua Horiba) used to measure pH (Hydrogen Potential), Electrical Conductivity (EC), and Total Dissolved Solids (TDS).

The analysis did not cover all physico-chemical elements because during the study, respondents expressed concern about the taste of water from the drinking water supply systems compared to floodwater. This relates to water conductivity. Similarly, the turbidity of the drinking water corresponds to Total Dissolved Solids (TDS). Therefore, the analysis focused on these parameters.

Results and Discussion

Status of Drinking Water Supply Facilities in the Municipality of Sô-Ava: The assessment of drinking water supply facilities across the seven (7) districts of the municipality of Sô-Ava yielded various results, illustrated in Figures-2, 3, and 4.

Village Water Supply Systems (VWSS): Figure-2 presents the functionality status of the VWSS in the different districts.

This Figure-2 shows that all seven (07) districts of the municipality are equipped with AEVs. In the districts of Dekanmey, Ganvié 1, Houedo-Aguekon, and Vekky, the majority of facilities are defective. There are fewer functional facilities than those out of order. The functionality rate of standpipes varies from one district to another. It is high in the districts of Ahomey-Lokpo and Sô-Ava. Conversely, this rate is low in Dekanmey (46%), Ganvié 1 (40%), Houedo-Aguekon (19%), and Vekky (27%). Regarding Ganvié 2, its functionality rate is 5%, with almost all drinking water supply facilities in poor condition, i.e., completely defective and non-functional. Out of a total of 20 standpipes, only one is functional.

Considering all of the above, the overall functionality rate of VWSS in the municipality of Sô-Ava is 31.36%, corresponding to 53 functional standpipes out of 169 across the 18 VWSS.

It is urgent to review the management of these facilities to prevent and protect the population from waterborne diseases such as diarrhea, cholera, typhoid, dysentery, and legionellosis.

Autonomous Water Points (AWP): The Figure-3 presents the status results of AWP in the different districts.

Regarding the results shown in the figure, it appears that within the municipality of Sô-Ava, the Autonomous Water Points (AWP) have been installed in four out of the seven districts in total. These are the districts of Ahomey-Lokpo, Ganvié 2, Houédo-Aguékon, and Vekky. It should be noted that the district of Ahomey-Lokpo currently has more functional SAWP than those out of service. However, the districts of Houédo-Aguékon and Vekky each have only half of their facilities in working condition, while in Ganvié 2, all the facilities are non-functional. Thus, the SAWP functionality rates for each district are as follows: Ahomey-Lokpo: 62.5%, Ganvié 2: 0%, Houédo-Aguékon: 50% and Vekky: 50%.

In total, the eight (8) AWP in the municipality of Sô-Ava are equipped with 34 taps (equivalent to 17 public standpipes), of which 20 taps (10 standpipes) are functional, representing a functionality rate of 58.88%. However, this still does not meet the population's needs. This situation makes the permanent availability of drinking water in the municipality difficult. Due to the shortage, residents may resort to using water from natural water bodies, which could have serious repercussions on their health.

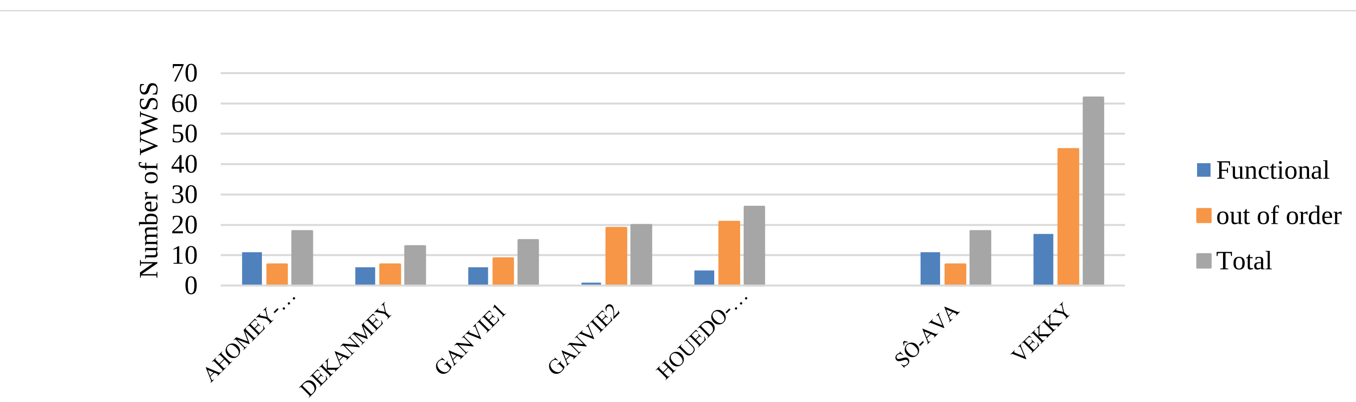

Figure-2: Functionality status of Village Water Supply Systems (VWSS) in the municipality of Sô-Ava.

Borehole equipped with manually operated pump (MOP): The Figure-4 presents the various results regarding the operational status of MOP in the different districts.

Among the seven districts in the municipality, only three districts (Ahomey-Lokpo, Houedo-Aguekon, and Vekky) are equipped with hand-operated pumps (MOP. However, none of the two FPMs in Houedo-Aguekon are functional, resulting in a functionality rate of 0%. Meanwhile, in the districts of Vekky and Ahomey-Lokpo, only 50% of the facilities are operational. It is crucial to repair these defective facilities and to increase their number considering the population growth in the municipality to protect inhabitants from waterborne diseases.

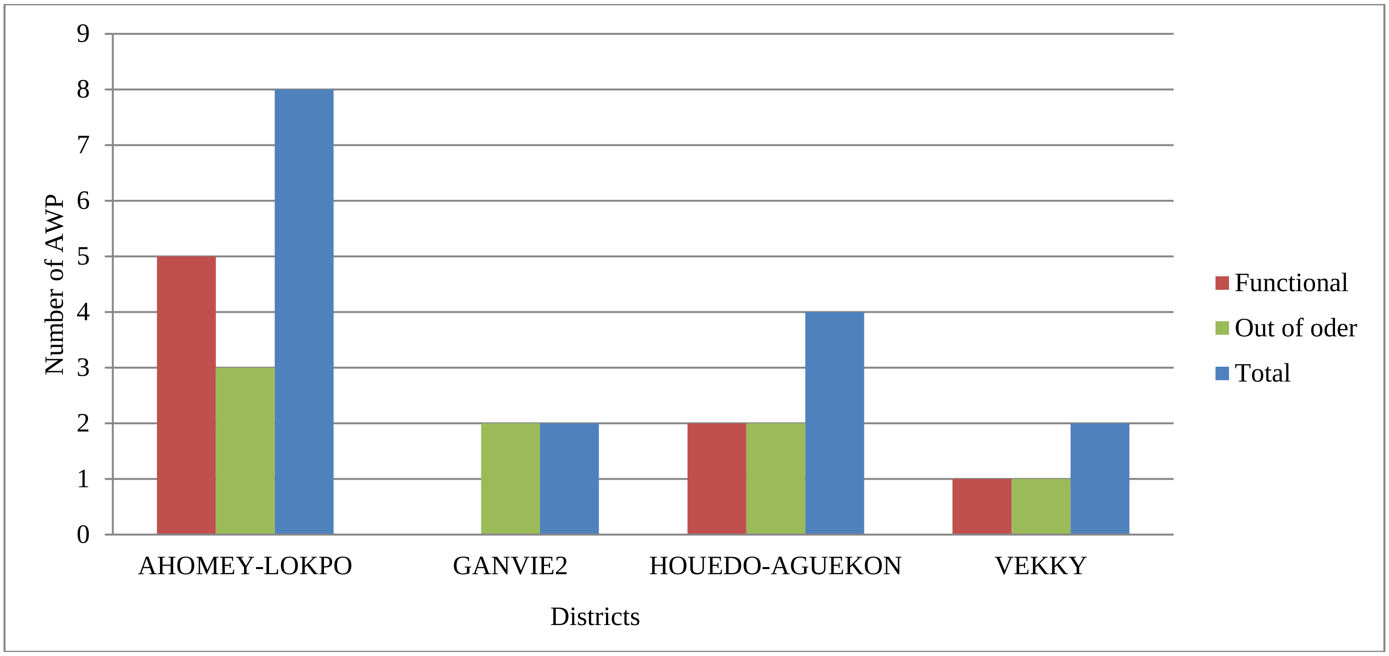

Figure-3: Functionality Status of the AWP Systems in the Municipality of Sô-Ava.

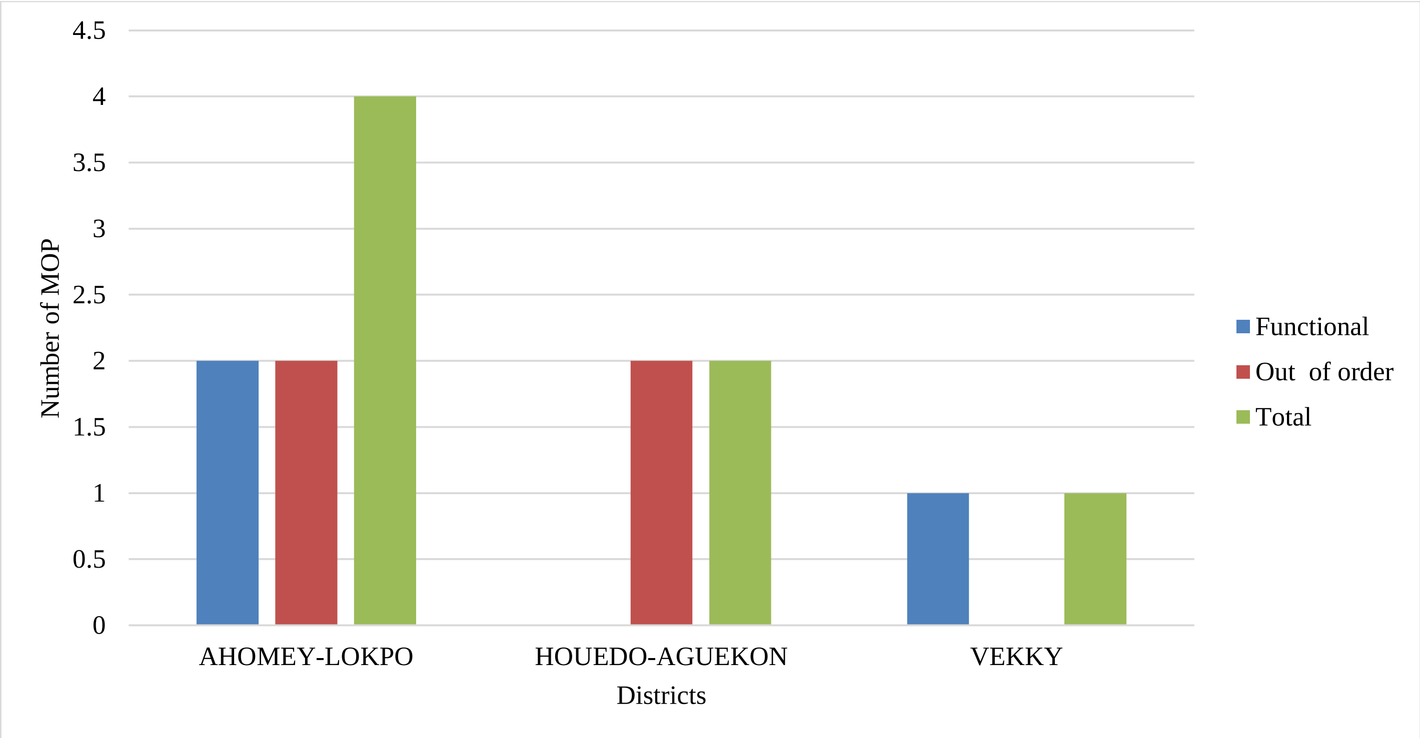

Figure-4: Functionality status of Hand-Operated Pumps (MOP) in the municipality of Sô-Ava.

Causes of Failures in Hydraulic Facilities: Many drinking water supply facilities in the municipality are out of order. The failures observed at water points are varied. They are caused by network breakages, insufficient maintenance of equipment (generators, pumps, chlorination or iron removal systems), lack of converters for older solar panel models, conflicts of responsibility among water point managers, vandalism of the network, wear and tear of spare parts exposed to weather conditions, etc. These failures are summarized in Table-5 and vary from one facility to another depending on the year of installation.

Lifespan of Facilities in Disrepair: According to standards, the lifespan of a drinking water supply facility (DWS) is twenty (20) years. Several DWS facilities constructed in the municipality of Sô-Ava are in a dilapidated state. These are presented in Table-6. It emerges from this table that nine (09) out of eleven (11) VWSS are more than twenty (20) years old. This age negatively impacts the condition of the facilities. To ensure their durability, the authorities responsible for these facilities should take practical measures to rehabilitate them in order to extend their lifespan over time.

Table-5: Types of failures and their causes.

Facility Name	Year Built	Non-Functional Standpipes (SAWP)	Type of Breakdown	Cause of Breakdowns
Kinto Hydraulic AWP	1990	2 out of 2	Equipment failure	Lack of equipment maintenance and abandonment since 2014
Kinto Hand Pump Borehole (MOP)	-	-	Degraded borehole	Lack of maintenance
Ahomey-Lokpo VWSS	2006	6	Failure of generator, pump, and worn tower	Poor equipment maintenance; powered by motor pump for 5 years
Dekanmey VWSS (SCDIH)	1987	1 out of 5	Network breakage and converter failure	5 standpipes reduced to 1; managed by priests
Emmaüs VWSS – Ganvié 2	2013	15 out of 15	Network breakages and hard-to-detect leaks	Pipes not buried deeply; outboard motor propellers damage the pipes
Ganvié 2 Hydraulic VWSS	1990	1 out of 4	Network breakages	Poor equipment maintenance; powered by motor pump for 8 years
Houédo-Aguékon VWSS	1987	1 out of 6	Failure of generator, pump, and worn tower	Poor equipment maintenance; powered by motor pump for 7 years
Ahomey-Gbékpa Hydraulic VWSS	1990	1 out of 5	Failure of generator, pump, and worn tower	Poor equipment maintenance; powered by motor pump for 3 years
SCDIH VWSS – Sô-Tchanhoué	1987	12 out of 12	Entire system failure	Works abandoned since 2016
Totakoun VWSS	1990	2 out of 5	Failure of generator, pump, and worn tower	Poor equipment maintenance; powered by motor pump for 3 years
Emmaüs VWSS – Sô-Zounko	2013	17	Worn taps, valves, meters; network leaks	Excessive breakages due to anarchic community construction damaging the network
Sô-Zounko Hydraulic VWSS	1990	4	Entire system failure	Poor network equipment maintenance; network abandoned since 2007

These various causes interact and affect the lifespan of the facilities.

Table-6: Lifespan of DWS facilities in disrepair.

Name of the Facility	Year of Construction	Lifespan	Current State of the Facility
Kinto Hydraulic SAWP	1990	24 years	Abandoned since 2014
Ahomey-Lokpo VWSS	2006	18 years	The pumping system, generator, and water filter are defective; the water tower is small; standpipes are worn out and insufficient; the VWSS has been powered by a motor pump for 5 years.
Dekanmey VWSS (SCDIH)	1987	37 years	The pumping system, generator, and water filter are defective; no dewatering system; standpipes reduced from 5 to 1; managed by priests.
Emmaüs VWSS of Ganvié 2	2013	11 years	Defective borehole; leaks in the network.
Dakomey Hydraulic VWSS (Ganvié 2)	1990	33 years	Standpipes reduced from 4 to 1; the pumping system, generator, and water filter are defective; the water tower is insufficient; the VWSS has been powered by a motor pump for 8 years.
Houédo-Aguékon VWSS	1987	37 years	No water tower; the pumping system, generator, and water filter are defective; no dewatering system; standpipes reduced from 6 to 1; the VWSS has been powered by a motor pump for 8 years.
Ahomey-Gbékpa Hydraulic VWSS	1990	37 years	No water tower; the pumping system, generator, and water filter are defective; no dewatering system; standpipes reduced from 5 to 1; the VWSS has been powered by a motor pump for 5 years.
SCDIH VWSS of Sô-Tchanhoué	1987	27 years	Rehabilitation works on the VWSS were abandoned since 2016.
Totakoun VWSS	1990	33 years	Standpipes reduced from 5 to 2; the pumping system, generator, and water filter are defective; the water tower is insufficient; the VWSS has been powered by a motor pump for 5 years.
Emmaüs VWSS of Sô-Zounko	2013	11 years	Worn-out taps, valves, and meters; uncontrolled leaks in the network.
Hydraulic VWSS of Sô-Zounko	1990	27 years	Entire system damaged since 2007; VWSS abandoned.

Management of Drinking Water Supply Systems (DWS) in the Municipality of Sô-Ava: According to the National Rural Drinking Water Supply Strategy 2016–2030, the entire rural population of Benin should have access to an improved drinking water source at home, with a permanent availability of at least 50 liters per person per day. The goal is to eliminate the water-fetching burden for women and children and to avoid water transport and storage at home. To achieve these objectives, reforms have been implemented in the water sector, including the creation of the National Agency for the Promotion of Rural Water Supply (ANAEPMR), aimed at professional and efficient management. This has enabled municipalities to delegate the construction and management of rural DWS systems to ANAEPMR, which recruited two regional operators responsible for managing DWS for a ten-year period starting from March 1, 2023.

The lacustrine municipality of Sô-Ava has aligned itself with this reform by transferring its hydraulic infrastructure to the Agency, which has already entrusted the management of eight VWSS and four AWP to the regional operator, namely the Beninese Water Company. Although the regional operator is present in the municipality, the issue of insufficient potable water persists. Moreover, being a lacustrine area, the municipality has abundant and permanent water sources; however, this water is not potable, meaning it does not meet drinking water quality standards. Therefore, sustainable management of DWS systems is essential to address this challenging situation.

Factors Influencing the Use of Drinking Water Supply Systems in the Municipality of Sô-Ava: Following the survey, several factors affecting the use of DWS systems were identified. These include flooding, the reddish color of DWS water, the cost of potable water supply, and the distance of DWS systems from households.

Flooding (Period of Rising Water): From the field survey on consumption of floodwater, it appears that the majority of households surveyed in the seven districts of the municipality use potable water from the DWS systems very little during the flooding period, which lasts about three months, from September to November. During this flood period, surface waters (Lake Nokoué, Sô River, ponds, and tides) become fresh, like the water from the water supply systems (DWS). Thus, the population prefers to use floodwater directly rather than water from the DWS systems.

Driven by curiosity to understand why the respondents emphasize the very soft nature of the floodwater, it appears that their perception is based on the taste of this water. To verify this claim, water samples from the improved water supply systems (DWS) and from the floodwaters were collected to measure their conductivity. The analysis results are presented as follows:

Electrical conductivity of water allows determining the amount of natural salts, organic substances, particles, and gases in the water that conduct electric current. However, soft drinking water generally has a conductivity of about 500µS/cm, but it varies considerably. The purer (less mineralized) the water, the lower its electrical conductivity. In the case of Table-7, the electrical conductivity of the river water from Ahomey-Lokpo, Kinto, and Ahomey-Ounmey is respectively 179.2µS/cm, 180.2 µS/cm, and 189.7µS/cm. These values are all below 500µS/cm. The same applies to all the investigated DWS sources. Out of the ten sources, nine have electrical conductivity values below 500µS/cm. Only that of the VWSS of Ahomey-Lokpo is at 709 µS/cm. Finally, the analysis results for the conductivity parameter confirm the assertion of the respondents that river water during the flood period is as soft as the water from the DWS.

Reddish Color of the Water: Figure-6 presents the results obtained from the survey regarding the reddish color of the water. From this analysis, it appears that the majority of households surveyed in the 7 districts of the commune do not appreciate this condition of the water. According to this population, they report that the water drawn and left to settle in a container for a few hours forms a reddish deposit at the bottom of the container. Thus, it is possible that the water from the DWS contains substances that could be harmful to health.

According to the respondents, the water from the DWS at the tap outlet often has a reddish color. Some households that collect potable water notice, after a few minutes, a reddish and slightly slimy deposit at the bottom of their container. Therefore, they prefer to use river water because it is non-stagnant and soft.

To verify this assertion from the respondents regarding the color of the water from the facilities, samples were taken from ten DWS facilities to analyze the total dissolved solids (TDS), which determine the color of the water. Table-8 presents the results of the TDS analysis.

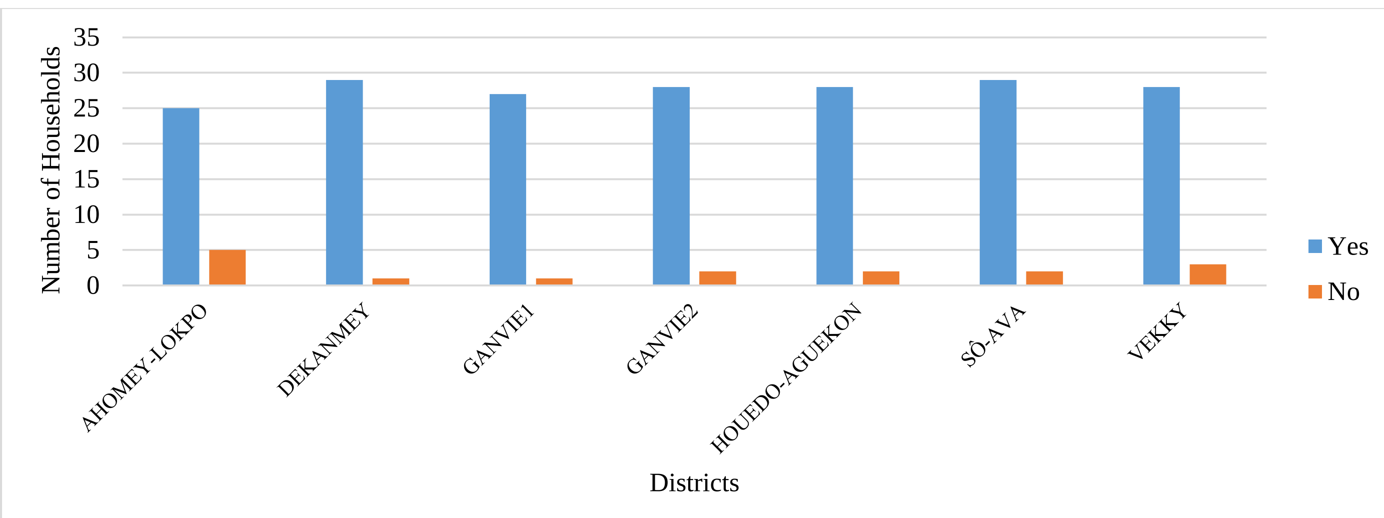

Figure 5: Respondents' Opinions on the Use of Floodwater.

Table-7: Results of pH and Electrical Conductivity Analyses of Water from AEP Facilities and the Sô River.

Parameters (Unit)	Samples												
	01 VWSS HA	02 VWSS GBE	03 AWP GBEG	04 VWSS AL	05 AWP AO	06 VWSS AGP	07 VWSS AGO	08 RW AL	09 RW KIN	10 RW AO	11 For G 1	12 VWSS DGm 2	13 VWSS ESO-TCH
pH -	6,4	5.92	5,39	6,53	6,54	5,73	6,12	6,57	6,55	6,57	5,49	5,94	5,99
Conductivity µS/cm	382	386	474	709	449	205	230	179,2	180,2	189,7	101	92,6	138,2

Number and name of water sources sampled: 01 – VWSS of Houedo-Aguekon; 02 - VWSS of Gbessou; 03 - AWP of Gbegbomey; 04 - VWSS of Ahomey-Lokpo; 05 - AWP of Ahomey-Ounmey; 06 - VWSS of Ahomey-Gbekpa; 07 VWSS Emmaüs of Ahomey-Gblon; 08 - River Water of Ahomey-Lokpo; 09 - River Water of Kinto; 10 - River Water of Ahomey-Ounmey; 11 - Artesian Well of Ganvie 1; 12 - VWSS of Dakomey/Ganvie 2; 13 - VWSS Emmaüs of So-Tchanhoue.

Total Dissolved Solids (TDS) consist of inorganic salts (magnesium, potassium, calcium, bicarbonates, sodium, chlorides, and sulfates) and small amounts of organic matter dissolved in the water. According to standards, water containing up to 300 ppm of TDS is considered good for drinking, while water with a TDS level of 1000 ppm or more is not recommended for consumption. In other words, 300 ppm < TDS < 500 ppm represents a good level for drinking water, and TDS > 1000 ppm indicates water unsuitable for consumption.

Considering the analysis results in Table ..., the TDS levels of river water samples (samples No. 8, 9, and 10) are below 300 ppm. Therefore, river water is considered safe for drinking. The same applies to almost all surveyed DWS facilities. Among the ten DWS sources, nine have TDS levels below 300 ppm. Only the VWSS at Ahomey-Lokpo shows a TDS level of 354 ppm, which is still within the acceptable range of 300 to 500 ppm. The water from the DWS facilities is potable.

Finally, the analysis results of the Total Dissolved Solids (TDS) parameter contradict the respondents' claim that the coloration of the DWS water is inappropriate. The observed coloration could be explained by the oxidation of metallic ions present in the water from the DWS facilities.

Cost of Drinking Water Supply: The results obtained from the survey on the factor of the cost of water supply at the AEP facilities in the Municipality of Sô-Ava are presented in Figure-7.

From the interpretation of this figure, it appears that the majority of households surveyed in the 7 districts of the municipality are unable to consistently obtain drinking water due to limited financial means. According to them, to meet all their daily needs (cooking, laundry, bathing, etc.), they must spend at least 200 to 300 FCFA per day. The respondents reported difficulties in making this daily expenditure. They prefer to use river water because it is free, especially during the flood season when the water from the water bodies is fresh. Furthermore, the price per cubic meter of water at the public standpipes, which was 405 FCFA before the establishment of ANAEPMR, has increased to 598 FCFA due to compliance and equalization of water pricing at the national level. This increase adds to their burden. The high cost factor of water from DWS facilities has become even more complicated for the lacustrine populations, who have turned to using river water because it is free and available at all times to meet their various needs.

Distance of AEP from Households: To obtain drinking water, households travel distances relative to their homes and the water points. This distance varies between 50 and 400 meters. Figure-8 presents the results obtained from the survey regarding the factor of distance for water supply at the different facilities.

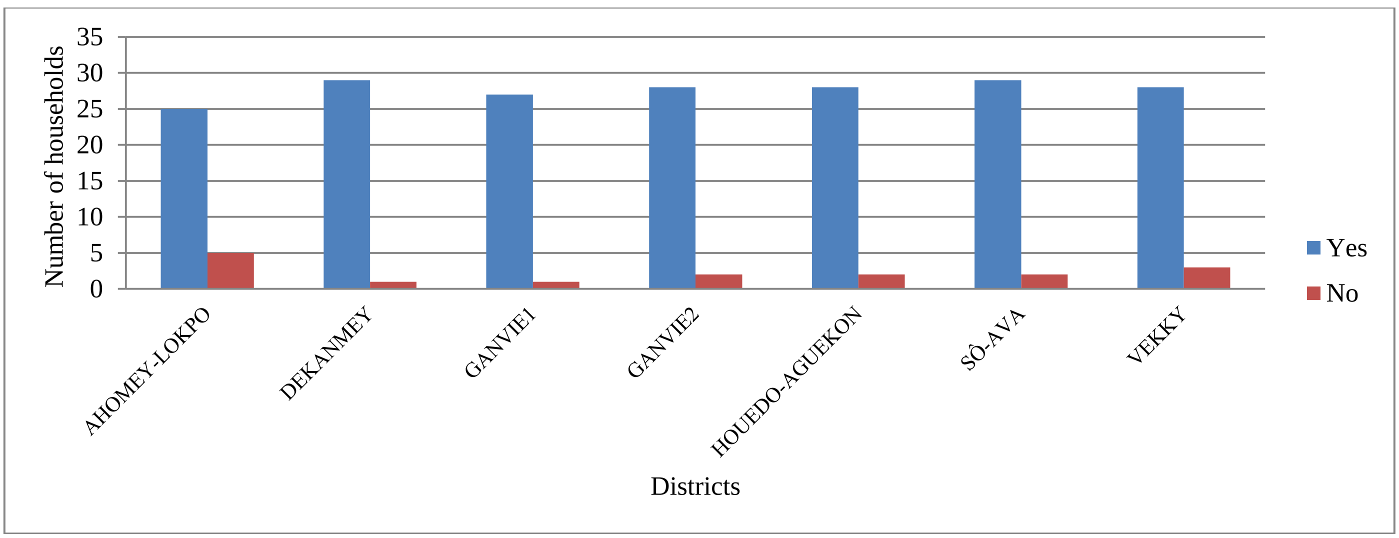

Figure-6: Respondents' Opinions on the Color of Water from DWS.

Table-8: Physico-chemical analysis results of total dissolved solids in water from DWS facilities and the Sô River.

Parameters Unit	Samples												
	01 VWSS HA	02 VWSS GBE	03 AWP GBEG	04 VWSS AL	05 AWP AO	06 VWSS AGP	07 VWSS AGO	08 RW AL	09 RW KIN	10 RW AO	11 For G 1	12 VWSS DG 2	13 VWSS E SO-TCH
pH-	6,4	5.92	5,39	6,53	6,54	5,73	6,12	6,57	6,55	6,57	5,49	5,94	5,99
TDS mg/L	191	193	237	354	224	102	115	90	90	95	50	45,3	69

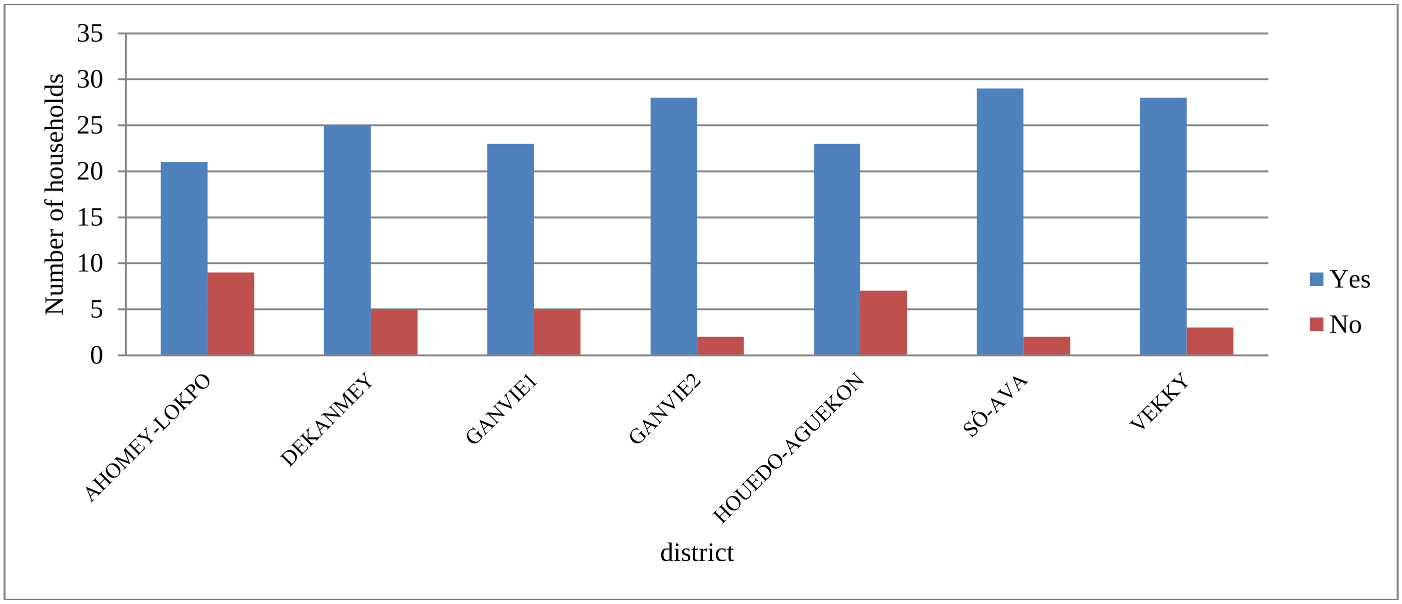

Figure-7: Respondents' opinions on the cost of water from AEPs.

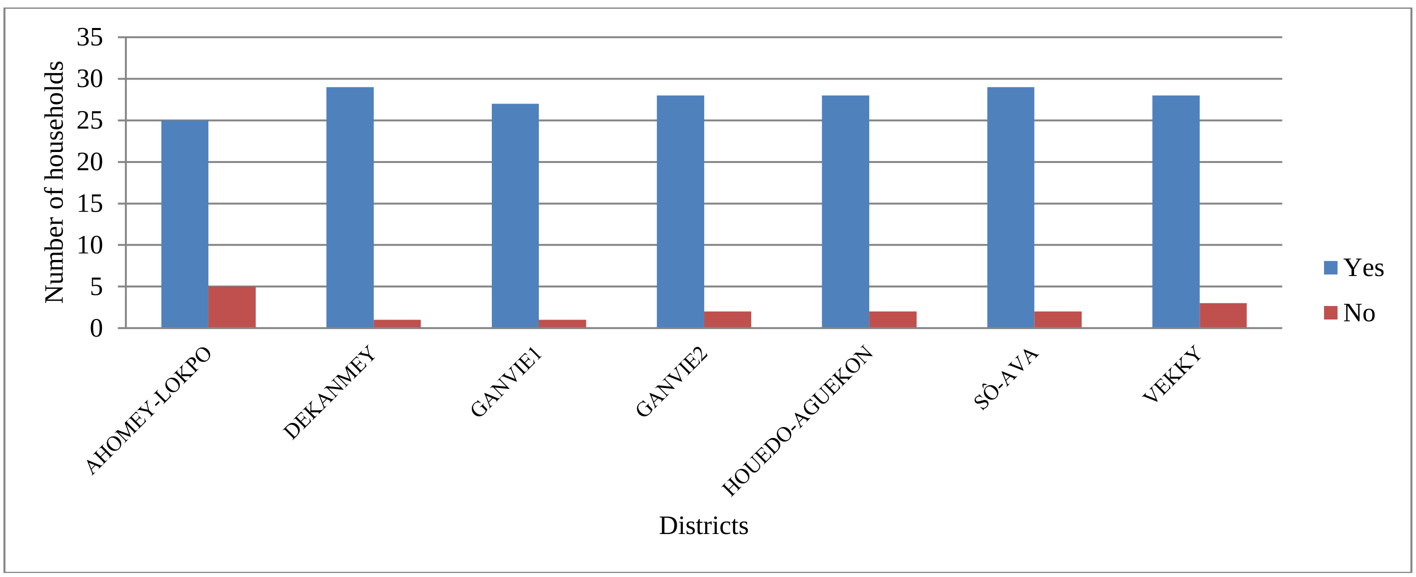

Figure-8: Respondents' opinions on the distance to DWS water sources.

According to the results, some households surveyed in the seven districts of the municipality face difficulties in accessing potable water due to the distance separating them from the public standpipes, especially those living within a 100-meter radius of the water points. They stated: "After returning from their daily activities (fishing, farming, etc.) and being tired, it is difficult to spend time walking long distances just to fetch a basin of water, whereas this water is easier to obtain from the river nearby. To better illustrate this claim from the respondents, a distribution map of DWS facilities in the municipality was created, shown in Figure-9.

Coverage rate of DWS in the municipality of Sô-Ava: Figure-10 presents the coverage rates of potable water supply in each district of the municipality. There is a noticeable disparity in access to potable water from one district to another within the municipality. The average coverage rate in the municipality is 28.54% (equivalent to a served population of 33,840), with a high coverage rate observed in the Ahomey-Lokpo district (52.14%) and a low rate in the Ganvié 1 district (15.66%). It should also be noted that except for the Ganvié 1 district, all other districts have coverage rates above 22%. These coverage rates for each district were calculated based on data from the 4th General Population and Housing Census (RGPH4) conducted in 2013.

If we take into account the population projections from 2013 to the present day, this coverage rate would be considerably lower. Meanwhile, the rural coverage rate advocated by the government is 65%. Therefore, the municipality of Sô-Ava is still far from this target, and objective, strong, and concrete actions are needed to address this issue within the required timeframe in order to align with the water sector reforms in the Republic of Benin and with SDG 6.

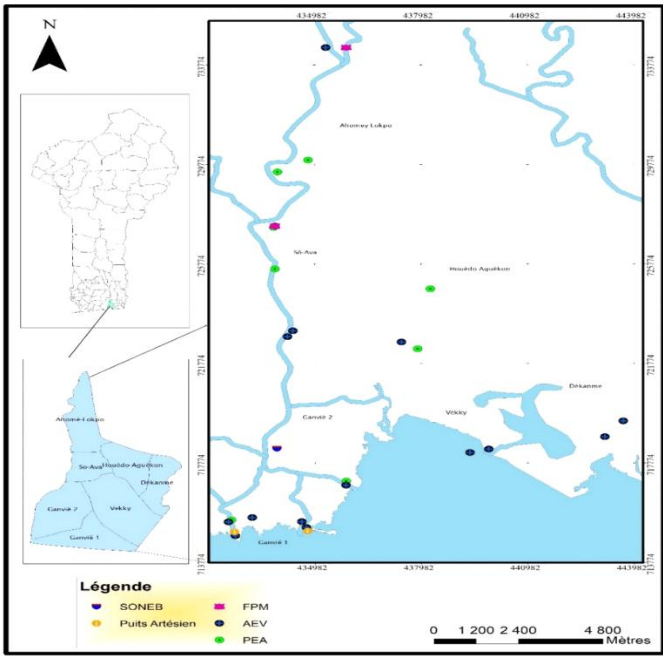

Figure-9: Distribution of DWS facilities in the municipality.

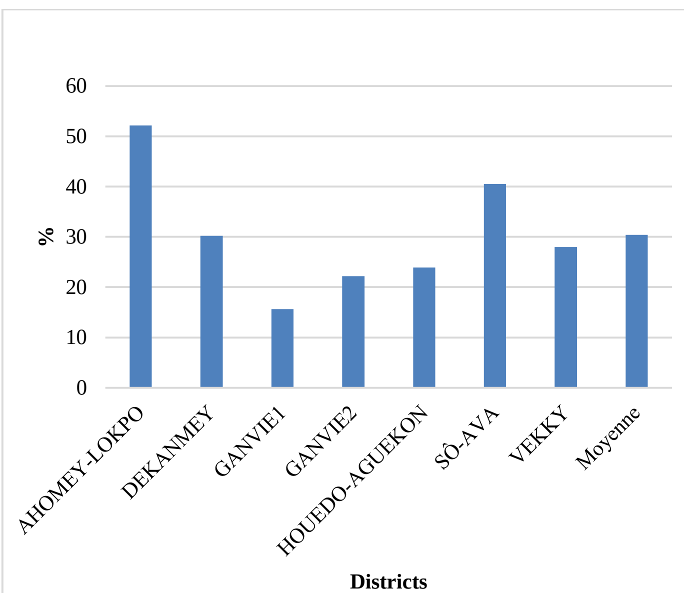

Figure-10: Coverage Rate of DWS.

Good Management Measures for DWS in the municipality of So-Ava: For effective and efficient management of water supply facilities (DWS) in the lacustrine area of Benin, measures based on strong involvement of all stakeholders in the potable water subsector must be taken to improve the management system of water points built for the benefit of the population of the Municipality of Sô-Ava. These measures include social, economic, environmental, and technical actions.

Social Measures for the Sustainable Management of DWS in the Municipality of Sô-Ava: These measures must take into account the lacustrine nature of the environment, i.e., the permanent availability of non-potable water. Therefore, it is necessary to: i. Promote private connections at a flat rate to allow multiple households to subscribe; ii. Apply a social tariff for the most disadvantaged households; iii. Improve the treatment of operators and fountain keepers; iv. Prioritize lacustrine zones in interventions in case of network breakdowns or leaks to prevent the community from resorting to river water; v. Prioritize in work planning the supply of drinking water to localities without DWS facilities and those whose facilities are in poor working condition; vi. Organize information, education, and communication sessions for the community on the risks related to the consumption of river water; vii. Raise awareness and penalize individuals who deliberately damage or build on the networks; viii. Organize interactive broadcasts on the consumption of drinking water to encourage the lacustrine community to change their behavior;

Economic Measures for the Sustainable Management of DWS in the Municipality of Sô-Ava: i. Significantly reduce the water selling price (200 to 300 FCFA) in lacustrine zones; ii. Promote private connections at a flat rate (15,000 to 20,000 FCFA) to facilitate subscription to the DWS network; iii. Extend the networks to remote areas to reduce users' time loss; iv. Implement multi-village drinking water supply systems; v. Create business conditions for water distribution: organization, schedules, and quantities available.

Environmental Measures for the Sustainable Management of DWS in the Municipality: i. Use renewable energy sources to power the DWS systems; ii. Promote hygiene and sanitation around distribution points and boreholes; iii. Ensure water hygiene throughout the water supply chain; iv. Protect drinking water sources from all forms of contamination and pollution; v. Ensure respect for the protection perimeter around water catchment sources; vi. Ensure compliance with the regulations in force concerning drinking water quality standards; i. Periodically monitor water quality.

Technical Measures: i. Maintain a stock warehouse for spare parts (taps, valves, meters, diesel) and replacement equipment (motor pumps, generators, pumps, and others); ii. Regularly inspect the DWS networks to limit water leaks; iii. Mandatorily use more durable pipes such as HDPE or equivalent for the pipelines; iv. Repair or replace faulty generators; v. Train plumbers in grouped sites for immediate repair of breakdowns; vi. Install and make operational water treatment devices for iron-rich water; vii. Reduce distances between water points by extending available water supply networks; viii. Rehabilitate all broken water points; ix. Secure the installations and equipment of DWS infrastructures.

Governance Measures for the Management of DWS in the Municipality of Sô-Ava: ANAEPMR should implement the following measures: i. Establish multi-stakeholder consultation frameworks between operators, municipalities, and ANAEPMR to facilitate dialogue among actors; ii. Create conditions for proper maintenance of equipment; iii. Improve collaboration between operators and the municipal authorities; iv. Update the ANAEPMR-municipality agreement to allow municipalities to monitor and oversee the management by operators within their territory;

These measures will enable ANAEPMR to achieve SDG 6, which aims to ensure universal access to water and sanitation and to guarantee sustainable management of water resources.

Discussion: It is necessary to conduct an in-depth analysis of the current status of potable water supply facilities and to evaluate certain parameters in order to assess their quality. Regarding the status, the seven districts of the municipality of Sô-Ava each have at least some potable water supply facilities. However, to date, the majority of these facilities are defective. This is due to the management policies implemented by the local authorities. The results related to various factors show that, concerning the flood period in the lake, the water is very soft, similar to that of the DWS facilities. During this period, the population prefers to use directly the river water rather than the water from the DWS. The DWS facilities are somewhat neglected, leading to their disuse and progressive degradation over time. It should be noted that electrical conductivity is used to estimate the overall mineralization and total soluble salts in water[7]. Similarly, the measurement of electrical conductivity of the groundwater in the Southeast of the Allada plateau showed low to moderate mineralization during the dry season[8]. Salinity follows the same trends as electrical conductivity[9]. However, the analysis results reveal that the conductivity of the lake and the DWS facilities ranges from 92.6 to 500 µS/cm. According to WHO guidelines, water containing up to 500 µS/cm is considered good for drinking. These results are consistent with those of Senouvo and Dedjiho, who found electrical conductivity below 500 µS/cm in their studies on the Sô River[10,11].

Regarding the reddish color factor, the majority of households surveyed in the seven districts do not appreciate this water condition. According to the population, the water from the DWS might contain toxic substances that could be harmful to health. Analyses of this situation have shown that the groundwater contains a high amount of iron. To address this issue, deferrization systems were installed on VWSS facilities built from 2014 onwards. However, most of these deferrizers are non-functional or defective in some locations due to lack of maintenance or poor installation. Nevertheless, the analytical results show that total dissolved solids (TDS), which determine the water color, vary between 45.5 and 354 mg/L. According to WHO, water containing up to 300 ppm TDS is considered good for drinking, while water with a TDS level of 1000 ppm is not recommended for consumption. These results confirm those of Amine[12].

The results obtained from the respondents' feedback on the cost of water supply reveal that they are unable to procure potable water from the DWS due to limited financial means. To meet their daily needs (laundry, cooking, bathing, etc.), they must spend at least 200 to 590 FCFA per day. Since the majority of the population cannot afford this daily expense, they prefer to use river water directly because it is free and available at all times to satisfy their various daily needs. Regarding the distance traveled by the population to access potable water, the service coverage rate is 28.54%[13]. Currently, this coverage rate is even lower in the municipality because per capita water consumption is below the prescribed standard. This is explained by the ease of directly drawing water from nearby rivers rather than traveling long distances to reach the DWS facilities. However, according to the government, the targeted rural potable water coverage rate is 65%. The municipality is still far from this reality (28.54%), and objective and concrete actions are needed to resolve this issue as soon as possible in order to align with the water sector reforms in the Republic of Benin.

Regarding the management of DWS facilities in rural areas of Benin, where the average coverage of potable water services is estimated at 73%, it should be noted that the lacustrine municipality of Sô-Ava remains far below this rate[4]. This is due to the rapid population growth which hampers achieving this target, given that the recent functional DWS facilities date back to 2014. Moreover, as the population increases, the potable water coverage rate decreases since the area occupied by the population is extensive. In this context, the entity responsible for managing the DWS must commit to reversing this trend in these lacustrine zones where surface water is permanently available.

Conclusion

This study firstly made an assessment of the potable water supply facilities in the municipality of Sô-Ava. The results reveal that the majority of the water supply facilities in the municipality are in poor condition, and practical measures are needed to improve the quality of water provided to the population. Secondly, the study identified four different factors influencing the use of potable water supply facilities in the municipality of Sô-Ava. According to the respondents, these four factors are flooding, the reddish color of the water, the cost of accessing potable water, and finally the distance between the water supply points and households.

In conclusion, for sustainable management of potable water supply systems, it is preferable to adopt a participatory approach that takes into account the sociological perceptions and socioeconomic realities of the beneficiary communities of projects and programs. It is also necessary to develop Multi-Village Drinking Water Supply Systems (MV-DWSS) in the municipality, in line with the new national water sector policy, and to facilitate the promotion of private connections so that each household can positively act on the factors mentioned above, leading to better behavior change.

References

1. Houssou C.J.L. (2010). Gestion de l’eau au Bénin et ses impacts environnementaux : Cas de l’arrondissement de Houin dans la Commune de Lokossa Mémoire de maitrise professionnelle FLASH/UAC. 68 p.

2. Sorenson, S. B., Morssink, C. and Campos, P. A. (2011). Safe access to safe water in low income countries: water fetching in current times. *Social science & medicine* (1982). (on-line), 72: 1522–6.

3. Ibrahima Sy, Mouhamadou Koita, Doulo Traoré, Moussa Keita, Baidy Lo, Marcel Tanner et Guéladio Cisse, (2011). Vulnérabilité sanitaire et environnementale dans les quartiers défavorisés de Nouakchott (Mauritanie) : analyse des conditions d’émergence et de développement de maladies en milieu urbain sahélien. VertigO - la revue électronique en sciences de l'environnement [En ligne], Volume 11 Numéro 2.

4. Gabert J., (2017). Marketing de l’assainissement : le « social business. au plus près des besoins locaux – Retours d’expériences de terrain du Gret à Madagascar, au Burkina Faso, en Mauritanie et au Cambodge, Nogent-sur-Marne, Gret, 2016, Cahier de capitalisation.

5. Anaepmr, (2023). Rapport du 2ème semestre 2023 Suivi du patrimoine et des performances du service public de l'eau potable en milieu rural au Bénin.

6. Flavien Edia Dovonou, Fulbert Rodrigue Adjimehossou, Marcel kindoho, Wilfrid Noudéhouénou Atchichoe, Thierry Azonhe, (2022). PROBLÈMES d’Assainissement de base : contribution à l’éducation à la santé environnementale à Vekky (SôAva). *J. Appl. Biosci*., 174, 2022. Submitted on 4th May 2022.

7. Rodier J., (2009). L’analyse de l’eau : eaux naturelles, eaux résidentielles, eaux de mer. Tome 9ème éd Dumod. Paris. 1573p.

8. Yalo Nicaise, Allé Christian and Descloitres Marc, (2013). TDEM study of variation of frech maker lans morphology between rainy and dry season in the coastal shallow aquifer of South Benin. International Journal of Current Research, 5(11), 3547-3553.

9. Sadeck A., (2011). Hydrochimie et faciès géochimiques des eaux souterraines, Plaine de Bekaa. *Hydrological Sciences Journal*, 56(2), 334-348.

10. Senouvo P., (2002). Etude de l’impact des pollutions en métaux lourds (plomb, cuivre, et zinc) sur l’écologie des huîtres crassestreagascar en zones urbaines du lac Nokoué et du chenal de Cotonou (Bénin). Mémoire de DEA en Gestion de l’environnement FLASH/UAC, 64p.

11. Dedjiho, C.A., Alassane, A., Chouti, W., Sagbo, E., Changotade, O., Mama, D., Boukari, M. and Sohounhloue, D.C.K. (2014). Negative Impacts of the Practices of Acadjas on the Aheme Lake in Benin. 5, 301-309. http://dx.doi.org/10.4236/jep.2014.54033

12. Amine R. et Abdelmalek A., (2012). Caractérisation physico-chimique des eaux superficielles de l’Oued Agrioun de la région de Bejaia. Diplôme d’Ingénieur d’Etat en Ecologie et Environnement. Université Abderrahmane MIRA de Bejaia. 54p.

13. RGPH-4. (2013). 4ème Recensement Général de la Population et de l’Habitation. Institut National de la Statistique et de l’Analyse Economique (INSAE). République du Bénin.