IJEAST

INTERNATIONAL JOURNAL
OF ENGINEERING APPLIED SCIENCE
AND TECHNOLOGY

VOLUME : 10 ISSUE : 08 Print / Issue Publication Date: 12-Feb-2026

ISSN : 2455-2143

DOI : 10.33564/IJEAST.2025.v10i08.001

Indexed In

Google SCHOLAR

OPEN ACCESS

doi

Crossref

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International Journal of Engineering Applied Sciences and Technology, 2025
Vol. 10, Issue 08, ISSN No. 2455-2143, Pages 01-20

WHY MEASURE THE CRITICALITY OF THE DRINKING WATER SUPPLY SYSTEMS IN RURAL AREAS OF DEVELOPING COUNTRIES?

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Abstract: **This paper answers the question "why measure the criticality of supply systems for drinking water in rural areas of developing countries? « A shared diagnosis through participant observation with three African communities in Angola, showed the limits to optimize the performance of whether public or private water utilities are of order in both architectural, operational and managerial. This criticality diminishes the chance for a drinking water supply system to be ecoefficient and, to develop both a normal resilience, optimal regulation, and ensure above all, abundant and continuous safe water service intended for human consumption. The research has shown also that, this criticality, when applied in the drinking water sector is an ante and ante-post evaluation' tool for effective operation of water supply systems in terms of their functions both main induced and constraints.**

Keywords: **Resilience, regulation, eco-efficiency, criticality, rural**

I. INTRODUCTION

Seeking to measure the criticality of an existing failing water supply system in a village, a locality, a commune or a municipality with regard to ecology, is a good practice in managing the water resources that nature offers to meet truly felt human needs. Engaging in such an approach is justified because humanity still needs a lot of water (World Bank, 2010) and a lot of water implies efficient, resilient water supply systems, appropriate for rural communities (Morris, 2017). Eco-efficient systems require design and implementation that take into account the environmental, economic and social dimensions. (PS-eau, 2001). Nearly 800 million of the world's population do not have access to drinking water (UN Water, 2015). This situation is of greater concern to rural populations than to urban ones, with an average proportion of over 65% of rural dwellers. The African continent is not immune either. The water crisis in Africa is acute, affecting approximately 48% of its population. African communities are experiencing the reality of resource scarcity on a scale greater than anywhere else in the world, followed by Asia and finally Latin America, while Africa alone holds over 80% of the world's freshwater reserves. In Congo, of course, the investment made in the water sector, not only in urban areas, but also in rural areas, is the expression of a political will seeking ways and means to resolve the problem of access to water for populations. Some villages benefit not only from the central government and non-governmental organizations but also from local private investors, subsidies under the program to combat poverty and inequality, to implement projects with a "visible" social impact, self-managed, including that of drinking water. Unfortunately, despite the public investments made, the results obtained are far from meeting the wishes of the target populations. The calculation of criticality as an imperative of field research, aimed to identify the functional limits of drinking water supply systems in the rural area of Belemiese in Bulungu territory, Kwilu Province, in order to take into account in the design of future systems, the omissions highlighted by this criticality measurement in the Belemiese village subject to the study, with regard to eco-efficiency indicators. To better understand the problem of drinking water in rural areas, by determining the degree of criticality of each water system studied. Subsequently, in its final part, this study presents the elements taken into account in the creation of the design model of eco-efficient water systems, focusing on production and treatment operations, regulation of supply, and water chain management. It establishes specific objectives, creates a checklist of all possibilities and subsequently determines the improvements to be made in the definition and characterization of the design model of eco-efficient drinking water supply systems in rural municipalities in developing countries. To this end, the execution of a self-assessment was considered within the framework of this study, as well as the possibility of collaborating with expert consultants on issues related to water management in southern countries.

II. THEORETICAL FRAMEWORK

Two theories served as the basis for this study: criticality theory and eco-efficiency theory. Max Horkheimer's criticality theory (1937) refers to two distinct concepts: the Critical Theory of the Frankfurt School (Karl Marx and

Sigmund Freud, 1930), a philosophical and sociological approach aimed at deconstructing the power structures and ideologies that enslave humanity, and criticality in engineering and management, which refers to the level of severity of a failure, risk, or resource, often quantified by a formula including the frequency, severity, and non-detection of an event. It provides a framework for making informed decisions by prioritizing issues, whether related to the maintenance of critical equipment, risk prevention to ensure business continuity, or strategic talent management within an organization. It is a structured method for prioritizing risks and system elements (equipment, people, and processes) based on their importance and the potential impact of a failure or adverse event. It combines the probability of occurrence of an event and its severity to determine its level of criticality, allowing organizations to focus their resources on the most strategic areas and implement optimized maintenance and risk management policies. This revolutionary theory has opened new perspectives in the understanding of complex systems and their dynamic behavior. This theory explores self-organizing dynamic systems and their behavior at the border between order and chaos. It suggests that many complex systems, such as the human brain, neural networks, or even natural phenomena like avalanches, exhibit critical properties. These systems can exhibit a particular sensitivity to small disturbances, which makes them capable of self-organizing efficiently and generating unpredictable emergent behaviors. The central idea of criticality theory is that these systems naturally stabilize at a point where they are both stable enough to avoid total collapse, yet sensitive enough to react dynamically to internal and external changes. This critical property can be observed in many fields, from physics to biology to economics, providing a powerful theoretical framework for understanding the complexity and diversity of natural and artificial systems. Criticality theory is also applied in the water sector, adapting it to the inherent limitations of water supply networks. This innovative approach aims to improve understanding of critical water system behaviors, identify points of vulnerability, and strengthen the resilience of these essential infrastructures. By integrating the concepts of criticality theory, stakeholders involved in water management can better anticipate risks, optimize maintenance and intervention processes, and ensure a reliable and sustainable water supply for the populations served.

This approach allows for a proactive vision of water management, with an emphasis on crisis prevention and the promotion of efficient and balanced use of water resources. The analysis of failure modes, their effects and their criticality (1960), introduces criticality as the product of the severity, probability of occurrence and detectability of potential failure modes of a system applied to the Belmiese drinking water supply system, AMDC allowed us to identify and assess the critical failure modes of this system.

Georgescu-Roegen's (2006) eco-efficiency theory is a management approach that aims to do more with fewer resources and waste, by optimizing the production of goods and services while minimizing environmental impact at all stages of their life cycle. It is about creating more value while reducing resource consumption and pollutant emissions, enabling companies to achieve their sustainable development goals and improve their competitiveness. It is based on eight key principles including (i) the inclusion of fewer resources for more goods and services, (ii) the minimization of waste and pollutants (iii) the Life Cycle Vision (iv) technological innovation; (v) competitive advantage; (vi) environmental performance; ((vii) Cost reduction and (viii) improvement of brand image.

III. MATERIALS AND METHODOLOGY

This shared diagnosis focuses on a single case study of the town of Belemiese in the Luniungu sector, one of the 10 local authorities in the Bulungu territory in the Kwilu Province of the Democratic Republic of Congo. The village of Belemiese is located in the Mudingombe groupement, Luniungu sector, Bulungu territory, and in the Kwilu province. This village is 23 km from National Road 1 from the Camp Bulungu entrance and 80 km from the town of Kikwit. It is bordered to the east by Kunga village, to the west by Yungu village, to the north by Kiyansi and Tatu villages, and to the south by Kingulu village. The Luniungu sector, in which the village of Belemiese is located, is one of the ten sectors in the Bulungu territory; namely: the Nko, Kwenge, Kilunda, Mikwi, Kwilu Kimbata, Dwe, Nkara, Imbongo, Kipuka and Luniungu sectors. A random sample of the study was made up of 34 individuals all from the aforementioned population, including the local authority, the head of the Belemiese center, nurses and patients from the hospital, schoolchildren, ISP students, weekly traders and rural households. The case study methods ((Yin 2014) and inductive (Quivy and van, 1995) associated with documentary techniques, direct observation and focus group were used to successfully carry out this research directly applied in the field in the Belemiese village.

IV. FINDINGS

Reference Framework for criticality elements of a drinking water supply system

This reference framework, on which the criticality assessment of the Belemiese drinking water supply system is based, takes into account all forty-one (41) functions divided into four (4) categories, including the primary function, induced functions, secondary functions, and constrained functions. Within this set, three (3) functions are induced, eleven (11) secondary functions, twenty-six (26) constrained functions, and one (1) function is primary. The primary function here refers to the abundant and permanent supply of quality drinking water intended for human consumption. The induced functions are those related to the design of an eco-efficient water system architecture, the operational effectiveness of the water chain, and ultimately, the management of the water system. Secondary functions include raw water extraction, raw water treatment, water transport from source to reservoirs and distribution points, treated water storage, raw water collection, raw water purification, transport, skills management, water supply, system maintenance, and research and development for optimizing water system performance. Finally, constraints are also considered as bottlenecks. In addition to these essential characteristics, there are the causes, effects, and detection possibilities, as well as actions to be taken to optimize the system.Reference Framework for Criticality Elements of a Drinking Water System

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Table 1. Reference framework for criticality elements of a drinking water supply system

Main function	Induced functions	Secondary functions	(Failure Modes)	Cause	Effect	Detection	Action
Abundant and permanent quality drinking water for human consumption	**Design of the architecture of an eco-efficient drinking water supply system**	Water extraction	Water extraction Qualitative choice of raw water supply sources	Microorganisms, bacteria, viruses, and protists live and develop naturally in the water, as do many parasites whose hosts require water to live or reproduce, polluted by animal and human waste from residences located downstream of the springs.	Transmission to humans of waterborne diseases that are the cause of the very high mortality rate among populations in developing countries. Typhoid fever, E. coli, cholera vibrio, amoebas, onchocerciasis, bilharzia.	Détection préventive	L’eau puisée dans l’environnement doit donc être analysée en continu avant de subir le traitement de potabilisation appropriée.

Human consumption			Generation of the exception regulation mode	Lack of community participation in the design of structures to indicate the springs and watercourses in the immediate vicinity of the village	Failure to assess natural capital due to the omission of peasant knowledges	Visible	
				Low flow rate of captured source	Less abundant and intermittent water supply	Visual	
					Discriminatory service	Visual	
					Limited economic development opportunities	Visual	
			Pumping method adopted	No use of alternative energy sources	Risk of Environmental pollution	Visual	
						Visual	
Abundant and permanent quality drinking water for human consumption		Water treatment	Water treatment Mode	Chemicals excess	Chlorine poisoning	Visual	
					Edema caused by ozone poisoning at concentrations of 4 to 10 ppm	Visual	
				Wasted water recycle absence	Environmental impact caused by elements harmful to health, organic micro pollutants containing pathogens such as viruses, bacteria, etc.	Visual	

					protozoa and helminths.		
			Choice of energy sources	Use of energy-intensive technologies for pumping and distributing treated water to users	Pollution of the environment		
		Transport of water from the source to the reservoirs and distribution points			Costly production dependent on fuel use		
			Choosing the type of pipes	Use of lead pipes	Lead poisoning		
			Purpose of the water supply	Purpose: purely domestic	Limited economic development opportunities for the system		
			Type of water distribution circuit	Unsectioned distribution lines	Difficult to prioritize sensitive targets in the event of exceptional regulations (hospitals, clinics, maternity wards, police stations, prisons, schools, official residences, hotels…).		
				Construction of reservoirs capable of holding only a	Limited opportunities for economic development		

			Storage capacity age	small volume of water	Drinking water shortage due to failure to consider spatial aspects and population growth in the design of the water system		

	Water system operation	Raw water extraction	Pumping power	Water network operating with thermic energy or motor pump	Pollution of the environment	Smoke	Pumping water system mode with kinetic, hydropower, solar or wind power.
					Limited water supply security	Visual	
					Operation depending of fuel	Visual	
			Installation water flow	Eau souterraine issue d’une résurgence naturelle à faible débit	Less abundant and discontinuous water supply		Surface water extraction with high water flow from streams

				Puits aménagé par forage (puits tubulaire) à faible débit			
				Seasonal surface water			

Table 1. Reference points for the criticality elements of a drinking water supply system (continued).

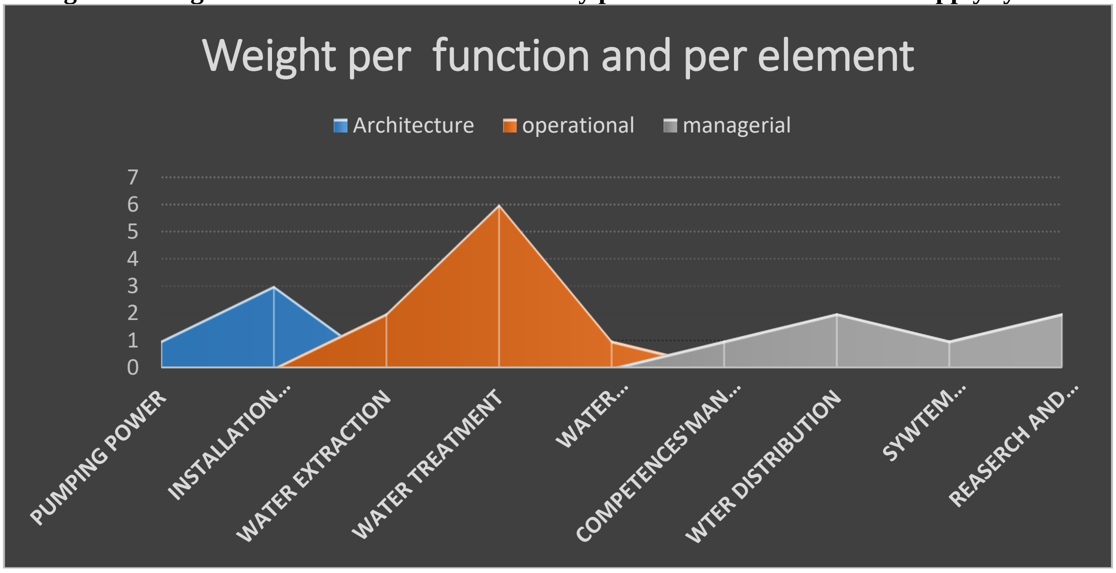
Abundant and permanent quality drinking water for human consumption		Water treatment	Absence of grids and sieves in the passage of the captured water	System conceptual limits	Passage of large debris .		Screening and sieving
			Lack of treatment of ferrous and of manganese		Very high organic load, presence of ammonia, iron or manganese in solution		Oxidation with chlorine or ozone to remove the organic load
			Manque du traitement de la dureté de l'eau		Corrosion et Entartage des canalisations		Traitement de la dureté de l'eau
				critical capacity of local actors			

			Water pollution with nitrates or pesticides		Animal and Human intoxication		Specific treatments of depollution
			Absence of disinfection with chloric		Presence of bacteria's and pathogeneses virus In the water		Désinfection. Avec du chlore, de l'ozone ou des Ultra-violets.
			Lack of disinfection with Ultraviolet Ray				
Abundant and permanent quality drinking water for human consumption		Transportation	Lead pipes	The company responsible for implementing the system has free choice of materials.	Lead is undesirable and, in high doses, can cause serious health problems. Regular or massive ingestion of lead can cause neurological disorders.	Visual	The user should let the water run for a few moments before filling a carafe to eliminate any potential lead particles in the water. Do not over-soften the water, and ensure the appliance is properly adjusted.
	Water system management		Qualified local staff	Critical capacity of local manpower	Incompetency of human resources		
		Skills Management	Fair service	Discriminatory water supply	Limited access to affected groups		

			Abundant water supply	Non-abundant and discontinuous water supply	Water shortage		
		Water Supply	Spare parts Storage capacity	Unavailability of spare parts	System Obsolescence		
			Maintenance of hydraulic installations	Destroyed environment	Evident pollution		
		System Maintenance	Renewability of infrastructures	Equipment's obsolescence			
			Captage et financement d'innovations technologiques	Limited Technology performance			

The weights of the elements of each function of the water chain have been determined and shown in Figure 2 below.

Figure1: Weight of the elements of the criticality per function into the water supply system.



Source : MUSEMA (2017).

The weights of the components of the various functions in the water chain, distributed in Figure 1 above, show that, in order of importance, the task related to water portability alone holds the greatest weight as a link in the water chain. It is followed by three other tasks, including installation flow, water supply, and research and development. The last three links, which occupy the last place in the ranking, are the pumping energy chain, skills management, and system maintenance.

Assessment of the criticality of the Belemiese drinking water system. Having known the weights of the various links in the Belemiese water chain, we were able to assess the degree of criticality of the existing water system in Belemiese. We decided to code the elements of the water chain functions before proceeding with the actual calculation of the criticality of the rural drinking water supply system studied in the Belemiese village under study, using the Failure Mode, Effects, and Criticality Analysis (FMEA) method.A set of three essential variables were considered to determine the criticality of the Belemiese water system. These variables are severity, likelihood, and detectability.

- Severity (G) corresponds to the impact of a water system failure. It measures the significance of the consequences and the anticipated impacts in the event of corrective measures being implemented, or in the event of the water supply system achieving eco-efficiency. In order for the severity to be as objective as possible, inefficient water collection, treatment, transport, storage, distribution, and service management are taken into account, as is the "blocking" effect of the situation at the stage considered (such as, for example, low flow from the source, the destination of the water in the event of a positive microbiological test on the water to be distributed => occasional water supply and cessation of its distribution for human consumption).
- Likelihood (V), for its part, expresses the possibility of the risk occurring, in other words, the potential for the failure to occur. We preferred the term likelihood to the term frequency, for the simple reason that the latter encourages confusion between the potential frequency of the accident and the frequency of exposure to the hazard, and also preferred the term probability because it implies a mathematical rigor that is not always necessary when approaching the field of risk management.
- Finally, detectability (D) shows that the system failure is very easily detectable through the design of the system architecture, water production and management, and water system maintenance. In order to calculate the criticality of the drinking water supply system studied in Belemiese, a risk weighting was performed to determine the criticality of each risk, then that of the Belemiese water system.

Moreover, to assess the criticality itself, three essential criteria are used. The assessment then makes it possible to obtain the criticality of the risks of the Belemiese water system failure, by applying the formula below:

Criticality (C)= G x Vx D

This evaluation of the criteria was carried out using a scale of 1 to 4, shown below, and took into account the following result: (i) Risk criticality between 1 and 11: minor risk (ii) Risk criticality greater than or equal to 12: critical risk.

Table2 : Notes for each criticality parameter.

Notes	Likelihood	Severity	Detectability
1.	Very unlikely	Low.	Effective
2.	Unlikely (rare)	Medium	Risky
3.	Probable (occasional)	Severe	Unreliable
4.	Very likely (frequent)	Very serious.	None

Source : AMDEC

To achieve the criticality assessment of the Belemiese water system, we first proceeded to the functional classification of the drinking water supply system. In a second step, the different functions of the water system were coded, followed by the criticality assessment itself. At this level, the evaluation criteria were identified and the weight of each function of the water system was determined. It is unequivocal that the ineco-efficiency of a water system can occur when its designer took the risk in the crucial design phase, to set aside, especially the environmental dimension and the participation of the beneficiaries. The appearance of anomalies caused by triggering events in the operation of the water chain, is accompanied by a probability that depends on the risk that was undoubtedly taken at the beginning.

Table 3: Evaluation of the criticality

	SECONDARY SYSTEMIC FUNCTION	CRITICALITY BY INDUCED SYSTEMIC FUNCTION				
		Criticality (C)= G x Vx D				
A1			G	V	D	C
	Raw Water Extraction	A11 Qualitative choice of water sources	A11 Qualitative choice of water sources	3	1	3
		A12 Generation of the exceptional regulation mode	A12 Generation of the exceptional regulation mode	4	1	16
	Transportation of Treated Water to Reservoirs	A13 Adopted pumping method	A13 Adopted pumping method	4	1	16

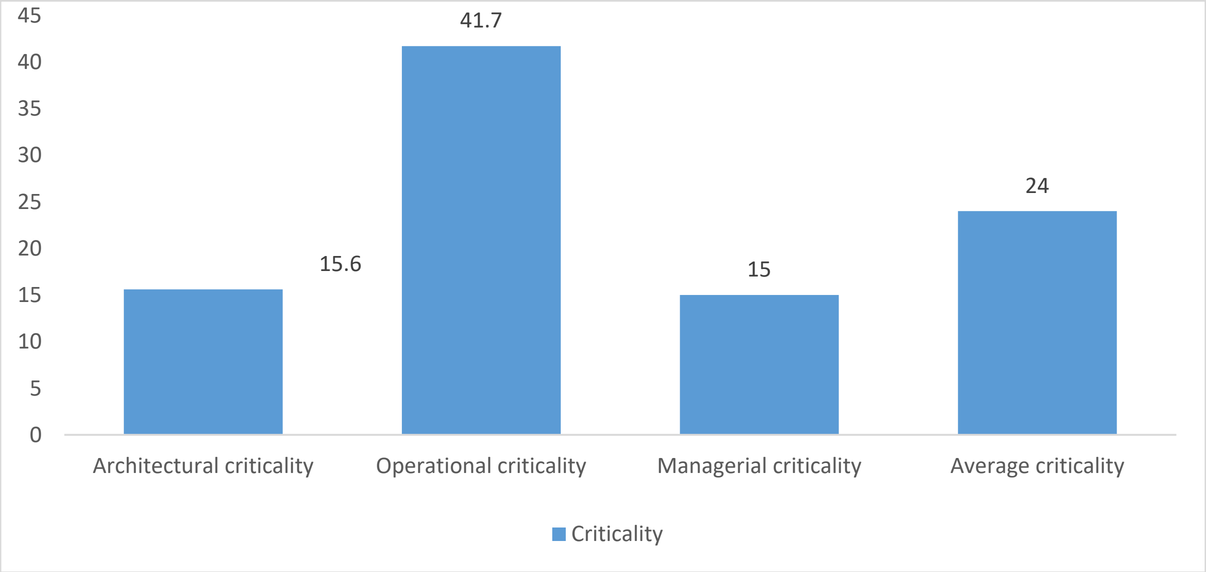
A2	Raw Water Treatment	A21 Method of treatment of captured water		A21 Method of treatment of captured water	4	4	64
A3	Treated Water Storage Raw Water Collection	A31 Choice of energy source	A31 Choice of energy source	4	4	1	16
		A32 Choice of pipe type	A32 Choice of pipe type	2	4	1	8
		A33 Purpose of the service	A33 Purpose of the service	2	4	1	8
		A34 Type of water distribution circuit	A34 Type of water distribution circuit	4	4	1	16
A4	Water Treatment	A41 Painting of tanks	A41 Painting of tanks	1	1	1	1
		A40 Storage capacity	A40 Storage capacity	2	4	1	8
O1	Transportation	O11 Water pumping energy chain	O11 Water pumping energy chain	4	4	1	16
		O12 Installation flow rate	O12 Installation flow rate	4	4	1	16
	System Implementation	O21 Absence of grids and screens at the captured water pass	O21 Absence of grids and screens at the captured water pass	4	4	1	16
O2	Skills Management Drinking Water Supply	O22 Lack of iron and manganese treatment	O22 Lack of iron and manganese treatment	4	4	4	64
		O23 Lack of water duration treatment	O23 Lack of water duration treatment	4	4	4	64
		O24 Water pollution by nitrates or pesticides	O24 Water pollution by nitrates or pesticides	4	4	4	64
		O25 Lack of chlorine disinfection	O25 Lack of chlorine disinfection	4	4	4	64
		O26 Lack of ultraviolet disinfection	O26 Lack of ultraviolet disinfection	4	4	4	64
O3	Water Supply System Maintenance	O31 Lead Pipes	O31 Lead Pipes	2	4	1	8

G1	Raw Water Extraction Raw Water Treatment	G11 Management Method	G11 Management Method	4	4	1	16
		G12 List of Activities to Be Carried Out	G12 List of Activities to Be Carried Out	4	4	1	16
		G13 Monitoring of Action	G13 Monitoring of Action	4	4	1	16
		G14 System Specifications	G14 System Specifications	4	4	1	16
		G15 Volume of Investments	G15 Volume of Investments	4	4	1	16
G2	Transportation of Treated Water to Reservoirs	G21 Qualification of Local Personnel	G21 Qualification of Local Personnel	4	4	1	16
		G22 Retraining of Local Personnel	G22 Retraining of Local Personnel	4	4	1	16
G3	Treated Water Storage	G31 Equitable Service	G31 Equitable Service	1	4	1	4
		G32 Abundant Service	G32 Abundant Service	4	4	1	16
G4	Raw Water Collection	G41 Storage of Spare Parts	G41 Storage of Spare Parts	4	4	1	16
		G42 Maintenance of Hydraulic Installations	G42 Maintenance of Hydraulic Installations	4	4	1	16
G5		G51 Infrastructure Renovation	G51 Infrastructure Renovation	4	4	1	16
		G52 Capturing and Financing Technological Innovations	G52 Capturing and Financing Technological Innovations	4	4	1	16
CA - Average Architectural Criticality (A1+A2+A3+A4)							156/10 15,6
CO - Average Operational Criticality (O1+O2+O3)							376/9 41,7
CM - Average Managerial Criticality (G1+G2+G3+G4)							196/13 15

MC=CA+CO+CM/n	**72,3/3** **24**

The Belemiese water system's criticality calculation reveals a negative criticality, with a score above the normal range, which varies on a scale from 1 to 11.

Figure 2: A histogram visualizing the criticality matrix of existing water system in Belemiese Village.



The figure above shows that the highest criticality is for the Operational dimension, at 41.7, followed by the Architectural dimension, at 15.6, and finally, the Managerial dimension, at 15. This leads to an average negative criticality of 24. This assessment therefore reflects the exposure of the water supply system and the severity of the apparent anomalies in the Belemiese area under study. The results of this criticality assessment should lead to an action plan consistent with the identified threshold for rehabilitating the current Belemiese water system. In other words, the corrective measures resulting from the criticality assessment, as actions to improve the existing drinking water supply system in Belemiese, must be commensurate with the criticality level obtained. It is clear that each anomaly generated by the system can lead to serious consequences. We have ensured that our criticality matrix prioritizes the most likely.

Measures to optimize the Belemiese drinking water system
The corrective measures applicable to optimize the Belemiese water system are grouped into four categories, namely: (i) innovation of the sustainable energy system; (ii) installation of a solar submersible pump; (iii) networking of the distribution system; and (iv) water treatment using the ultraviolet system.

Energy system innovation

These innovations improve the reliability, efficiency, and sustainability of drinking water supply systems, particularly in isolated areas or areas with poor access to the conventional electricity grid. They promote the use of renewable energy and better energy management. Solar Submersible Pump Installation
This is a pump designed to be submerged directly in water, whether from a well, lake, or other water source. This configuration allows water to be drawn directly from the source, without the need for a surface suction system. The pump is powered by photovoltaic solar panels installed nearby; solar energy is converted into electricity to operate the pump autonomously without the need for a connection to the electrical grid. This submersible pump and solar panel energy combination offers several advantages for drinking water supply systems:

- Energy independence: no dependence on traditional electricity sources, ideal for isolated areas,
- Reliability: no power outages that could interrupt the water supply;
- Low operating costs: no electricity bills, only pump maintenance is required;

Environmentally friendly: Use of renewable energy without greenhouse gas emissions.
A solar-powered submersible pump enables autonomous and sustainable drinking water distribution, particularly suitable for rural or isolated areas.

Distribution System Networking: Drinking water distribution system networking refers to the interconnection and integration of the various components that make up the water distribution network, highlighting the various distribution points. It also involves interconnecting water storage tanks to ensure flexible and redundant distribution.

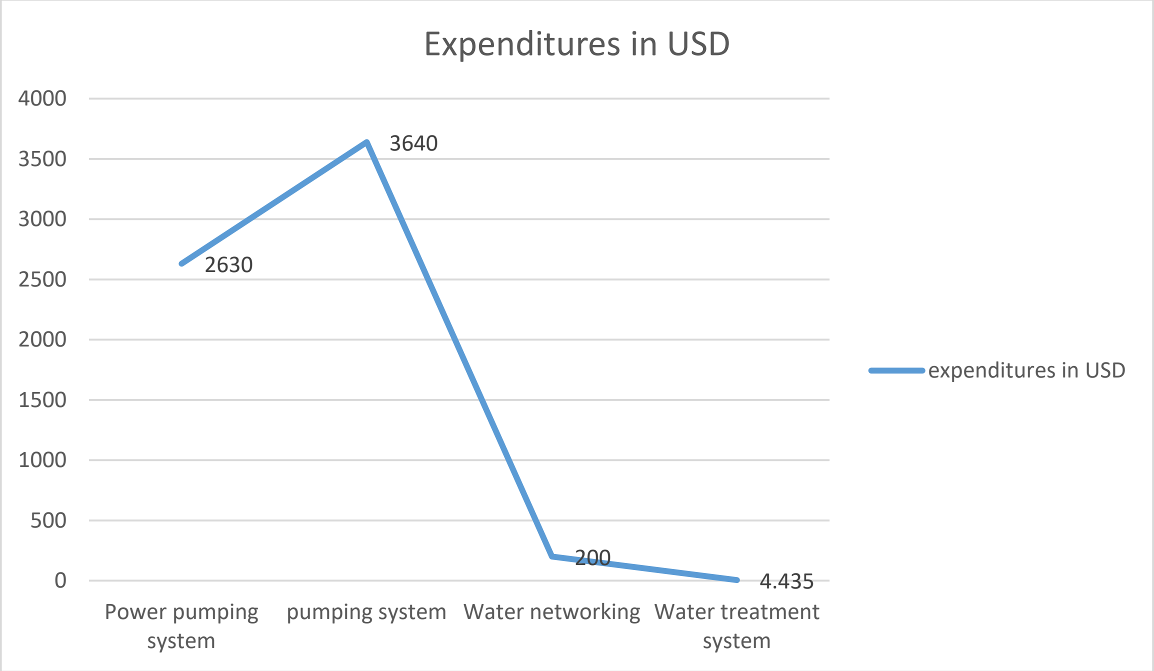
Ultraviolet Water Treatment: Water treatment with a UV (ultraviolet) system is an effective disinfection method. The UV system exposes water to high-intensity ultraviolet radiation. This UV radiation can inactivate and destroy pathogenic microorganisms present in the water (bacteria, viruses, protozoa) by up to 98%.

Drinking Water Supply System Upgrade Costs: These are the additional costs involved in operationally upgrading the Belemiese drinking water supply system.

Table4: Costs of optimizing the Belemiese village water system

N°	Coûts d'optimisation du système d'eau		
	Classes	**Details**	**Expenses ($)**
1	Energy System	▪ 6 solar panels Felcity 36v, 325Watts; ▪ 20m of cable 4×6mm^3; ▪ 15m of cable 4x6m m^3;	
		▪ 4 DC fuses; ▪ 3 colored insulators; ▪ 1 kg of sheet metal; ▪ 1 DC surge protector	2630$
2	Pumping system	▪ Solar Water Pump ▪ Model: 3ws-SD3-8-180-110-1500 ▪ Maximum flow rate: 3.8 m3/h ▪ Head: 180m ▪ Power: 1500w ▪ Power supply: DC110 volts ▪ Outlet diameter: 1.25 inches	3460$
3	Distribution Network	▪ 3 public distribution Tabs ▪ 1Hospital ▪ 3 schools (Primary, secondary and Higher (ISP)) ▪ 1Market	200$
4	Water treatment	▪ Treatment station equipped with filtration and ultraviolet disinfection processes to make the water suitable for human consumption.	430$
TOTAL			**6.720$**

Figure 2: Costs 'level per expenditure's classes



The table and figure above show that the costs of the Belemiese water system rehabilitation amount to $6,720. The highest expenses are those allocated to the pumping system with 51%, followed by the energy system expenses with 39%, the portability expenses amount to 6% while the networking expenses represent 3%.

Impact of the drinking water system failure on the socio-economic life of the local population of Belemiese

Certainly, the failure of the drinking water supply system has significant repercussions on the socio-economic life of the local population of Belemiese. This impact is measured in two dimensions: the health dimension and the economic dimension.

Heath dimension

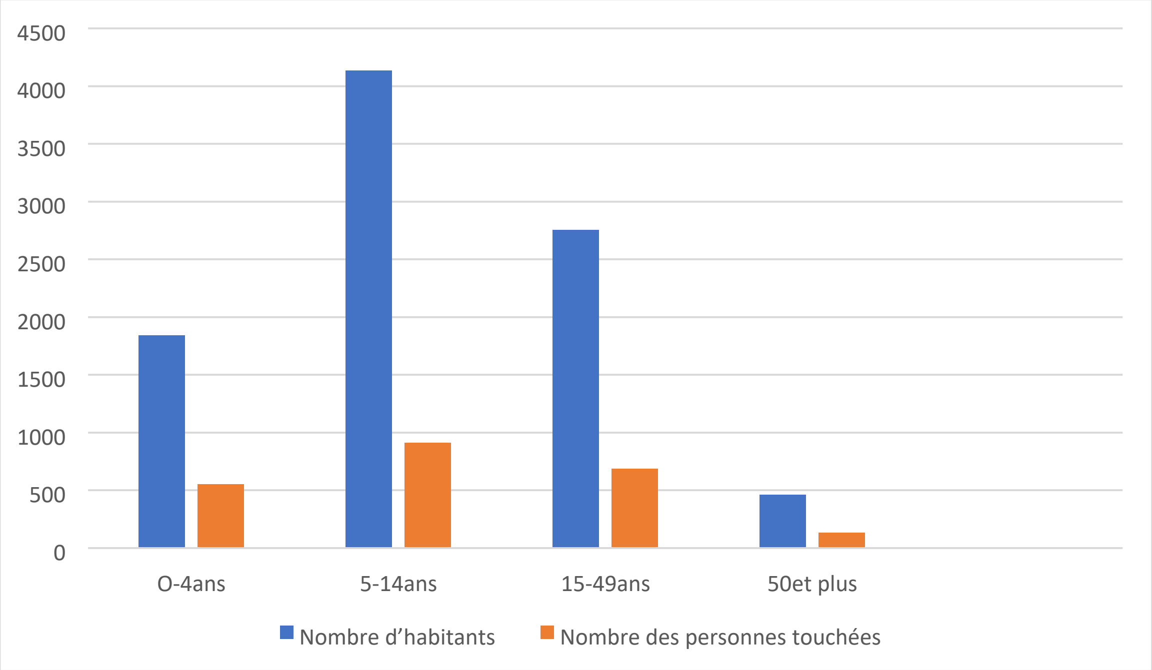
The failure of the water supply system in Belemiese has adverse impacts on health, in that the population resorts to unsanitary alternative water sources to draw water, which is used for domestic purposes and human consumption. This increases the risk of waterborne diseases such as diarrhea, cholera, amebiasis, typhoid, and other gastrointestinal infections. All of these diseases deteriorate the quality of life of the local population of Belemiese.

Tableau 5: Les personnes touchées par les maladies hydriques par tranche d'âges sur une année (2023)

Age group	inhabitants	**Number of people affected**	**% of people affected**
O-4 years	1838	552	24,2
5-14 years	4134	912	40
15-49 years	2757	684	30
50 and plus	460	132	5,7
Total	9.189	2.280	100

Source: Belemiese Reference Health Center.

Figure 3: People affected by waterborne diseases by age group over one year (2023)



This table shows that the people most affected by waterborne diseases are those aged 5-14 years, or 40%, followed by those aged 15-49 years, or 30%, and those aged 0-4 years, or 24.2%, followed by those aged 50 and over, or 5.7%. Out of a total population of 9,189, 2,280 residents are affected by waterborne diseases in a year, or a quarter of the population. This represents an extremely worrying health situation for the village, requiring immediate investment to restore access to drinking water.

Economic Dimension

This failure negatively affects agriculture and livestock farming. In practice, the population of Belemiese is hampered from developing homestead agriculture, a form of family farming practiced in many rural communities, due to a lack of water to irrigate their vegetable crops. As long as this crop is highly dependent on access to a reliable source to ensure crop growth and productivity, this has negative repercussions on food self-sufficiency and household incomes. This underscores the crucial importance of reliable access to water for maintaining small-scale farming practices at the household level.

Similarly, the lack of access to drinking water has a considerable impact on small-scale livestock farming at home. The majority of households surveyed reported not having access to sufficient drinking water, which has negative consequences on animal health, production, and livestock farmers' income. Other households do not practice this type of livestock farming due to difficulties accessing a reliable source to ensure the growth and production of these animals.

V. CONCLUSION

Certainly, this unique case study on Belemiese has demonstrated that the criticality of water systems must be measured to identify the most dangerous points of failure in order to guarantee health security, protect the population, and ensure continuity of service. This allows for risk prioritization, targeted maintenance actions, and the implementation of effective contingency plans for potential failures of water production and distribution infrastructure. Identifying and managing risks will require, among other things:

- To protect public health, criticality assessment helps prevent health risks related to water contamination by identifying points where hazards may occur and implementing control measures.
- To ensure service continuity: The failure of critical equipment can lead to a water supply shutdown, which can have serious consequences for the population. Criticality measurement helps prevent such situations by prioritizing maintenance interventions.
- To optimize maintenance: By classifying equipment according to its criticality level, operators can allocate resources more efficiently and implement targeted maintenance strategies, thereby reducing costs and the risk of failure.
- For proactive management: Failures must be anticipated and informed decisions must be made: At this level, criticality analysis makes it possible to identify the system's sensitive points, from water sources to the consumer's tap, and to plan the necessary actions to strengthen them. This approach allows for a shift from a reactive approach to a

more objective one based on real risk, relying on data rather than individual perceptions.

• To implement emergency plans: In the event of an incident, such as a flood or contamination, knowledge of critical points allows for a rapid and effective response by implementing appropriate intervention plans. The criticality of water systems is measured to identify the most dangerous points of failure in order to guarantee health security, protect the population, and ensure continuity of service. This makes it possible to prioritize risks, target maintenance actions, and implement effective emergency plans to deal with potential failures in water production and distribution infrastructure deteriorate the quality of life of the local population of Belemiese.

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