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VENTURI PASSIVE CHLORINATOR GO TO MARKET STRATEGY PRELIMINARY DATA COLLECTION AND ANALYSIS

FINAL REPORT

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EXECUTIVE SUMMARY

Over the past 15 years, significant strides have been made in rural water service delivery in Kenya, emphasizing governance, planning, monitoring, and finance over infrastructure development. Nevertheless, persistent challenges in water quality and safety necessitate tailored solutions for rural areas. The prevailing water safety methods fall short in ensuring long-term sustainability, leading to recurring disease outbreaks. To address this issue, CARE and the University of California, Berkeley are jointly piloting inline chlorination devices (Venturi passive chlorinators) to provide alternative technology solutions for water quality service for decentralized water systems and contribute to paradigm shift from reliance on point-of-use treatment method.

The primary objective of piloting this technology is to contribute to improvement of water service safety in Kenya's Western region, where reliance on untreated Lake Victoria waters poses health risks and economic losses due to waterborne diseases. Implementing passive chlorinators at healthcare facilities serves a dual purpose: ensuring safe water access for vulnerable populations and influencing government resource allocation for water treatment, backed by evidence of health benefits. This intervention has proven to effectively address global health challenges related to safe water access and maternal-neonatal mortality in low-income settings.

This report also sheds light on the evolving landscape of water treatment solutions in Kenya. It discusses the market space of chlorinators like Klorman, Dosatron, and Venturi devices, their pricing and operational aspects, as well as the challenges and regulations surrounding water quality and safety in the context resource allocation, commercialization opportunities, and sustainability options for water treatment for the underserved populations. This report underscores the need for comprehensive solutions to address water quality and safety challenges effectively.

Special thanks go to the CARE International in Kenya Senior Leadership Team, the Project Team led by Samwel Odongo, PQAL Manager Stephen Mbaabu Karuntimi and Devinsight Consultants.

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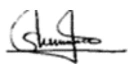
Sign/ Stamp	: 
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ABBREVIATIONS AND ACRONYMS

CECM	County Executive Committee Member
CPHO	County Public Health Officer
CSDW	Children's Safe Drinking Water
D&S	Davis & Shirtliff
DBPs	Disinfection Byproducts
FCR	Free Chlorine Residual
HCFs	Healthcare Facilities
KIIs	Key-Informant Interviews
KIWASCO	Kisumu Water and Sanitation Company
LMICs	Middle-Income Countries
NTU	Nephelometric Turbidity Units
NGOs	Non-Governmental Organizations
POC	Point of Collection
POU	Point-of-Use
SDG	Sustainable Development Goal
TTC	Total Coliforms
UN	United Nations
WASH	Water, Sanitation, and Hygiene
WASREB	Water Services Regulatory Board
WRA	Water Regulatory Authority
WSPs	Water Service Providers

1.0. STUDY BACKGROUND

Over the past decade and a half, there has been substantial progress in rural water service delivery, mainly as a result of shifts in donor and partner approaches. Instead of solely focusing on building more infrastructure ("hardware"), there has been a deliberate emphasis on systems-strengthening approaches that prioritize WASH service governance, planning, monitoring, and finance. These elements are crucial for ensuring that water services function reliably and safely for the intended population.

However, despite these advancements, rural water service delivery still faces significant challenges in terms of water quality and water safety. This is mainly due to the limited emphasis from donors and partners on two key aspects: integrating water quality and water safety into the overall WASH (Water, Sanitation, and Hygiene) systems strengthening framework, and developing a toolkit of approaches and solutions specifically for addressing water quality and safety in rural areas.

Current approaches to water safety often rely on point-of-use (POU) treatment methods and intermittent water quality surveillance. While these approaches can provide short-term solutions, they fail to address the need for proactive, long-term strategies to ensure sustained water quality and safety, which are essential for protecting public health. Although there have been improvements in water access in key counties in Western Kenya, due to devolution of government structures and increased budget allocation, the reliance on untreated Lake Victoria surface waters and the absence of proactive approaches to water quality and safety create a chronic emergency scenario. As a result, there are persistent and recurring disease outbreaks such as cholera and typhoid, leading to significant economic losses each year.

In response to this challenge, CARE is working towards a transition communities away from POU treatment methods by ensuring water service safety and reliability by implementing both interim approaches and long-term governance and systems-strengthening strategies. As part of the long-term approaches, CARE is collaborating with the Venturi team, a research group within the University of California, Berkeley. The Venturi team focuses on identifying scaling pathways for the Venturi device in health facility settings in the Western region of Kenya. CARE's role in this collaboration includes supporting the installation, routine operation, and maintenance of the Venturi device. They are responsible for device operation and maintenance tasks such as chlorine refills, free chlorine residual testing, engaging with service authorities and providers. CARE also conducts water quality sampling and analysis, particularly in production validation pilot sites. Stakeholder engagement is another critical aspect, involving training technical staff to operate and maintain the Venturi devices, capacity building with health workers, teachers, and water management committees, as well as identifying private-sector interests to support community entry processes. Furthermore, CARE is involved in social marketing and scaling efforts, piloting a go-to-market strategy with a focus on structured monitoring, iteration, and learning to assess the viability of hybrid public and private scaling models.

1.1. Project Targets

The implementation of passive chlorinators at healthcare facilities (HCFs) has the potential to provide safe water to vulnerable populations, including patients, newborns, and mothers. Moreover, this intervention can generate evidence of health benefits, which can influence the allocation of government resources towards water treatment. By directly addressing the lack of safe water access and high maternal and neonatal mortality in low-income settings, passive chlorination interventions at HCFs address two persistent global health issues.

The scaling of the Venturi device is expected to occur through both public and private pathways. The public pathway focuses on leveraging the commercialization aspects of passive chlorination in Kenya and capitalizing on the decentralization of water services budget functions to the county level. Specifically, the counties of Kisumu and Migori are targeted for triggering public pathway initiatives, such as influencing water quality budgets and investment policies. These efforts aim to facilitate Venturi social marketing and scaling in over 40 healthcare facilities. Since the counties have the autonomy to prioritize and allocate budgets, including overseeing local water utility operations, CARE intends to use evidence of impact or progress to influence co-investment opportunities with the counties. This involves integrating water quality improvement technologies into existing water systems.

On the other hand, private scaling pathways aim to explore opportunities for private sector investments in device production scaling, product marketing, distribution, and service chain establishment. The private sector has the potential to contribute significantly to the improvement of water quality services in healthcare settings and make crucial investment decisions that can drive the commercialization of passive chlorination technologies.

At the national level, the implementation of health service policies creates an enabling environment for technology incubation, standardization, and certification. Both county governments and the private sector can rely on these policies to test and validate new technologies for water chlorination. This facilitates the adoption and integration of passive chlorinators into the existing healthcare infrastructure.

1.2. Overall and Specific Objectives:

The main objectives of this assignment were to:

1. Characterize Venturi's market valuation & competitive advantage within the national and county level health care service structures, with a specific focus on Kisumu and Migori healthcare facility settings,
2. Gather water treatment information and venturi market feasibility insights from local water technologies distribution network that includes Davis & Shirtliff (D&S) stores,
3. Identify potential national and county-level potential public financing avenues for investment in passive chlorination including in health facilities, schools, and other relevant public service points and
4. Explore Venturi scale up and business case.

Specifically, the study sought to provide insights on:

1. How Venturi devices compare to other chlorinators available in the local markets in terms of capital, chlorine refill cost, capacity, compatibility with infrastructure, ease of installation/use, and connection with bulk liquid chlorine supply for potential non-subsidized device sales promotion.
2. Map out D&S stores, and D&S water treatment products retailers in Nairobi, Kisumu, and Migori, identify alternative passive chlorinators available in the local market and production location, potential market for Venturi and installation locations, lessons on D&S technical assistance to partners including cost segmentation,
3. To establish which 3rd, party retailers sell D&S water treatment products.

4. To identify what passive chlorinators are available in the local markets, where they are produced, who are the primary customers, and user point installation options.
5. To ascertain the technical assistance D&S provides to customers/retailers and what is the cost, and warranty including installation and maintenance/troubleshooting aspects.
6. To establish the distribution chain for chlorine testing strips including pricing and quantity.

Further, the study aimed at finding out:

1. The regulatory landscapes of each county (who regulates water infrastructure) and to understand the supply chain of other existing products and their quality assurance.
2. Procurement channels in county government: Explore the business and regulatory framework of each county.
3. Review of POU water treatment methods (manual chlorination like WaterGuard, filtration, etc) being sold by D&S retailers, including their cost and estimated required time use.
4. Identify main water treatment retailers across Kisumu County (and other counties) and their products, in addition to D&S.
5. To understand from D&S: who are their primary customers, where do they install passive chlorinators, and how many units are sold yearly by D&S.
6. To understand from HCFs, what they spend their budget on, and how they decide which products/from whom to purchase.

The scope entailed collection of both quantitative and qualitative data in selected D&S stores in Busia, Kisumu, Migori, and Nairobi and from and healthcare facilities and relevant government and private sector actors, to produce a brief report and slide deck that can be used and viewed by market actors and government partners to showcase the feasibility for a water treatment technology such as Venturi to enter the market. The data collection tools also explored the acceptability of a potential subsidy for the water systems since it is targeted at healthcare facilities.

1.3. Key questions that have been addressed

A. Characterize Venturi's market valuation & competitive advantage.	B. Gather information from local Davis & Shirtliff stores.
a) What passive chlorinators are being sold in the local markets? Where are these products produced (are any made locally in Kenya?)?	a) Which 3rd party retailers sell D&S water treatment products?

b) Does D&S sell any electro-chlorinators? c) Compare Venturi to other chlorinators sold by D&S in terms: i. Capital cost (local market price at D&S) ii. Chlorine refill type and cost (e.g., custom cartridges, powder, liquid, etc.) iii. Installation needs iv. Capacity (# Litres treated per chlorine refill) v. Compatibility with infrastructure vi. Repair Needs d) Identify the local bulk supply of liquid chlorine.	b) Is D&S currently stocking liquid chlorine and if so, where do they get it from, and what is the price (KES/L)? c) Who buys these passive chlorinators (primary customers) and where do they install them? d) How many units are sold yearly? ● What technical assistance does D&S provide (what is the cost, warranty, etc.)? i. installation assistance and technical maintenance/troubleshooting? e) Does D&S sell chlorine testing strips (cost, quantity, range of detection, etc.)?
C. Identify marketing and sales channels for the Venturi devices.	D. Identify national and county-level potential public financing avenues for investment in passive chlorination including health facilities, schools, and other relevant public service points.
a) What are the current and expected purchasing power and willingness to pay for Venturi devices among healthcare facilities not connected to the main water supply for Nairobi? b) What are the consumer profiles and target segments for Venturi devices? Are there other target markets besides HCFs and kiosks that we should consider? c) What are the potential marketing, distribution, and sales avenues for the Venturi devices and spare components in the target counties/region?	a) Learn about planning processes and decision-making triggers for health facility investment/scaling of water treatment technologies. ● Who are the key persons/offices/departments at the national and county level involved in final budget decisions on water quality management at the county health service/water utility levels? ● Do they make these decisions based on existing guidelines/criteria? Are the guidelines objective to resolving the current water quality status at the county health service/water utility levels? ● What are the key considerations in the prioritization of water quality improvement/sustenance budget proposals at the county health service/water utility levels? b) How does the national level IPC guideline/WASREB-WSP guideline contribute to water quality management (resource mobilization, planning,

	allocation, and spending) at the county and national health facility and water service supply points/levels? c) What is the existence or non-existence of national and county-specific health policy and advocacy structures attributable to water quality management status at the county health service/water utility levels?

2.0. APPROACH AND METHODOLOGY

The data collection exercise was conducted in Kisumu, Migori, Busia, Siaya, and Nairobi Counties, Kenya, and adopted a comprehensive and participatory multi-stakeholder approach to gather relevant data and information. The approach aimed to ensure the inclusion of diverse perspectives and stakeholders through qualitative research methods. The participatory nature of the survey involved active engagement with key project stakeholders including local government partners, and health institutions throughout the data collection process.

2.1. Desk Review

Review of secondary data acquired from the project and reliable sources was conducted. The review focused on relevant publications and documents from government sources and reports from non-state actors.

2.2. Qualitative Phase

1) Key-Informant Interviews (KIIs)

Key informant in-depth interviews were mainly undertaken with subject matter experts, policy makers and opinion leaders. They provided data in the form of feelings, opinions, experiences and recommendations. The respondents were purposively sampled according to their roles, targeted county departments and as well as their availability for an interview.

The distribution of KIIs was as herein stipulated:

Key Informant	Contribution/Purpose	Target Number
Davis & Shirtliff store managers and staff	Provide information on D&S water treatment products, including passive chlorinators, electro-chlorinators, liquid chlorine supply, pricing, technical assistance, warranty, and distribution chain for chlorine testing strip	10
Health facility representatives (HCFs)	Gather information on the market valuation and competitive advantage of Venturi devices, compare Venturi to other chlorinators in terms of cost, capacity, installation needs, compatibility with infrastructure, repair needs, and identify potential installation locations, elucidate user perspectives and recommendations	15
National and county-level government officials	Identify potential public financing avenues for investment in passive chlorination in health facilities, schools, and other public service points, learn about planning processes, decision-making triggers, budget decisions, guidelines, and criteria for water quality management at the county health service and water utility levels	8
Venturi customers, partners, and regulators	Obtain insights on the market valuation and competitive advantage of Venturi devices, purchasing power, willingness to pay, consumer profiles, target segments, and potential marketing, distribution, and sales avenues for	15

	Venturi devices and spare components in the target counties/region	
TOTAL		48

1) Mapping

Mapping out D&S stores, and D&S water treatment products retailers in Nairobi, Kisumu, Migori, and Busia identify alternative passive chlorinators available in the local market and production location, potential market for Venturi and installation locations, lessons on D&S technical assistance to partners including cost segmentation.

1. Map out D&S stores and D&S water treatment products retailers in Nairobi, Kisumu, and Migori.
2. Identify alternative passive chlorinators available in the local market and their production locations.
3. Identify potential markets for Venturi devices and suitable installation locations.
4. Gather lessons on D&S technical assistance provided to partners, including cost segmentation.

3.0. DOCUMENT REVIEW

3.1. Access to Safe Water: A Background

Water is incredibly important for various aspects of human lives, from the economy to health and overall well-being of all persons. Crucial sectors, including agriculture and energy, rely on water as a pivotal input, with 78% of global employment directly contingent on water-related activities[1]. Nevertheless, the emergence of hindrances that impede development has become pressing, owing to the escalating impacts of climate change and population expansion that exert ever-mounting pressure on existing water systems. The rationale for fortifying the water sector becomes clear in this context.

In Sub-Saharan Africa, the attainment of universal access to enhanced water sources and basic sanitation could potentially yield annual economic benefits amounting to a staggering 34.7 billion USD[2]. The United Nations underscores this by calculating a global benefit-to-cost ratio of 5.5x for improved sanitation and 2.0x for upgraded drinking water facilities[3]. The developmental outcomes linked with enhanced water access are particularly pronounced among impoverished populations, a disparity that is even more pronounced among women and children who are traditionally tasked with water collection responsibilities. This often involves extensive journeys that consume several hours each day, entailing costs considerably higher than those associated with water derived from formal piped connections. Notably, residents of low-income areas (LIAs) might find themselves paying up to tenfold more for water. Hence, augmenting water access for marginalized communities can substantially economize time, bolster disposable incomes, and elevate overall health standards.

Kenya's development blueprint, Vision 2030, outlines an ambitious aim of achieving a consistent 10% annual GDP growth rate from 2012 to 2030. Water plays an indispensable role in underpinning this growth trajectory as an essential input for sectors such as agriculture, manufacturing, and others, simultaneously contributing to the sustenance of up to 200,000 jobs. Acknowledging this pivotal role, the Kenyan government has directed its efforts toward ensuring universal access to improved water and sanitation services by the year 2030, in alignment with the objectives of Sustainable Development Goal six.

However, prevailing access to reliable water sources remains wanting. Only a mere 26% of the population is served by regulated water providers, leaving the remaining 74% reliant on small-scale private operators, community-managed systems, or self-supply arrangements[4]. Unfortunately, these alternatives may offer water of dubious quality, be procured from unsustainable sources, or be excessively costly. Complicating the situation further is the burgeoning population growth. Predictions indicate a 27% rise in Kenya's population to approximately 60,470,000 individuals between 2019 and 2030. Attaining universal water access by 2030 will engender a substantial upswing in water demand. In a nation that is already grappling with water scarcity, this will necessitate the utilization of a staggering 81% of available water resources, a remarkable increase from the current utilization rate of 14%[5].

[1] UNESCO World Water Assessment Program, 2016, Water and Jobs
[2] Frontier Economics, 2012, Exploring the links between water and economic growth, A report prepared for HSBC
[3] UNESCO World Water Assessment Program, 2016, Water and Jobs
[4] Water Services Regulatory Board, 2019, Impact: 11 – 2017/18, Issue No.11
[5] Ministry of Environment, Water, and Natural Resources, 2014, National Water Master Plan

Addressing this mounting demand mandates significant investments. The government estimates an annual requirement of 100 billion Kenyan Shillings (equivalent to 981 million USD)[6]. However, the present investment falls significantly short of this mark, hovering around approximately 40 billion Kenyan Shillings (392 million USD) each year. Beyond the inherent challenges in meeting this escalating demand, alterations in climate patterns are poised to place immense pressure on water supply. Rising ambient temperatures and the anticipation of heightened and erratic rainfall patterns are projected. It goes without saying that the health implications of intermittent water supply are concerning, as it has been linked to an increase in cases of diarrhea and typhoid fever. Furthermore, it's important to recognize that even sources categorized as improved, such as piped water, do not consistently deliver water free from contamination. Shockingly, an estimated 1.4 billion people rely on contaminated water from these improved sources.

To mitigate these issues, a point-of-use (POU) water treatment approach has been advocated as an interim solution. POU treatment has demonstrated its ability to improve water quality and reduce the incidence of diarrheal diseases. Chlorine treatment, in particular, stands out as an affordable option, costing as little as 0.05 USD per 1000 L of water when purchased in bulk in certain regions. Moreover, chlorine treatment offers the advantage of residual protection against contaminants.

However, the widespread adoption and scaling up of POU technologies remain challenging. One of the primary reasons for this is that POU places the burden of water treatment on individual households, necessitating sustained behavior change for effectiveness. Achieving the potential health benefits of POU treatment hinges on high and consistent compliance with these treatment methods.

Given this complex matrix of challenges, an exigent demand exists to restructure and optimize the functioning of the water services delivery sub-sector.

3.2. Current Approaches to Water Safety in Kenya

In Kenya, the pursuit of ensuring water safety and enhancing water quality has proven to be a formidable undertaking, influenced by a convergence of factors including pollution, inadequate infrastructure, population growth, and the looming threat of climate change. Nevertheless, a comprehensive array of approaches and initiatives have been marshaled to confront and overcome these multifaceted challenges:

Water Quality Monitoring and Surveillance Initiatives stand at the forefront of these efforts. Collaborative endeavors involving the Kenyan government, non-governmental organizations (NGOs), and international partners have given rise to robust programs. These programs entail systematic testing of water sources, meticulous scrutiny for contaminants like bacteria, viruses, heavy metals, and chemicals. Water quality testing in various parts of the country, as documented by various studies, indicates dire conditions that often fall below WASREB

[6] Ministry of Environment, Water, and Natural Resources, 2014, National Water Master Plan

standards.[7,8,9,10] By vigilantly overseeing these crucial sources, this monitoring enables the prompt identification of polluted outlets, facilitating swift implementation of measures to mitigate risks.

Infrastructure Development has been a concerted thrust, orchestrated by both the government and international entities. The transformational blueprint encompasses the establishment and enhancement of water supply and sanitation infrastructure. This manifests as boreholes, wells, and water treatment plants yielding pristine water sources. Simultaneously, a conscious effort to establish proper sanitation facilities aims to preempt potential contamination of these vital water sources.

Within this overarching framework, **Community Engagement and Education** have emerged as pivotal pillars. NGOs and community-based organizations serve as vital conduits for disseminating knowledge. These grassroots agents play a pivotal role in explaining the importance of water safety and sanitation to local communities. Through well-crafted awareness campaigns, interactive workshops, and insightful training sessions, these organizations diligently instill proper hygiene practices, efficient waste disposal methods, and the protection of water sources within the community's collective consciousness.

Bolstering these grassroots initiatives, **Policy and Regulation** form the bedrock upon which sustainable water safety efforts are built. Recognizing the urgency, the Kenyan government has enshrined policies and regulations advocating for water quality and safety. These regulatory frameworks provide guidelines for holistic water management, robust pollution control, and prudent water resource utilization. Regulatory bodies, acting as vigilant guardians, ensure adherence to these elevated standards.

Climate Resilience, given Kenya's vulnerability to climate change, has gained prominence within water safety strategies. Proactive measures incorporate climate resilience into water safety initiatives. This strategic integration involves adapting infrastructure and methodologies to ensure the consistent provision of clean water, even amidst climatic fluctuations.

Continuing forward, **Cross-Sector Collaboration** stands as an indispensable tactic. Water safety pursuits require harmonious collaboration across diverse sectors, including water resource management, public health, environmental stewardship, and agriculture. This convergence results in integrated strategies that infuse water safety imperatives into broader developmental goals.

In tandem with domestic efforts, **International Assistance** catalyzes progress. International organizations, donor agencies, and foreign governments provide crucial financial and technical resources for Kenya's water safety endeavors. This support has been instrumental in fostering capacity building, expediting the transfer of cutting-edge technologies, and breathing life into ambitious large-scale projects.

[7] Ondieki, J. K., Akunga, D. N., Warutere, P. N., & Kenyanya, O. (2021). Bacteriological and physico-chemical quality of household drinking water in Kisii Town, Kisii County, Kenya. Heliyon, 7(5), e06937. https://doi.org/10.1016/j.heliyon.2021.e06937

[8] Nyakundi, V. , Munala, G. , Makworo, M. , Shikuku, J. , Ali, M. and Song'oro, E. (2020) Assessment of Drinking Water Quality in Umoja Innercore Estate, Nairobi. Journal of Water Resource and Protection, 12, 36-49. doi: 10.4236/jwarp.2020.121002

[9] Nduku, M. A., N., A. D., & J., N. (2022). Bacteriological quality of drinking water for Masinga-Kitui water supply system, Kenya. International Journal Of Community Medicine And Public Health, 10(1), 126–133. https://doi.org/10.18203/2394-6040.ijcmph20223536

[10] WASREB. GUIDELINES ON DRINKING WATER QUALITY AND EFFLUENT MONITORING. https://wasreb.go.ke/downloads/Water_Quality_&_Effluent_Monitoring_Guidelines.pdf

Leveraging innovation, **Innovative Technologies** invigorate water safety initiatives. Noteworthy projects harness advanced technologies like water purification systems, tailored mobile applications for water quality reporting, and remote sensing technologies to vigilantly monitor water source conditions.

3.3. Passive Chlorination for Improved Water Quality

Studies underscore the potential of innovative water treatment technologies and the importance of addressing microbial contamination and disinfection by-products in ensuring access to safe drinking water. In a recent comprehensive review conducted by Lindmark et al. in 2022 and published in the Environmental Science and Technology journal, the potential of deploying and managing passive chlorinators at scale was highlighted. These innovative devices have the capacity to significantly enhance the quality of accessible water services by offering effective water disinfection solutions, either before or at the point of collection, all without the need for daily user input or electricity. This approach aligns with the objectives of Sustainable Development Goal 6.1, which aims for universal access to safely managed drinking water by 2030.[11]

Passive chlorinators, particularly popular in regions like South Asia, provide a scalable solution to enhance water quality. Various passive chlorinators have been implemented for drinking water disinfection in resource-constrained settings using a variety of chlorine sources and dosing control mechanisms (Table 6.2).[12] Research also underscored the potential of passive chlorination technologies, especially in low- and middle-income countries (LMICs). Their study estimated that over 2 billion people in LMICs rely on microbially contaminated drinking water sources that are either compatible or potentially compatible with passive chlorinators. While South Asia was identified as the largest target market, interestingly, the practice of chlorination was more common in African and Latin American regions.[13] This research highlights the need to adapt passive chlorinators to various water sources and identify viable implementation models.

Crider et al. conducted an evaluation of passive chlorination technologies within gravity-fed, piped water systems in Nepal. Their research demonstrated a significant reduction in Escherichia coli contamination at taps after 1 year of system-level chlorination. While the study highlighted the potential of passive chlorination in rural systems, it also emphasized the critical factors of safe storage, effective service delivery models, and reliable supply chains for the successful implementation of this technology.[14]

Similarly, a study on the effectiveness of household-based chlorine disinfection for water treatment across various turbidity levels commonly found in rural water sources found chlorination to be effective up to 20 nephelometric turbidity units (NTU) using both single and

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[11] Lindmark, M., Cherukumilli, K., Crider, Y., Marcenac, P., Lozier, M. J., Voth-Gaeddert, L., ... Pickering, A. (2022). Passive chlorinators deployed and managed at-scale have the potential to elevate the quality of existing accessible and available water services to meet "safely managed" requirements. Environmental Science and Technology, 10.1021/acs.est.1c08580

[12] Ibid

[13] Cherukumilli, K., Bain, R., Chen, Y., & Pickering, A. (2022). Passive chlorinators are most popular in South Asia. medRxiv, 10.1101/2022.10.27.22281472

[14] Crider, Y., Sainju, S., Shrestha, R., Clair-Caliot, G., Schertenleib, A., Kunwar, B., ... Ray, I. (2022). Passive chlorination technologies have the potential to radically improve how rural households gain access to safely managed water. Environmental Science and Technology, 10.1021/acs.est.2c03133

double doses. However, effectiveness decreased at higher turbidities, emphasizing the limitations of chlorine disinfection in highly turbid water.[15]

In 2015, the United Nations (UN) established Sustainable Development Goal (SDG) 6.1, aiming to ensure access to safely managed drinking water for all, characterized by its availability on premises, ready availability when required, and freedom from microbial and chemical contaminants[16]. Despite these aspirations, as of 2020, more than 25% of the global population, approximately 2 billion people, still lack access to safe drinking water. To address this issue, various conventional water treatment methods have been employed, including chlorination, biosand filtration, ceramic pots, UV irradiation, and ozonation, with the goal of inactivating or eliminating waterborne pathogens. These disinfection techniques can be applied across different institutional scales, encompassing point-of-use (POU) systems at household taps and stored water, point-of-collection (POC) systems at community shared taps, and municipal utility distribution networks.

The efficacy and scalability of these disinfection technologies hinge on multiple factors. These include electricity availability (critical for ozonation and UV irradiation)[17], residual disinfection protection (unique to chlorination), water supply intermittency, user burden (especially for manual methods like filtration and chlorination), local manufacturing capabilities, and the overall costs associated with technology, installation, operation, and maintenance.

Chlorination, a widely adopted approach in resource-limited contexts, is appealing due to its low cost, lack of electricity requirement, and provision of a free chlorine residual (FCR) that safeguards stored water against recontamination for a certain period. While it may not eliminate certain pathogens like Cryptosporidium and Giardia or remove chemical contaminants, chlorination is highly effective in deactivating most microorganisms. However, it leads to the formation of disinfection byproducts (DBPs) and can sometimes result in taste and odor issues, impacting user acceptance. Though chlorination alone may not ensure complete safe drinking water, it has proven to significantly reduce the risk of diarrheal diseases and mortality, supporting public health. Previous reviews on drinking water chlorination have mainly focused on manual POU chlorination methods used in households, and chlorine usage in emergency situations[18].

Passive chlorinators, devices that automatically release chlorine into water prior to collection, have emerged as a means to enhance water safety. It's important to note that while the chlorine dosing process is passive, the operation and management of passive chlorinators still require active efforts, such as refilling chlorine, ensuring consistent dosing accuracy, and ensuring treated water meets disinfection and user taste/odor standards[19]. A comprehensive review of passive chlorinators is necessary due to the plethora of devices developed in recent years. This critical review aims to provide a thorough analysis of the evidence on the effectiveness of

[15] Mohamed, H., Brown, J., Njee, R. M., Clasen, T., Malebo, H., & Mbuligwe, S. (2015). Chlorination of water from 43 sources representing a range of turbidities was effective using both single and double doses up to 20 nephelometric turbidity units. Journal of Water and Health, 13(2), 544, 10.2166/wh.2014.001

[16] World Health Organization and the United Nations Children's Fund . *Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines*, 2017

[17] Hendrickson C.; Oremo J.; Akello O. O.; Bunde S.; Rayola I.; Akello D.; Akwiri D.; Park S.-J.; Dorevitch S. Decentralized Solar-Powered Drinking Water Ozonation in Western Kenya: An Evaluation of Disinfection Efficacy. *Gates Open Research* 2020, 4, 56. 10.12688/gatesopenres.13138.1

[18] Bivins A.; Beetsch N.; Majuru B.; Montgomery M.; Sumner T.; Brown J. Selecting Household Water Treatment Options on the Basis of World Health Organization Performance Testing Protocols. *Environ. Sci. Technol.* 2019, 53 (9), 5043–5051. 10.1021/acs.est.8b05682

[19] Skinner B.Chlorinating Small Water Supplies. *Water, Engineering and Development Center*; Loughborough University, 2001

passive chlorinators, identifying their impact in elevating water supplies to the safely managed standard by delivering an adequate dose of free residual chlorine. The review examines performance, advantages, limitations, and potential research directions for passive chlorinators, offering guidance to researchers and practitioners involved in their development and implementation.

Passive chlorinators are devices designed to disinfect water by releasing a controlled amount of chlorine into the water supply. This ensures that the water is safe to consume and reduces the risk of waterborne diseases. In Kenya, where clean and safe water access can be challenging in certain areas, passive chlorinators have been considered as a cost-effective solution to improve water quality, particularly in schools, healthcare facilities, and other public places. The implementation involves several key considerations:

1. **Water Quality Improvement**: Healthcare facilities require clean and safe water for effective medical services. Passive chlorinators can be installed in these facilities to disinfect water and remove pathogens that can cause waterborne diseases.
2. **Partnerships and Collaborations**: Successful implementation often requires collaboration between government agencies, NGOs, international organizations, and local communities. These partnerships provide the necessary support, funding, and expertise.
3. **Training and Capacity Building**: Effective usage requires training facility staff and community members on proper operation, maintenance, and monitoring of the chlorinators to ensure ongoing access to clean water.
4. **Monitoring and Maintenance**: Regular monitoring and maintenance are essential for proper functioning. This includes checking chlorine levels, addressing technical issues, and replacing chlorine cartridges as needed.
5. **Community Engagement**: Involving communities and facility staff enhances ownership and encourages proper usage. Community members can also report any issues with the system.
6. **Impact Assessment**: Evaluating the impact of passive chlorinators on water quality and health outcomes is crucial. Monitoring the reduction of waterborne diseases resulting from access to clean water is important.
7. **Challenges**: Challenges may include initial costs, chlorine cartridge availability, training, and consistent maintenance. Addressing these challenges requires a comprehensive approach.
8. **Scaling Up**: Successful implementation at individual facilities can serve as a model for expansion to cover more facilities and communities

3.4. Water Quality in Western Kenya

Water resource governance in Kenya has long called for the integration of a participatory approach to address its complex challenges. A pivotal study by K'akumu in 2008 examined the reforms initiated by the Water Act of 2002. This legislative effort aimed to transform water management in the country.[20] However, it is essential to recognize that despite these reforms, the government remains a dominant force in water management. This underscores the critical need to fortify local institutions to enhance water resource governance in Kenya.

In Western Kenya, particularly in counties such as Kisumu and Migori, an enduring issue has been the persistent water scarcity, even though these areas are in close proximity to Lake Victoria. A comprehensive analysis conducted by IRO ONG'OR and Shu Long-cang in 2007 identified a multitude of contributing factors to this water scarcity challenge. These factors include the weak implementation of by-laws, societal attitudes, corruption, reliance on outdated technology, inadequate financial resources, and limited managerial skills.[21] To effectively address these multifaceted challenges, a combination of short-term and long-term strategies is imperative.

While commendable progress has been made in expanding access to piped water, significant gaps in water accessibility still persist. To bridge these gaps, substantial upfront investments in water infrastructure are needed. Additionally, there is a pressing need for the rehabilitation of existing water networks. Furthermore, adopting a demand-based service delivery approach is crucial to ensure that a broader population can access safe and reliable water services, as highlighted by the research of Wagah, Onyango, and Kibwage in 2010.[22]

Post the promulgation of the constitution in 2010, the spotlight shifted to the advantages of enhancing access to piped water. Research has underscored how impoverished urban households in the lake region of Kenya rely on a diverse array of water sources for various purposes. Notably, the research highlights the indispensable role played by protected springs, shallow wells, and community-managed boreholes in providing accessible water sources to these communities. Furthermore, the emphasis is on the critical importance of ensuring that these communities have access to good-quality water.

In Western Kenya, particularly in the informal settlements of Manyatta A and Migosi in Kisumu, there is a growing concern regarding the quality of drinking water. Over time, the risk of water contamination has escalated, primarily due to an increasing number of hazards. Research conducted by Okotto-Okotto et al. in 2015 indicated that the presence of Total Coliforms (TTC) in a water sample is a clear indicator of contamination by fecal matter, raising concerns about the potential presence of harmful pathogens.[23]

Further investigation in Kericho District revealed troubling findings. Too et al. (2016) reported that a significant proportion of household drinking water in this region is contaminated with TTCs, including pathogenic multidrug-resistant E. coli. This contamination is linked not only to the source of water but also to household hygiene practices and handling. Factors such as source of water, transportation containers, covering during transportation, storage containers,

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[20] K'Akumu, O.A. (2008). Mainstreaming the Participatory Approach in Water Resource Governance: The 2002 water law in Kenya. Development, 51(1), 56-62. DOI: 10.1057/palgrave.development.1100457

[21] BASIL TITO IRO ONG'OR basil_iro@hotmail.com & SHU LONG-CANG (2007) Water Supply Crisis and Mitigation Options in Kisumu City, Kenya, International Journal of Water Resources Development, 23:3, 485-500, DOI: 10.1080/07900620701488554

[22] Wagah, G. G., Onyango, G. M., & Kibwage, J. K. (2010). Accessibility of Water Services in Kisumu Municipality, Kenya. Journal of Geography and Regional Planning, 2, 114-125.
http://www.academicjournals.org/journal/JGRP/article-abstract/E9F373C39648

[23] Okotto-Okotto J, Okotto L, Price H, Pedley S, Wright J. A Longitudinal Study of Long-Term Change in Contamination Hazards and Shallow Well Quality in Two Neighbourhoods of Kisumu, Kenya. International Journal of Environmental Research and Public Health. 2015; 12(4):4275-4291. https://doi.org/10.3390/ijerph120404275

methods of drawing water from storage, feces disposal, and garbage disposal methods were all found to have a significant impact on the presence of E. coli in household drinking water.[24]

The implications of these findings are significant. They underscore the importance of good hygiene and sanitation practices in ensuring the safety of drinking water at the point of use. Ondieki et al. (2022) concluded that capacity building in the region is essential to raise awareness and educate the local population about the risks associated with consuming contaminated water. Addressing these issues is crucial in combating water-borne diseases that pose a serious health threat to the community.[25] In Western Kenya, water quality and safety are pressing concerns, and concerted efforts are needed to mitigate the risks associated with water contamination and promote healthier practices among residents.

4.0. FINDINGS

4.1. Introduction

Thirty-two (32) Key Informants (KIs) out of the 48 targeted KIIs, representing a diverse group of stakeholders representing various sectors and regions were done.

Table 2: Respondent Category

Institution/Organization	Target Number	Achieved number
Davis & Shirtliff store managers and staff	10	5
Healthcare facility representatives (HCFs)	15	12
National and county-level government officials	8	8
Venturi customers, water departments, and regulators	15	7
Total	**48**	**32**

The respondents were sampled from five counties in Kenya namely Busia, Siaya, Kisumu, Migori, and Nairobi. These key informants collectively offered a comprehensive perspective on the challenges and opportunities related to water treatment and healthcare services across different regions and sectors.

4.2. Water treatment products stocked and sold in the local markets by D&S

The world is not on track to meet Sustainable Development Goal 6.1 to provide universal access to safely managed drinking water by 2030. Removal of priority microbial contaminants by disinfection is one aspect of ensuring water is safely managed. Passive chlorination (also called in-line chlorination) represents one approach to disinfecting drinking water before or at the point of collection (POC), without requiring daily user input or electricity.[26] Accessibility to clean water sources and treatment facilities a concern, with limited distribution of water treatment chemical and unaffordability of treatment infrastructure hindering communities'

[24] Too, J. K., Kipkemboi Sang, W., Ng'ang'a, Z., & Ngayo, M. O. (2016). Fecal contamination of drinking water in Kericho District, Western Kenya: role of source and household water handling and hygiene practices. Journal of water and health, 14(4), 662–671. https://doi.org/10.2166/wh.2016.137

[25] Ondieki, J. K., Akunga, D. N., Warutere, P. N., & Kenyanya, O. (2022). Socio-demographic and water handling practices affecting quality of household drinking water in Kisii Town, Kisii County, Kenya. Heliyon, 8(5), e09419. https://doi.org/10.1016/j.heliyon.2022.e09419

[26] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9261193/

access to safe water in some regions in Kenya. Engaging communities in knowledge of water quality and water treatment processes and emphasizing safe water's importance offers an improvement avenue through training and awareness programs.

> *{So , we needed to help community members know the quality of water and water treatment options - so they spend less time in hospitals when they can spend less treating water...} Sub county medical officer port Victoria subcounty hospital Busia.*

The interviews with Davis & Shirtliff at the Nairobi headquarters, as well as their branches in western Kenya in Migori, Busia, Kisumu, and Kisii provided an in-depth analysis of various chlorinators available in the Kenyan market, with a primary focus on Venturi devices, Dosatron, Klorman, and Mixtron as well as other water treatment products sold by the company. These devices and products play a crucial role in water treatment and disinfection, especially in regions with diverse water sources. The analysis covers critical aspects such as chlorine refill, pricing, customer base, installation requirements, treatment capacity, compatibility with infrastructure, maintenance needs, and the source of chlorine.

4.2.1 Capital Cost (Local Market Prices):

Understanding the capital cost of chlorinators in the local market is vital for potential buyers. Klorman units are notably popular, with sales ranging from 50 to 100 units per month, reflecting their demand in the Kenyan market. The cost of a Klorman unit is approximately KES 26,000, making it a competitive choice for various consumers.

> *"So, for Klorman units, we sell around between 50 to 100 units per let's say around 100 to 150 units per month." (D&S Hq)*

> *"The Klorman …unit is about twenty-six thousand twenty-six K (26,000)." (D&S Busia)*

The urban-rural divide influences purchasing patterns, with rural areas relying on communal boreholes, where Klorman units are highly suitable due to their cost-effectiveness and water purification capabilities. Urban centers, characterized by individual boreholes, present a fragmented market.

> *"It's difficult to say because where do people do many boreholes? Is it really in the rural or is it in the urban center? In the rural, I believe it is the urban." (D&S Hq)*

> *"Because in rural, you just need one borehole that will serve a very big community, yes. For the urban people. So, every plot has its own borehole." (D&S Hq)*

In addition to individual consumers, various organizations, including NGOs, UNICEF, municipal water suppliers, and even the Kenyan army, are potential buyers of water treatment solutions.

> *"So, we also work with organizations such as NGOs, UNICEF, and ICIC. We also have municipal water suppliers in every county. There's a county water supply in Nairobi. We deal with Nairobi Water and Nairobi County. Some of the traders that I can think of are the Kenyan army." (D&S Hq)*

In terms of alternative water treatment options, such as reverse osmosis (RO), costs vary based on the volume of water to be treated, with the range typically exceeding 500,000 Kenya shillings for higher volumes.

"Then it's also dependent on what volumes he wants to treat. But basically, for reverse osmosis, is the range of anything be above 500,000? Yeah. Can below 500,000." (D&S Kisii)

Comparatively, Dosatron chlorinators tend to be slightly more expensive, with prices ranging from around 200,000 Kenya shillings, whereas Klorman units are priced at approximately 25,000 Kenya shillings.

"Dosatron are slightly expensive when you compare them with the Klorman. And in most cases, we normally supply them to the county water supply systems and municipal water supply systems. But for these Klormans, normally we sell them domestically." (D&S Migori)

"Roughly? (Dosatron) Could be around 200,000." (D&S Migori)

"Klorman is about 25,000." (D&S Migori)

The market also features alternative dosing pumps, such as Mixtron dosers, with varying price ranges depending on size and capacity.

"Yeah, different prices. Prices have different price ranges. They can range from Dosatron, which would be around close to around just this rough estimate, around 200 shillings to almost a million. Mixtron would be around close to maybe 150,000 to around 600,000 Kenya shillings. Six hundred. Those are just ranges. Okay. Depending on the sizes, the capacity." (D&S Kisumu)

Thus, Klorman units stand out as cost-effective solutions, especially for rural communities, while Dosatron and Mixtron dosers cater to higher-capacity applications at varying price points, addressing diverse consumer needs in the Kenyan water treatment market.

4.2.2 Chlorine Source, Refill Type, and Cost:

Understanding the chlorine source is crucial for operational planning. In Kenya, chlorine is predominantly sourced from companies that produce liquid chlorine. However, due to chlorine's volatility, there is a preference among chlorinator users for solid chlorine. Solid chlorine, such as chlorine 65, is dissolved on-site to create a chlorine solution, ensuring stability and effectiveness.

"We have companies that generate this liquid...So, what we normally do for most of these dispensers is that we have our chemical that is solid chlorine 65. Then you prepare a solution on-site, so you dissolve it on-site." (D&S Hq)

The source and cost of chlorine refills are critical considerations in evaluating chlorinators. Dosatron and Klorman both rely on sodium hypochlorite cartridges for chlorine refill. These cartridges are available at varying costs, influenced by factors like usage and brand. For instance, Klorman refills are priced around KES 9,000, while Dosatron and Klorman cartridges, costing approximately KES 3,000 to KES 3,500, can treat up to 500,000 liters of water.

"Yeah, they are the same (Dosatron and Klorman). We normally use what do you call it? The sodium hypochlorite in the form of a cartridge." (D&S Migori)

While exact pricing figures may vary, the current market price for chlorine in Kenya generally ranges between 300 to 320 Kenyan shillings per kilogram. The availability of chlorine can also be influenced by factors like shipping methods, with container shipments potentially arriving in two months and loose cargo taking longer.

> "I don't have that figure off-head. But if you go to the market currently, the current market price for us is between 300 to 320 Kenya shillings per kilogram of chlorine." (D&S Hq)

4.2.3 Installation Requirement:

The ease of installation is pivotal for potential buyers when considering chlorinators. Klorman, a passive chlorinator, is often regarded as "plug-and-play" and requires minimal additional components. To ensure optimal functionality, pressure considerations play a significant role, especially when dealing with different pressure ranges. The system's sensitivity to pressure underscores the importance of understanding water flow volume and pressure regulation. For electric chlorinators, two common installation methods prevail: wiring them with a pump or integrating them into the primary pumping system. Proper regulation of electric chlorinators is imperative to prevent over-concentration and potential health hazards due to excessive chemical dosing.

> *"We just look at the pressure so we do them online inline. Inline and again we look at the pressure. Pressure is very important because they work along a given pressure ranges so if you put it where there's low pressure it is not injected too much pressure lap a problem so it's a bit delicate to handle. You have to know what volume of water passes and how to regulate and the pressure. Unlike the electric we put, there are two ways of doing the electrics. In most cases, we always wire them with a pump so as it pumps, we regulate. So that if doni doses, it also triggers electric run when they are the main pump. Pumping water is running because if it keeps on dosing and there's no water passing, what will happen? There'll be a lot of concentration. The person who received that chlorine acetate to push will just drink chemical so we wire them." (D&S Kisumu)*

> *"So, you can install an electric doser that can dose as low as around two liters an hour. You can also get very large inquiries, maybe doing around 900 liters per hour, depending on the application." (D&S Hq)*

While passive chlorinators like Klorman are relatively straightforward to install, the cost-effective Venturi-type and Dosatron chlorinators, despite their slightly higher pricing, offer the advantage of versatility in installation. Venturi devices can be set up in areas without electricity and offer proportional dosing based on flow rates. However, it's worth noting that Venturi-type chlorinators are sensitive to water quality, and the presence of suspended particles can lead to clogging and compromised performance.

> *"You find that in terms of cost because these are really brands and slightly, and also, they can do a wide range of flow and pressures, you find that the Venturi type, the Dosatron, are slightly costly compared to the electric ones. Also, the advantage is that you can install that in areas where you don't have electricity and you have proportional dosing based on the flow rates. For the electric ones, it requires some sort of automation because for example, if you want to dose only when water is going through or when you're pumping water, then you need to do some small automation. And again, some of these pumps are constant dosing. They supply constant volume. So, if you want*

again to do proportional dosing, you need to do a little bit of automation. The best disadvantage with this venturi type is the kind of water that you use because if the water has particles in, it's going to clog some of, let's say the dosatron type because you have a plunger and a piston." (D&S Hq)

"I can say the key feature about them (Dosatron and Klorman) is they do not need day-to-day human intervention for them to work, because once you replace the cartridge, as long as the water is flowing, can say passively without intervention of a human being, the chlorine will be dosed in that water as the water flows." (D&S Migori)

"The Dosatron is actually surpass it because it doesn't use electricity. It also works with almost the venturi principle. Whereas the water flows through the line, it sucks in the chlorine. But again, these ones are mostly used in larger water supply systems." (D&S Busia)

To ensure the proper installation of Dosatron, considerations for pressure rating, pipe compatibility, and pump integration must be made. Klorman, in contrast, offers a hassle-free installation process, making it a plug-and-play option for users.

"Now, for Dosatron, since they are of larger capacity applications, of course, you need to consider the pressure rating of the pipes and the pumps, and then you need to identify strategic points where you install that Dosage run." (D&S Migori)

"Yeah, Klorman is so easy (to install). I can say it's a plug-and-play because you only need the normal pipe plus what you call a bypass valve, whereby whenever you don't need the Klorman, you can just lock the valve and your water flows without being chlorinated. Okay." (D&S Migori)

The installation requirements for chlorinators in Kenya can vary significantly, with each type offering distinct advantages and considerations. Understanding these installation nuances is critical to meeting the diverse needs of customers across different regions and water sources in Kenya.

4.2.4 Capacity (# Litres treated per chlorine refill or # Litres treated per filter lifetime):

Chlorinators vary significantly in their water treatment capacity, catering to diverse applications. Venturi devices offer versatility with a broad treatment range, suitable for various purposes. As stated, *"So, the venturi has a bigger range compared to or you can use one type of venturi to pump a wide range of applications compared to an electric," (D&S Hq).*

Dosatron, conversely, is engineered for high-capacity applications, making it an ideal choice for large-scale water treatment systems. It possesses the capacity to treat substantial volumes of water efficiently. As supported by the quote, *"Dosatron is for high-capacity applications, so the refill in terms of cost, of course, is high, but also the amount of water that you will chlorinate with… Will be a high-capacity, I can say maybe 50,000 liters," (D&S Migori).*

Klorman falls in between, offering a capacity of approximately 30,000 liters. It finds its primary application in bulk production scenarios, such as pumping water from a lake to a holding tank, especially suitable for community water supply or high-usage environments. This is attributed to its versatility in accommodating a wide range of flow rates, ensuring a consistent supply. As highlighted, *"In terms of liters, (Klorman takes) around 30,000,"* (D&S Migori).

While Venturi devices excel in versatility, Dosatron stands out for its high-capacity capabilities, and Klorman provides a balanced solution catering to mid-range water treatment needs. Understanding these capacity distinctions is essential in selecting the right chlorinator for specific applications.

4.2.5 Compatibility with Existing Infrastructure:

Chlorinator compatibility with existing infrastructure is a crucial consideration for adoption. All types of chlorinators can be integrated, but it depends on the specific installation and pressure requirements. For instance, Venturi devices may necessitate minor plumbing adjustments and adaptations to the existing water lines:

> *"Whereas with a venturi, depending on the material of construction, you need to do a little bit of plumbing, and some little bit of adaptation to the existing line." (D&S Hq)*

> *"Compatibility with existing infrastructure depends, but I think all of them it depends because assuming you're buying from a borehole pump to a tank, you wouldn't monitor just the pressure and see where to put it. You can put it next to the borehole. Or we put it closer to the tank because we've done those kinds of installations, many of them." (D&S Kisumu)*

The compatibility of these systems is facilitated by the ability to adjust dosage based on water volume. If the water flow is low, the concentration can be increased, and if the flow is high, the concentration can be diluted, making them adaptable to various existing infrastructure setups.

> *"It stops up. It doses to that. When the volume is a lot, you open it up, it takes a lot. When its line has little water, you also adjust or you play with the concentration. So there are two ways of doing it. You make this highly concentrated and dose very little or you open it up and dilute this. So those are two ways of playing with that. So it is compatible with existing infrastructure. You can always adjust that one issue." (D&S Kisumu)*

The ease of introducing chlorinators into existing pipelines makes them very compatible with different infrastructure setups.

> *"Very compatible. Because it's just to be introduced into the pipeline." (D&S Busia)*

4.2.6 Operations and Maintenance:

Efficient operation and maintenance significantly impact the total ownership cost of chlorinators. Electric chlorinators, when properly managed, often require minimal repairs and can operate for extended periods.

> *"For example, for the electric ones, you might run it for a very long time without doing any repairs, as long as you've put the right measures to prevent things like power surges." (D&S Hq)*

However, it's important to emphasize that regular maintenance is vital for the longevity and performance of all chlorinators. This includes routine checks, particularly on the level of the chlorine cartridge for Dosatron and Klorman, to ensure consistent and effective water treatment. Properly dissolved chemicals and high-quality water are also key factors in maintaining chlorinator functionality.

Additionally, technical assistance plays a significant role in the overall operation and maintenance of chlorinators. Services such as installation, sizing, and ongoing support are available to ensure trouble-free operation and extend the lifespan of these technical devices.

> *"So, one, because this is technical equipment, what we do is that we offer installation services. So, we'll go once you purchase it, we'll be able to install it for you. The automation that you require, is the sizing. Then periodically we can have a contract with a service contract that will be visiting your facility quarterly, just to check if everything is okay. Basically, the after-sale service and the installation services." (D&S Hq)*

While electric chlorinators may appear low-maintenance, all chlorinators benefit from regular upkeep, and technical assistance is available to facilitate smooth operation and minimize the need for repairs. The technician's hiring cost varies based on their proximity to the central point or nearest town, ranging from 5,000 to 10,000 Kenyan shillings.

4.2.7 Other Water Treatment Products:

In addition to chlorinators, a range of complementary products is available to address various water treatment needs.

> *"We have the standalone chlorine test strips. I think that they're going for around 2000." (D&S Hq)*

These standalone chlorine test strips serve as a quick and cost-effective method for assessing chlorine levels in water.

> *"So, yes, we do have chlorine, both solid and liquid. For liquid, we use sodium hypochlorite, whereas solid is calcium hypochlorite. Apart from that, we have hydrogen peroxide." (D&S Hq)*

Apart from chlorinators, the product portfolio includes sodium hypochlorite and calcium hypochlorite, which are essential for water disinfection. Additionally, the inclusion of hydrogen peroxide, parasitic acid, and citric acid provides customers with options that do not form problematic byproduct complexes. These chemicals serve various water treatment needs, offering flexibility and effectiveness.

Furthermore, the company offers a variety of dosing pumps, including electric valve dosing pumps, which utilize electricity for precise chemical dosing. A test kit for chlorine and pH testing is also available, simplifying water quality assessment. Additionally, a range of chemicals, such as coagulants like aluminum sulfate, caters to specific treatment requirements, including addressing issues related to scaling. This diverse product range equips customers with comprehensive solutions for water treatment, ensuring water safety and quality across various applications.

4.3. Water Treatment Methods

Although chemical solutions play a significant role in the water treatment, products offered by D&S like "chlorine," "sodium hypochlorite," "hydrogen peroxide," "citric acid," and "aluminum sulfate" were not top of mind those recommended by ministry of health professionals. And although these chemicals are used for various water treatment applications, including disinfection, pH adjustment, and coagulation, and underscores the D&S commitment to offering comprehensive water treatment options they were said to be few in the market. Most homes use liquid chlorine, Aquatab and WaterGuard. The price is also a factor that affect accessibility and usually the methods used are the affordable ones. Embracing new technology was also said to be an issue as well as not trusting some of the water treatment chemicals.

> *{So far, water treatment products that we may procure are few. Like we normally procure liquid chlorine. We can procure other products like the Aqua tab and water guard. So those are the products that in fact, most of the homes we advise them to procure water guard because it is easily found, they can access it easily. It's a bit cheap to use at home, but most of them may not be able to get it given the status, and the standards of their living. Some of them are a little in fact, we may not say they are poor, but they may not be able to afford the water treatment all the time} County Government Migori - PHO Migori*

> {…The primary customers for the passive chlorinators are schools and community projects like NGOs. Individuals may struggle to afford water treatment consistently.,{Some of them are a little in fact, we may not say they are poor, but they may not be able to afford the water treatment all the time….} County Government Official CO-PHO, Migori.

> {One, these are new, let me say new technology. And chlorine, also something people don't trust chlorine. They imagine it's foreign. Anything foreign sometimes is not accepted. There are certain gossips. If you add chlorine, put a quan of a toto. Yes. So you can easily install your dispenser. But people take water, they rather prefer raw water than the disinfectant water because they don't trust either the equipment or the chemicals being used. Then that's number one people's perspective. Then the other one is that we need thorough education. Somebody can easily overdose intentionally. Like I've seen the one at the practical action. You just have a drop into ten liter jerrican. But sometimes, if they're either an adult or even children, they put a lot of chlorine, which now makes water even more unsafe than me. Yeah. Where to? Even, you know, some this these are community, we are assessing the communities.} Sub Basin Area Coordinator, Water Resources Authority

Institutions involved in water treatment face various challenges, ranging from financial limitations, chemical procurement, and treatment facility costs. Infrastructure and technical challenges like inadequate equipment and maintenance concerns, while maintaining water quality remains a recurrent theme, encompassing issues like turbidity and contamination. Ensuring the long-term sustainability of water treatment initiatives presents ongoing difficulties, while building trust in methods, especially chlorine, faces misconceptions and misuse. Supply disruptions of treatment chemicals and equipment can hinder efforts, and climate-related factors, including insufficient rainfall and waterlogging, impact water availability and quality. Highlighted rural-urban disparities underscore opportunities for enhancing water supply and treatment access in rural regions.

4.4. Chlorine testing strips pricing and quantity.

4.4.1 Chlorine Testing Products:

D&S offers a range of chlorine testing products, including accredited lab services, digital meters, photometers, color disks, and test strips. According to a D&S HQ representative, they emphasize the use of accredited lab services and digital meters due to the challenges with color interpretation using test strips. The representative noted, *"The challenge with these strips is that many people, or it varies depending on you. As for us men, we are colorblind. So,* *determining the actual color that will give you the exact concentration is sometimes difficult."* These alternatives offer more precise readings and ensure accurate chlorine dosages.

The chlorine test strips are described as having different colors that change when dipped into water to indicate chlorine levels. A D&S Kisumu representative explained, *"They're different colors. So when you dip it, you look at the color it gives, and you check again. That will tell you the chlorine is a lot."*

4.4.2 Rural Usage and Customer Awareness:

In rural areas, ensuring accurate chlorine dosage is crucial, often requiring testing products alongside installations. The D&S HQ representative emphasized that consumers need to be informed about potential under-dosage or overdosage of chlorine, especially in rural settings. The interviewer further highlighted the importance, stating, *"Our consumers actually need to know when maybe there's under dosage or overdosage of chlorine."* As such, D&S adopts an add-on sales approach, offering chlorine testing products as add-ons when customers inquire about chlorination units. This approach ensures that customers have the means to determine chlorine content effectively. According to the D&S HQ representative, *"It's an add-on cell that we normally provide to customers."*

4.4.3 Pricing, Product Variety and Market Dynamics:

Standalone chlorine test strips are priced at around 2,000 Kenya shillings. Additionally, multi-parameter test strips, which measure more than just chlorine, are available for approximately 6,000 Kenya shillings. The D&S HQ representative clarified, *"Not expensive. We have the standalone chlorine test strips...going for around 2000 [shillings]. Then we have a combined test strip...that go for around six k [6000 Kenya shillings]."*

Regarding market dynamics, the demand for chlorine testing strips may be limited, especially in regions with low awareness. These strips are primarily used in swimming pools, as confirmed by representatives from D&S Busia and D&S Kisumu. A representative from D&S Busia mentioned, *"For this market, it has not been an activated business."* Similarly, a representative from D&S Kisumu noted, *"Mostly we use them for swimming pools...not a lot."*

Table 3: Summary of price range, manufacture, and other details based on interviews with D&S staff

D&S Chlorinator/Water Treatment Products/Filters etc.	Cost/Price (KES)	Manufacturer	Installation Requirements	Water Treatment Capacity / Dosage Capacity	Users/Type of Customer
Alldos Dosage Pump	70,000 - 500,000	Grundfos	Pressure gauge, screen filter, piping	-	Industries, general water treatment
Seko Kompact Chemical Dosing Pump	55,000 - 140,000	Seko	-	5 liters/hr	Industries, general water treatment
Dosatron - 5 models (chemical feeder)	228,000 - 1,150,000	-	-	-Variable depending on model but range is: xxxx-xxxx	Institutions (e.g., schools, hospitals), municipalities
Klorman	26,000	Klorman	Piping, cartridge	-	Small scale/household
Dayliff Mixtron (2 models)	104,000 / 109,000	-	-	-	Institutions (e.g., schools, hospitals), municipalities, community projects
Reverse osmosis (various products)	36,000	-	-	-	Domestic treatment

Chlorine tablets	11	-	-	-	-
Liquid chlorine	193/liter	-	-	-	-
Sediment Cartridges	350	-	-	500,000 liters	Small scale/household
Flocculants	870/5kg	-	-		-
Ultra-filtration systems	-	-	-	500 liters/hour	-
Sand filters	40,000	-	-	-	-
Inline screen filters	1,200	-	-	-	-
Chlorine strips	2000-6,000	-	-	-	Institutions with swimming pools

- Comprehensive description of details and costs different water treatment products is found in the appendix (pp. 37-38)

4.5. HCFs current water treatment practices

The importance of reliable and consistent access to clean and safe water for healthcare facilities cannot be emphasized enough. One of the most important reasons to have access to clean drinking water is that it prevents water borne diseases, improves child mortality rate, prevents deaths and also boosts economic growth.

{clean and safe, means that our patients, their caregivers and our staff consume clean safe water. And hence there'll be no cases of water borne diseases…} subcounty medical officer port Victoria subcounty hospital Busia.

{Having clean water for a healthcare facility, it's significant for not only the members of staff who use water consumption but also outpatients, especially the patients who are admitted in the wards to avoid transmission of hospital-acquired illness. It is good they have access to clean water for their safety, and also for the safety of the community} ***Facility in Charge Muhkobola-Sub County HCF***

Different health care facilities use a variety of water treatment methods. These methods include WaterGuard, PUR, and chlorination. PUR is very good for turbid water, but it's not easily available. Other methods include chlorine dispensers, water kiosks where Aquaguard is sold as well as sterilization and boiling.

{We are able to use water guards for treatment only, although other sources are there, but we are not able to use them because of the resources.} ***Health Care Staff-Arombe, Migori***

{The use of PUR is the main method that you are using for the water treatment}…Kanyanrwanda HCF staff member, Migori.

{PUR is very good that we use for turbid water. But you can't get it easily}. PHO Migori

{We have chlorine dispensers that are streams and water drawing points. Moving dispensers are the ones which dispense chlorine solution to the water which is drawn. That is one. Then secondly, at the water kiosks, the people sell the aquagad, the chlorine solution. At the facility level, there is sterilization using boiling, but it's not very common. And then they also use chemicals, and especially the most common is chlorine- And then for the water treatment works are mass treatment using alum sulfate and chlorine granules, the 45%, which is very common. There is solar disinfection water. Those are minor ones, which sometimes you cannot interact with, but the most common one is chlorine use of chlorine at all those levels, household up to the treatment. CPHO Migori

However, interviews with stakeholders, revealed that chemicals to treat water are not easily available and not affordable at both health facility and household levels. There other challenges mentioned are operation and maintenance of the treatment works both small scale and large scale. The issue of adoption, i.e. is behaviour change and availability of water itself to be treated were also mentioned. The most common water treatment products available in the market are aqua tabs, P&G supplied by Care Kenya and other products by other NGOs like UNICEF as shown by the quote below.

{But, you know, chlorine is not easily available, Aquaguard it's only found in town. You cannot get Aquaguard in the village shops. Some of these chemicals are not easily available}. WSA

{..So, one is availability of the chemicals. Yes, there is availability. There is the cost. You know, availability and costs are very different. You might have the money, but you may not be able to get it. Then there are issues of the operation and maintenance of the treatment works, both small scale and large scale. And then, there issues of adoption, of behavior change. Then there's issue of availability of water itself to be treated. …Sometimes you have chlorine solution, but your water is very turbid. You know, the challenges that come with that. And then the issues of accessibility. We want to maybe make sure that we have 100% clean, safe water. But then we are talking of rural areas which are inaccessible, where even the products cannot reach. And then we have different products in the market that are also confusing} CPHO Migori

{At times we have been having the Aquatabs and at times we have been having the P&G, which we are supplied with Care Kenya. And these other ones, like chlorine brandings, we have been supplied with UNICEF, who come in handy} Sub-County medical officer- Victoria cub county hospital Kisumu.

4.5.1 Sources of water for HCFs

Seasonality and inequalities at the facility and administrative level are critical determinants of water source choice, water availability, cost, and safety. As far as monitoring is concerned, the capacity for national monitoring of WASH in healthcare facilities in Kenya remains very low and widely non-existent in the rural settings at the sub-national level[27]. During an interview with health facility in charges, the main water sources for HFs are boreholes, rainwater harvesting, springs, Rivers, WSPs e.g. port Victoria water supply and KIWASCO and Port Victoria sub county hospital in charge in Kisumu, she said for Victoria Hospital, they get treated water from Port Victoria Water Supply is in the west. Arombe Health Care Facility, get their water from rainwater harvesting. The water harvested is stored in tanks but it is not adequate for all year round use as shown by the quote below while quite a few purchases water from the water truckers.

{So far, the facility we have, the main water source that we have is roof catchment. We have three tanks, although it's small as per what we are supposed to use. Within a period. During the rainy season, we have an adequate amount of water because the tanks are always full, but during the dry season, we have a shortage of water. The roof is able to help us catch a lot of water, but because the tanks are small, we only use whatever we can}. Health Care Staff-Arombe, Migori

Some of the causes of water contamination is population increase, flood water, open sources like dams and water is getting contaminate directly from the dam or river,

[27] https://www.researchgate.net/publication/347974329_WASH_in_Healthcare_Facilities_in_Africa_The_case_of_Kenya

{There is, because people are settling everywhere and the more we have more people, the more waste we generate, which actually contaminates water sources, we still have people getting water directly from open source, even those dams, the rivers.} Arombe HCF staff member, Migori

4.5.2 Challenges faced by HCFs in Water Treatment

Staff at healthcare facilities face several challenges in water treatment. These include lack of adequate storage facilities and a shortage of treatment chemical supplies. As noted by one healthcare staff member,

{the tanks are small" and "we don't have adequate containers for doing the treatment…} Arombe HCF staff member, Migori.

Several healthcare facilities mention inadequate funds as a challenge in maintaining water treatment processes. This financial constraint can lead to shortages of essential treatment supplies like chlorine.

{*…When you don't have the funds to buy the chlorine for me, but an abrupt shortage of water*" (Ndori Sub-County HCF staff member, Siaya).

Some healthcare facilities face challenges of donor driven water treatment projects which when the project comes to an end and the funding is stopped, the disruption of water supply happens.

{And we also don't want the situation where the donors yes, chlorine dispenser, then if it is, it has the lifespan. So beyond that, if it breaks down, then people go back to the situation they had before). Water Resource Authority

The need for training is mentioned as a challenge in some healthcare facilities. Adequate training is crucial to ensure that local staff can effectively use and maintain water treatment equipment and methods using locally manufactured chemicals.).

{locally maintained chemicals are locally available and people so when you are getting awareness the need for treatment whoever is involved either in producing those chemicals or manufacturing the dispensers is also getting some making some money. Yeah. It's in business. Yeah. Not donor based. It's in business} WRA.

4.5.3 Financing mechanisms on water quality management at the county health service/water utility levels?

The findings provide insights into financing mechanisms for water treatment in healthcare facilities, shedding light on various sources of funding and decision-making processes. The county government has allocations each financial year for community chlorine. For example, the last financial year the allocation for community refilling chlorine was about Kshs 5000, 565, while for this year 2023, they have set aside Kshs 758,399. The only challenge is that the money allocated is not sufficient to afford effective water treatment methods. The HCFs also have their own budgets for water treatment approved by the hospital boards. The facility incharge drafts a budget and then presents to the hospital committee for scrutiny and approval.

{For us, we don't budget for water chemicals. The budget that we have is for behavior change, which is actually geared toward water quality improvement. As I said, we have software and hardware for the provision of a budget for behavior change. That one we have, but for chemical purchase and all that. No, that one we don't.} ***County Public Health Officer Migori***

{Yeah, yes, we have. I think even from the last financial year for community chlorine, we had set aside about 500,565 to get up for refilling of chlorine. And now this current financial year that started in July, we had an allocation of about 758 399, that is for refilling of community chlorine.} Finance officer Busia County

And then budgetary allocation by the county government, the money allocated is very small, cannot manage to afford a cost-effective water treatment methods.

{ the budget allocated for water treatment in HCFs is negligible because you see, at a hospital setup, people first of all think of drugs, think of equipment, think of all those. But you know, water now they don't look at it as a very important thing.}

The facility in charge drafts a budget and then presents it to the Committee for Scrutiny and Approval. And then it's passed. After it has been passed, we now forward it to the county.

The County Director of Public Health in Busia County emphasized their commitment to sourcing water treatment supplies from trusted accredited suppliers, saying,

{Most of the time, when you want to procure these supplies, we go through the accredited list of suppliers and equipment written for them to supply us with what we inquire."

{They come up with a budget and the needs of the department, then submit their budgets to the health management team, then the committee, then the health management committee with the budget will also submit what they have discussed to the host. Then if the hospital board approves that, go ahead and allocate the budget or sometimes acquire what is needed} Mukhobola HCF in charge.

4.6. Regulatory Frameworks and Their Significance in Water Treatment

There are guidelines both local and international. The local ones are from the ministry of water in Kenya, from the East African region and from WHO. All the guidelines indicate a strong emphasis on water quality monitoring and analysis. The water department has policies that govern water sources, those public water sources also regulations to just guard even having the boreholes. There are also regulations to guide and look at the treatment part of it, the usage, and water that goes to waste.

{Both Kenya within local and internationally, and these days, also East Africa, because we are talking about using the same guidelines in the whole of East Africa.} WRA

1. The procurement act is what regulates the procurement of products and everything everywhere, all around and everywhere.
    a. The county has a central procurement process that has a list of tender suppliers who have been accredited by the county tender Committee. When they want to procure these supplies, they go through the accredited list of suppliers and equipment written for them to supply. Competitive bidding is done.

{Yes, the water department has policies that govern water sources, those public water sources that so many people share that somebody should not hold and keep for themselves, so everybody will use it. And there are also regulations to just guard even having the boreholes. So, they prevent that. So, there are regulations to that and the laws are there} CECM, County Government of Migori

2. At the county level, WASREB guidelines[28] are adhered to. These are:-
    a. Guidelines on Provision of Water Services in the Rural and Underserved,
    b. Water Safety Planning and Water Vending guidelines,
    c. Corporate, Governance Guideline which addresses the corporate governance standards in the water service providers (WSPs), especially with regards to appointment of board members and the role of the County, Government as the water services function, owner, in the management of the WSPs in their areas.

{Yeah, we have our guidelines as water sources authority. But, you know, those guidelines are also approved and developed by a team in consultation with the Ministry of Water. So, guidelines are almost the same. But when we are talking about the guidelines and harmonizing capitalists with, let's say, East African community, it means it goes beyond our country. And then the Ministry is the one responsible} WRA

{Recently we developed in our department we have Kisumu County Environmental Health and Sanitation Act of 2022, which is already our act in our department, which is…} WRA

4.7. Collaboration with Private Sector in Water

There are WASH forums with stakeholders who are investors in water and sanitation. The INGOs like UNICEF were mentioned as having partnered in water safety and WASH programs. They are the ones who supply the water treatment chemicals. Safe Water and AIDS project (SWAP) and the Department of Water Natural Environment and Natural Resource and Climate Change are involved in promoting water sanitation and hygiene.

{…we have a Wash Forum where we could comfortably introduce this product and really sensitize. The Wash Forum actually has stakeholders who are very keen listeners, and they are actually investors in water and sanitation. So that is one.} CPHO Migori

{Previously we partnered with UNICEF a lot in terms of water safety and wash programs. And most of the time they are the ones that have even been supplying us with some of these water treatment chemicals. Western Kenya sanitation project that is also working in this county in addition to other counties in the western region. And I know they are dealing} CPHO Migori

References to public forums and public participation, as seen in Port Victoria Sub-County Hospital, highlight the involvement of the community in decision-making processes. This suggests that decisions related to water treatment consider the perspectives and needs of the local population.

The mention of the IFMA system and transparency in the WASH Coordinator in Migori implies that decision-making processes have been streamlined for transparency and accountability. It suggests that requisitions for water-related activities are subject to a formal system, ensuring that only budgeted items are considered.

[28] https://wasreb.go.ke/downloads/AQUALINK-JULY-DECEMBER-2019.pdf

Additionally, a collaborative approach is used where stakeholders in the water quality arena are involved. This approach ensures that decisions regarding water quality are made collectively, with a focus on upholding quality standards.

> *{We shall have the stakeholders meeting and then we look at it. It goes through the standards that we normally take care of}* WASREB staff

Furthermore, WASREB staff mentioned that the water safety planning guidelines are in place. They also mentioned a comprehensive approach to public health as they have come up with other guidelines on sanitation.

> *{And by so doing, we have come up with what we call Water Safety Planning Guidelines, which actually guides on the best way to approach all this "On top of that, we have also some other guidelines on sanitation because sanitation is equally our role}."* WASREB

4.8. Technical Assistance D&S Provides to Customers/ Retailers in Water Treatment

The role of D&S is not only selling products but also assisting customers in setting them up effectively. The company offers workmanship warranties within six months, promising support if the equipment does not function correctly during that period.

> *{Yes, we do. As I mentioned earlier, we do installations. Yes, I think that's the major technical support that we offer. So, we do the installation and also, we train customers on the use and then on how to check when the tablet is exhausted and how they need to replace it. That's where we come in.} D&S Kisii*

In addition, customers were being offered training on the use and then on how to check when the tablet is exhausted and how they need to replace it. Government officials also mentioned having received technical support from D&S in procuring water treatment chemicals and other equipment's healthcare facilities, they mentioned assistance provided in repairing generators and pumps'

The need for financial support to ensure the availability of technical assistance is evident. Informants mentioned budget allocations county Governments to enhance their water and sanitation systems.

4. LIMITATIONS

- *Sampling and Regional Focus:* The study focused on five counties in Kenya: Busia, Siaya, Kisumu, Migori, and Nairobi. While this provides valuable insights into these specific regions, it may not capture the full diversity of challenges and opportunities related to water treatment and healthcare services in the entire country. The findings might not be fully generalizable to other regions.
- *Limited Stakeholder Perspectives:* Although 32 key informants were interviewed, there were 16 targeted key informants who were not included. This may have resulted in a potential bias in the perspectives collected, as those not interviewed might have provided different insights or additional context.
- *Subjectivity in Interviews:* The data collected relied on interviews with key informants, which can be subjective. Respondents' perspectives and responses may have been influenced by their own experiences, biases, or the context in which they operate.

- *Limited Time Frame:* The study appears to be conducted within a specific time frame, and the data might not capture long-term trends or changes in the water treatment and healthcare services landscape in Kenya. Long-term observations and data could provide a more comprehensive understanding of the challenges and opportunities.
- *Lack of Quantitative Data:* The study primarily relies on qualitative data from interviews, which provides valuable insights into perceptions and experiences but lacks quantitative data that could offer more robust statistical analyses and a broader perspective on trends and patterns.
- *Generalizability:* The study primarily focuses on the perspectives and experiences of key informants, and while it provides valuable insights for the regions covered, caution should be exercised when generalizing the findings to broader contexts beyond Kenya.

These limitations should be considered when interpreting the findings of the study and may inform areas for further research and investigation.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The report provides a comprehensive overview of the challenges and opportunities in water treatment and healthcare services in Kenya, with a primary focus on water chlorinators and related products available in the market. It underscores the critical importance of ensuring safe water access and quality, especially within healthcare facilities, as a means to prevent waterborne diseases, reduce child mortality rates, and stimulate economic growth. From interviews with stakeholders and insights into various aspects of water chlorinators, we arrive at specific conclusions to guide actionable recommendations. One noteworthy finding is the varying suitability of chlorinators for different healthcare facility (HCF) types. In particular, we recommend the use of Klorman as it emerges as an ideal choice for smaller HCFs located in areas without electricity due to its cost-effectiveness, easy installation, and solid chlorine refill system. In contrast, we found that Venturi-type chlorinators can serve larger HCFs but come with certain challenges, such as sensitivity to water quality. Another critical finding is the underutilization of allocated budgets for water treatment in HCFs. This issue points to a need for better financial management and resource allocation within healthcare facilities. Moreover, the challenges faced by healthcare facilities in water treatment, including inadequate storage, and supply shortages, emphasize the need for increased financial support and training programs. The report highlights the significance of regulatory frameworks, collaboration with the private sector and international organizations, community involvement in decision-making processes, and technical assistance in setting up and maintaining water treatment equipment.

5.2 Recommendations:

1. County Governments and Regulatory Bodies:
   - *Increase Accessibility and Affordability:* County governments should allocate sufficient funds specifically designated for water treatment in healthcare facilities, taking into account the unique budgetary needs of each facility. These funds should prioritize improving the affordability and accessibility of water treatment solutions, especially in rural areas. Explore cost-effective options like Klorman for communities and HF facing financial constraints.

- *Strengthen Water Quality Monitoring:* Collaboratively, WASREB, WRA, and county governments should enhance water quality monitoring efforts to ensure the safety and accessibility of water sources. Regular assessments and data collection should guide improvements in water treatment infrastructure and practices.
- *Behavior Change Initiatives:* Invest in behavior change initiatives, supported by WASREB, WRA, and county governments, to foster trust and encourage the adoption of water treatment chemicals and methods. Public awareness campaigns and community engagement can play a pivotal role in this regard.

2. Healthcare Facilities
    - *Optimize Budget Utilization:* Healthcare facilities should optimize the use of allocated budgets for water treatment. Ensure that these budgets are efficiently managed to guarantee a consistent supply of clean and safe water within the facilities.
    - *Staff Training:* HF should develop and implement comprehensive training programs for staff, empowering them with the knowledge and skills necessary for effective water treatment and equipment maintenance. Regular training sessions should be conducted to keep staff up to date.
    - *Collaboration with Local Suppliers:* HF actively seek collaborations with local suppliers and relevant organizations to secure affordable and accessible water treatment chemicals and equipment. Leverage local partnerships to negotiate favorable pricing and ensure a consistent supply chain.
3. Private Sector and NGOs:
    - *Technical Assistance and Affordable Solutions:* Private sector and NGOs should collaborate closely with government entities and healthcare facilities to provide not only technical assistance but also affordable water treatment solutions. They should also tailor these solutions to meet the specific needs of each facility while maintaining cost-effectiveness.
    - *Community Awareness Programs:* Private sector and NGOs should expand existing awareness programs and campaigns to educate communities on the significance of water treatment and safety. Engage communities directly to ensure that they are well-informed and actively participating in water quality improvement initiatives.
    - Advocacy for Affordability: Private sector and NGOs should advocate vigorously for the availability and affordability of water treatment chemicals and technologies, particularly in underserved regions. They should also engage with policymakers and donors to secure the necessary resources for these initiatives.
4. Davis & Shirtliff:
    - *Technical Support and Custom Solutions:* D&S should continue offering robust technical support to customers, including comprehensive training on equipment usage and maintenance. Collaborate closely with healthcare facilities to provide customized, cost-effective water treatment solutions that align with their specific requirements.
    - *Expand Availability:* D&S should explore opportunities to expand the availability of water treatment products and chemicals in underserved areas, making them easily accessible to communities in need. Consider establishing distribution networks and partnerships to reach remote regions.

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6.0. APPENDICES

6.1. List of Key Informants

	INSTITUTION	ROLE	COUNTY
1	Mukhobola Sub-County Hospital	Medical Superintendent	Busia
2	Sisenye Dispensary	Facility in Charge	Busia
3	Sirimba Mission Hospital	Facility in Charge	Busia
4	Ndori sub-county hospital	Facility in Charge	Siaya
5	Mama Ann's Odede health centre	Hospital Administrator	Siaya
6	Rabel Dispensary	Facility in Charge	Siaya
7	Migori County - Department of Water services	Director of Water services	Migori
8	WASREB	Senior Monitoring & Inspectorate officer	Nairobi
9	MoH -Manyuanda sub-county hospital	Facility in Charge	Kisumu
10	Davis & Shirtliff	Branch Manager	Kisumu
11	WRA	Sub-catchment coordinator	Siaya
12	Port Victoria Sub- County hospital	Medical Officer of MoH	Busia
13	Busia County Water Services Department	Director of Water services	Busia
14	Davis & Shirtliff	Branch Manager	Busia
15	Davis & Shirtliff – Migori	Technical & Sales Supervisor	Migori
16	Migori County Water Dept.	CO Water Services	Migori
17	Migori County Water Dept.	CECM Water Services	Migori
18	Migori County Hospital/Public Health Office	WASH Coordinator	Migori
19	Migori County Water Dept.	Sub-county water officer	Migori
20	Migori County Public Health Dept.	CO Public Health	Migori
21	Macalder sub county hospital	Public Health Officer	Migori
22	Ungoe community medical and dental clinic	Clinical Officer	Migori
23	Arombe dispensary	Nurse and Facility in charge	Migori
24	Ministry of Education	Director of Education	Kisumu

25	County Government of Busia	Sub-county Watter Officer	Busia
26	Ministry of Education	Sub-county Quality Assurance Officer	Busia
27	MoH - Kisumu County	Sub-county Public Health Officer	Kisumu
28	Public Health Unit - Busia	Finance/Budget Coordinator	Busia
29	Public Health Unit - Busia	Director of Prev and Prom Hlth Services	Busia
30	Migori County Public Health Dept.	County Public Health Officer (CPHO)	Migori
31	Davis & Shirtliff	Sales Manager	Kisii
32	Davis & Shirtliff	Country Head of Sales - D&S HQ	Nairobi

6.2. Types of Passive Chlorinators

passive chlorinator (product info)	chlorine dosing mechanism	flow regime	current system compatibility	dosing control mechanism	associated costs (USD, inflation adjusted)
Tablet					
ADEC Clorador/Adapted CTI-8***b (self-constructed)	dissolution	gravity or pressurized	prior to storage tank	manual bypass valve	device: $150–200.00
					chlorine refill: 10 tablets included in device cost
A'jin Chlorinator*** (not reported)	dissolution	not reported (evaluation underway)	not reported (evaluation underway)	not reported (evaluation underway)	device: cost not reported, evaluation underway
AkvoTur (self-constructed)	dissolution	gravity	after storage tank, pretap	number of slits in the tablet chamber exposed	device: $7.00
Arch Chemical Pulsar 1 (commercially available)	dissolution + Venturi	gravity or pressurized	not reported	manual bypass valve + internal slit position	no costs reported
Aquatabs Flo (commercially available)	dissolution	gravity	prior to storage tank	screw restricting outflow	device: $20.00 (including tablets)-$46.00 (cost of full installation with additional hardware)
Aquatabs Inline*** (commercially available)	dissolution	gravity or pressurized	prior to storage tank or tap	manual bypass valve	device: $58.00
Aquaward (commercially available)	dissolution	gravity or pressurized	prior to storage tank	manual bypass valve	device: $608.35
chlorine dosing bucket (self-constructed)	dissolution	gravity	at the tap	manual bypass valve	device: $50.00
CTI-8 (self-constructed)	dissolution	gravity or pressurized	prior to storage tank	manual bypass valve	device: $267.06
					device: $49.50
floating chlorinator (not reported)	dissolution	N/A	floating in well or storage tank	no. of tablets, slit position	device: $7.00

passive chlorinator (product info)	chlorine dosing mechanism	flow regime	current system compatibility	dosing control mechanism	associated costs (USD, inflation adjusted)
Fluidtrol Process Technologies Chlorinator (research grade)	dissolution	pressurized	prior to full distribution system	not reported	no costs reported
MINSA (Panama) chlorinator (self-constructed)	dissolution	gravity or pressurized	prior to storage tank	none	device: $32.95
					device: $15.00
Norweco (commercially available)	dissolution	gravity	prior to storage tank	manual bypass valve	device: $82.50
PurAll 50H (commercially available)	dissolution	gravity	handpumps	none	device: $60.00
PurAll 100 (commercially available)	dissolution	gravity or pressurized	prior to storage tank or tap	manual bypass valve	device: $662.00
					installation: Cost of full installation + installation hardware included
T-shaped erosion chlorinator (self-constructed)	dissolution	gravity or pressurized	prior to storage tank	manual bypass valve	no costs reported
Waterway + OceanBlue (commercially available)	dissolution	gravity	prior to storage tank	none	device: $168.24
Water Mission Erosion Chlorinator*** (commercially available)	dissolution	gravity or pressurized	not reported	linear flow control valve	no costs reported
Vulcano Code 102200*** (commercially available)	dissolution	gravity or pressurized	prior to storage tank	manual bypass valve	no costs reported
Water4 NuPump*** (not reported)	dissolution	not reported	not reported	not reported	no costs reported
Liquid					
AguaClara (research grade)	linear chemical dose controller	gravity	multi-stage water treatment plant	linear chemical dose controller	device: $49063.00-83382.00 (cost of full treatment plant, not just chlorinator)
Blue Tap (research grade)	Venturi + patented hydraulic control	gravity or pressurized	prior to storage tank	needle valve regulator	device: $160
Nirapad Pani (research grade)	suction	pressurized	handpump (inlet)	internal regulator	device: $26.12
Stanford-MSR Venturi (research grade)	Venturi	gravity or pressurized	at tap	needle valve regulator	device: $34.00 (estimated cost at scale)
Zimba (commercially available)	suction	gravity	handpump	not reported	device: $112.16
Granular					
hypochlorinator (self-constructed)	dissolution	gravity or pressurized	prior to storage tank	manual bypass valve	no costs reported
pot chlorinator (self-constructed)	dissolution	N/A	floating in well or storage tank	none	device: $3.12

6.3. Photos of D&S Stores and Products

D&S Store – Busia Branch

D&S Filters – Kisumu Branch

D&S pH Minus – Kisumu store

D&S water purifier – Kisii store

D&S Filters, Cartridges, and Dosatron

6.4. D&S water treatment products (Comprehensive List)

D&S Chlorinator/Water treatment products/Filters etc.	Cost/Price in KES	Manufacturer	Installation requirements	Chlorine refill requirements	Water treatment capacity /dosage capacity	Users/type of customer
Alldos Dosage Pump (DDE 6-10)	96000+VAT	Grundfos	Chemical tank Power	Depends on dosage and flowrate	6Ltrs/hr chemical dose 1:2000 for flowrate	Industrial where precise dosage is required
Seko Kompact Chemical Dosing pump (AML and DPT)	96000+VAT for DPT 68000+VAT for AML	Seko	Chemical tank Power	Depends on dosage and flowrate	5ltrs/hr chemical dose 1:2000 for flowrate (1Ltr supports 2 cubic of water)	Both domestic and industrial (DPT is an alternative to Grundfos)
Dosatron chemical feeder	250,000 – 1.1 million + VAT	Dosatron	Line pressure Chemical feeder tank	Depends on line flowrate The feed is not limited to chlorine, other chemicals can be used: fumigation, acetic acid etc.	0.01cubic (10litres) - 20 cubic of chemical dose 1:500 for flowrate (20cubic can support up to 10,000 cubic metres of water)	Domestic Municipal Industrial

Chemical tanks (60L-1000L) GRP tanks	21,800 - 213,000+VAT	Davis&Shirtliff	-	Depends on concentration requirement	Any	Domestic Municipal Industrial
Klorman (inline, and 2000)	23500 cost of inline klorman 317,000 cost of Klorman 2000	Klorman	Connecting plumbing works	For smaller units 1ppm - 10ppm (Klorman inline) Uses tablets for dosing/it is not a venturi	16000 cubic meters	Domestic Municipal Industrial
Mixtron (MX 250 and MX 300)	MX 250 is about 104,000 MX 300 is 109,000	Mixtron	Line pressure Chemical feeder tank	Depends on line flowrate but limited to 2% concentration Chemical not limited to chlorine alone - can support any non-corrosive chemical including acids, alkalis and polymers	Can support 0.01 to 3 cubic meters of chemical flow 1:500 for flowrate (3cubic can support up to 1500 cubic metres of water)	Domestic Municipal Industrial
Reverse osmosis (various products)	Different depending on raw water TDS (for mini-RO, smallest - 35,400 to the largest RO for 5000ppm goes for 11.6 million	Davis&Shirtlif -components such as membranes and pressure vessels are imported	Power Tank Plumbing and electrical works Plant room for the bigger system	Disinfection required for stored treated RO water at 2ppm of chlorine	10Ltrs/hr to 20,000 ltrs/hr	Smallest can be used for domestic. Medium and largest are used or municipal and industrial purposes
Various filters and softeners (cartridges, multimedia filters, UF systems)	Cartridges: 790 - 3,500 Multimedia filters: 32800-1.4 million UF system: 206 -11.1 million	Davis&Shirtlif -components such as membranes, pressure vessels and pumps are imported	Power Tank Plumbing and electrical works Plant room for the bigger system	Disinfection required for stored filtered water at 2ppm of chlorine	10Ltrs/hr to 30,000 ltrs/hr	Smallest can be used for domestic. Medium and largest are used or municipal and industrial purposes

Chlorinators/dosing system	Chlorine cost	Repair requirement	Compatibility
Venturi type (dosatron, mixtron)	Min 5kg costs 2200, largest which is 45kg costs 16425	Moving parts tend to wear, spare parts are needed Technician needed to replace and repair broken parts	Pressurized pipeline Adopt appropriate pipe size for compatibility
Electro chlorinator (Seko and Grundforce)		Electronic components tend to wear, spare parts are needed Technician needed to replace and repair broken parts	Pressurized pipeline Availability of power Adopt appropriate pipe size for compatibility

Source: D&S Headquarter, Nairobi

Notes

- Third party retailers of D&S water treatment products are all over Kenya
- Cost of chlorine ranges from 350 to 450 per kg of chlorine 65
- D&S stocks multiparameter testing chlorine strip (lamotte instar test strips)
- Liquid chlorine (20Lts) costs 3500
- Local sources for bulk liquid chlorine include Angelica, Panafric chemicals, Eurochem, Orbit chemicals.