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Establishment of District-Led Production of WHO-Recommended Alcohol-based Hand Rub (ABHR) during the COVID-19 Pandemic: A Model for Improving Access to ABHR during Health Emergencies

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Abstract

In response to the COVID-19 pandemic, we established and sustained local production of alcohol-based handrub (ABHR) at district scale for healthcare facilities and community, public locations in four districts in Uganda. District officials provided space and staff for production units. The project renovated space for production, trained staff on ABHR production, and transported ABHR to key locations. The production officer conducted internal ABHR quality assessments while trained district health inspectors conducted external quality assessments prior to distribution. Information, education, and communication materials accompanied ABHR distribution. Onsite ABHR consumption was monitored by site staff using stock cards.

On average, it took 11 days (range: 8-14) and 5,760 USD (range: 4,400-7,710) to set up a production unit. From March-December 2021, 21,600L of quality-controlled ABHR were produced for 111 healthcare facilities and community locations at an average cost of 4.30 USD/L (range: 3.50-5.76). All ABHR passed both internal and external quality control (average ethanol concentration of 80%, range: 78-81%). This case study demonstrated that establishing centralized, local production of quality-controlled, affordable ABHR at a district-wide scale is feasible and

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Conflict of Interest
Some project implementers (FT, MK, FO, IH and YS) were part of the evaluation.

Competing interests: None

strengthens the ability of healthcare workers and community locations to access and use ABHR during infectious disease outbreaks in low-resource countries.

Keywords

Alcohol-based hand rub; Community locations; Hand hygiene; Health emergency; Healthcare Facilities

Introduction

The supply of alcohol-based handrub (ABHR) is a critical need to support easily accessible, quick, effective hand hygiene in healthcare settings and is an important complement to handwashing with soap in non-healthcare facilities (CDC, 2022; Pittet and Donaldson, 2005). However, commercial production of ABHR in low- and middle-income countries (LMICs) is limited by the persistently high cost and limited availability of materials (Lamorde et al., 2020), which are exacerbated during public health emergencies (McMahon et al., 2020; Uganda Radio Network, 2020). Before the COVID-19 pandemic, about 38-56% of hospitals in selected LMICs, which included Afghanistan, Democratic Republic of the Congo (DRC), Haiti, Nepal, and Tanzania, had access to ABHR; access was even lower in smaller, frontline healthcare facilities (HCFs) (McMahon et al., 2020). Community and public locations are likely to even have had more limited access to hand hygiene materials given the few standardized hand hygiene guidelines for those locations; however, formal assessment of ABHR coverage in these settings is limited (World Health Organization, 2020).

To improve access to quality ABHR at lower cost, the World Health Organization (WHO) has published protocols for local, facility-level production of two ABHR formulations (World Health Organization, 2010). Relatedly, SARS-CoV-2—the virus that causes COVID-19—and Ebola virus strains are susceptible to the WHO ABHR formulation, with log reductions greater than 5.9 in laboratory settings (Siddharta et al., 2017). In 2016, a cost analysis conducted in Rwanda found that locally-produced ABHR was 71% less expensive compared with commercial ABHR available for purchase (Budd et al., 2016). However, ABHR production typically is not feasible for smaller, primary facilities that may be unable to order raw materials and lack the space and technical capacity to produce ABHR (Lamorde et al., 2020). Although prior work in southwestern Uganda since 2018 suggests that ABHR production at a district scale is feasible and useful for outbreak response when established prior to outbreaks in Uganda (Tusabe et al., 2023), the establishment of new ABHR production sites, distribution, and monitoring systems during an active public health emergency or outbreak response has not been attempted. This study therefore assessed the feasibility of establishing and maintaining local production of high-quality ABHR and concurrent distribution to and monitoring at HCF and non-HCF settings at district or sub-district scale during an active outbreak in an LMIC. Results can inform considerations for and best practices in establishing local ABHR production during outbreak settings, in contrast to other methods of ABHR procurement.

Methods

Prioritization of ABHR Distribution Locations

During the early stages of the COVID-19 pandemic in Uganda, Amuru and Tororo Districts were identified as areas of concern for viral transmission as border districts due to high levels of use by migratory populations, including truck drivers (Berendes et al., 2022). The Population Connectivity Across Borders (PopCAB) toolkit (NCEZID, 2021) was implemented to characterize population movement patterns in HCFs and community settings at high risk for COVID-19 transmission in Tororo and Amuru districts. The PopCAB results were utilized to prioritize locations for ABHR distribution in the two districts. Subsequently, Moroto and Kotido districts were identified as areas of concern for COVID-19-related challenges due to having largely pastoral populations and a semi-arid climate with challenges to water availability (Nicol et al., 2021); all public and private not-for-profit HCFs were prioritized. Locations prioritized across districts are shown in Table 1.

ABHR Production Unit Set up

Production units were established in Amuru and Tororo districts in March and April 2021 and in Kotido and Moroto districts in August 2021. Where needed, minor renovations were planned and performed as shown in Photo 1, including securing and upgrading the space with improved ventilation (generally by installing air conditioning systems). All production units were situated near the district medical storage locations to facilitate quality control and distribution.

ABHR Production

In each district, a technical officer with previous experience in ABHR production assessed the space proposed by the district government for ABHR production using a checklist for local production of ABHR (supplementary material 1) adapted from the WHO protocol (World Health Organization, 2010). Two WASH project officers (one for both Amuru and Kotido and the other for Tororo and Moroto) were hired and trained on the local production and quality control of the ABHR.

To promote sustainability, 12 district staff (three in each of the four districts) nominated by the District Health Officer were mentored for three days on the production and quality control of ABHR. The ABHR was produced by the trained WASH officers, based on the WHO guide on the local production of ABHR (World Health Organization, 2010). Internal quality control was performed immediately post production and externally at pre-distribution by measuring the alcohol content using an Economy Tralle & Proof alcoholmeter model number MT307 (Brewmaster, Pittsburg, CA) as described in supplementary material 2. ABHR production and distribution was demand-driven based on amounts requested by HCFs and non-HCF settings monthly during consumption monitoring (see below).

ABHR production quantities were recorded by the producer at the production (L) and were compared with national data on confirmed positive cases recorded during the ABHR project cycle. Covid-19 disease data was provided by the Uganda's Ministry of Health Public Health Emergency Operations Center.

The assignment of roles and responsibilities was consistent with those proposed when establishing ABHR production in non-outbreak settings shown in Table 2 (Tusabe et al., 2023).

ABHR Distribution and Consumption Monitoring

Distribution in the two districts, responding to the heightened demand during the COVID-19 pandemic, used hired vehicles. Last-mile distribution of ABHR in Amuru and Tororo to HCFs and community spaces was supported through project funds given that there was no established government supply chain for hand hygiene or WASH-related materials to community locations.

ABHR consumption was monitored at the receiving locations using standardized stock cards (supplementary material 3). At the healthcare facility, the liters of ABHR received was entered in a stock card by the person at the medical store for the HCF as received item and the remaining amount of ABHR was tracked accordingly on the stock card as the facility filled and refilled its 1-L empty ABHR containers. Similar stock cards and tracking was done by wardens at markets and places of worship, the officer in charge at police checkpoints, POEs and police stations and prisons, and the teacher in charge of health at schools.

Cost analysis

All raw materials involved in the ABHR production were procured from local markets.

Costs included production site renovations, procurement of production equipment (buckets, mixing paddles and alcoholmeter), ingredients (distilled water, 95% ethanol, 100% Glycerol, 6 and or 3% hydrogen peroxide) dispensers, distribution, and salary costs. Costs per liter of ABHR were calculated by dividing the total costs involved (raw materials, one-off supplies, staff salaries, overhead and distribution costs) by the total ABHR (L) produced (Table 3).

Results and Discussion

Once a production location was identified, it took 5-17 days for the project to establish an ABHR production site in a district, which included renovations and set up as shown in photo 1.

In 2021, 21,600L of quality-controlled ABHR were produced using WHO formulation 1: 7,980L and 8,720L were produced between April and December 2021 for Amuru and Tororo, respectively, and 2,980 L and 1,920L produced between August and December 2021 for Kotido and Moroto, respectively. All ABHR batches produced (n=535) passed internal quality control (IQC) and external quality control (EQC) for alcohol concentration (target: 75-85%) (World Health Organization, 2010) (Table 2).

The highest monthly production of ABHR was 2,000 L in Amuru district in November (Figure 1A), 1,100 L in Tororo for June (Figure 1B), 900L in Kotido for October (Figure 1C), and 1,040 L in Moroto for August (Figure 1D). Larger volumes of ABHR were produced even during non-COVID-19 disease peak months, this could have been due to preparedness efforts. With all the COVID-19 disease increases, the districts had enough ABHR to quickly respond to its demand that may have been triggered by high-risk perception.

COVID-19 data from Uganda Ministry of Health Public Health Emergency Operations Center Between March and December 2021, 6,420L of ABHR were distributed to 34 locations in Amuru and 5,120L to 36 locations in Tororo. Between August and December 2021, 1,200L were distributed to 19 HCFs in Moroto and 1,140L to 22 HCFs in Kotido (Supplementary material 4). Using project vehicles, the project supported last-mile delivery (Davison et al., 2021) during the first month of implementation in Kotido and Moroto. After this period, some HCFs made direct requisition requests to their respective District Health Office and, upon approval, which usually was received in less than a day. HCF representatives picked up the ABHR from the district medical stores. Direct-to-HCF distribution was facilitated by the National Medical Stores (NMS) distribution system that delivers essential drugs quarterly to public HCFs. Otherwise, ABHR distribution was coordinated by the district IPC and store person with project staff support.

The average monthly ABHR consumption for HCFs across all districts was 7.0L for HCII, 15.0L for HCIII, 29.8L for HCIV, and 29.9L for hospitals. Across community locations, which were limited to Amuru and Tororo, the average monthly consumption was 22.0L for schools, 10.5L for markets, 11.8L for churches, 27.3L for guesthouses, 21.5L for POEs, 23.0L for checkpoints, 13.1L for police stations, 16.0L for prisons and, and 14.2L for truck checkpoints (Supplementary material 4).

Renovation, including air conditioning systems installation costs, ranged from $2,300 (Tororo) to $5,600 (Kotido) in USD. The average cost per liter of ABHR was $4.30 across the four districts (range: $3.50–$5.76) (Table 4a).

Increasing ABHR access and utilization is important in reducing the transmission of highly infectious diseases like COVID-19 and the Ebola virus. Similarly, providing access to multiple user-friendly hand hygiene points (functional ABHR dispenser bottles) minimizes sharing and allows for increased social distancing (Hayashi et al., 2022), which is partly a preventive measure for contagious diseases. Local production of ABHR at a district scale was feasible to establish, maintain, and adapt to new production needs during the height of the COVID-19 pandemic in Uganda, as well as in subsequent years when the pandemic was waning. Critically and uniquely, it enabled both HCFs and priority community locations to have regular and routine access to quality-assured ABHR, even during times of increased need for ABHR. The average total costs per liter of ABHR were affordable ($4.30) and similar to findings during non-pandemic times in Uganda (Tusabe et al., 2023). It was also less expensive than commercial ABHR, which was about $10/L until pandemic-driven supply limitations and inflation increased overall costs to about $60/L (Uganda Radio Network, 2020). The cost difference for local production between sites is attributed to the high renovation costs of the ABHR production units and the low ABHR volumes demand for Moroto and Kotido. The low demand was attributed to the concurrent infection prevention and control programs funded by non-governmental organizations in these districts that supported the HCFs with commercial ABHR. Despite this difference, costs were less than that of commercial ABHR (Uganda Radio Network, 2020). With increased production that would ensure access to lower-cost raw products, costs could significantly scale down even further compared with commercial ABHR.

ABHR consumption in frontline HCF was higher during the pandemic than during pre-pandemic, non-outbreak periods, which necessitated increased production capacity. In southwestern Uganda in 2018 and 2019, HCIIs had lower average monthly consumption of ABHR (3.0L) prior to the COVID-19 pandemic (Tusabe et al., 2023) than during the pandemic (7.0L). Given that primary HCFs receive fewer supplies yet are the frontline of the healthcare system (Armstrong-Hough et al., 2018), ABHR demand and subsequent consumption by healthcare workers may have been higher than pre-pandemic levels, with use increased even further due to risk perception. Notably, this study is one of the first to document locally produced ABHR consumption in community, public locations in Uganda, which will be informative as hand hygiene guidance and normative standards become more detailed in these locations (World Health Organization, 2020).

Considerations for ABHR production and last-mile delivery during an outbreak

The infrastructure and systems established during COVID-19 were subsequently utilized in response to the Sudan ebolavirus disease (EVD) outbreak in Uganda (CDC, 2023). When the EVD outbreak was first declared on September 20, 2022, affected HCFs did not have to rush to find hand hygiene materials because many were rapidly provided with a supply of ABHR through the existing district-led program for ABHR local production built during the COVID-19 response. The project team rapidly mobilized resources to the affected districts with the EVD outbreak and produced over 17,000L of ABHR within 7 days of the outbreak being declared. Nearby ABHR production units pivoted from district-level production to supplementary production for response to affected locations. Non-governmental organizations aiming to provide ABHR to HCFs opted to purchase raw materials for the production units to produce ABHR locally rather than purchase commercial ABHR in response to the EVD outbreak (CDC, 2023). This rapid production was more sustainable than alternatives and resulted in more than enough ABHR to support every HCF in the affected districts, including the Mubende Hospital, giving healthcare workers easy access to hand hygiene resources. These investments helped the global community to support more sustainable local preparedness and response measures rather than one-off measures.

Although manually-filled standardized stock cards worked well for reporting ABHR consumption both in community locations and HCF, reliable monitoring of ABHR consumption during an emergency is complex and may require context-specific solutions to be defined and operationalized. These approaches would need to be examined during future emergency responses.

To improve sustainability and manage ramping up production during periods of peak demand, associated risks like high cost of raw materials and staff burnout, we involved government and key stakeholders from the project conception. This ensured the inclusion of ABHR to the list of medical countermeasures (MCM) and obtained stakeholder buy-in to the contingency plan for emergency ABHR provision aligned to the national countermeasures plan. To leverage response efforts to spread expertise to partners, we developed and are piloting an online training curriculum to build ABHR production capacity in collaboration with stakeholder entities to align with the Global Health Security Agenda's call for improved global access to MCMs (Simpson et al., 2020) in a more sustainable manner. These efforts can improve future preparedness efforts; however, the approach is still primarily donor-funded, especially during response efforts. As such, there is no budget at the national level to facilitate the rapid mobilization of resources (e.g. trained producers, raw materials) when there is a public health emergency to scale up production. There is a need to establish and sustain the local ABHR production approach (including sustainable supply chain and delivery mechanisms) within emergency response support and funding measures nationally, as well as scale it for access in Ugandan HCFs and community settings during non-outbreak periods with a particular focus on addressing the gaps identified during past pandemics and epidemics (World Health Organization, 2023).

Conclusions

Although this approach can serve as a guide, roles and responsibilities for stakeholders in production and distribution may differ in other countries and by the outbreak vs. non-outbreak production contexts. Costs were relatively low because the model capitalized on existing structures (e.g. personnel, buildings that were converted to ABHR production units, and systems/vehicles for delivery); however, if such structures were not in place, cost per liter would have been higher. District officials can support local ABHR production with space, staff, and distribution logistics, while non-governmental organizations can support renovations, initial raw materials, training, quality control, and monitoring of consumption. Country-specific optimization of roles, responsibilities, and shared costs (leveraging existing economies of scale) are important areas of future research for this model.

For cost-saving and destruction of any possible contaminating spores, WHO guides suggest cleaning and disinfection (reprocessing) of re-usable ABHR containers between new ABHR refills (World Health Organization, 2010); however, step by step guides are limited and feasibility has yet to be assessed especially in community locations. In the current project, guidelines for reprocessing ABHR containers were developed and piloted only in HCFs. Future research is needed to identify whether these guidelines are sustainable and feasible as communicated to existing healthcare facilities, as well as assess feasibility in non-healthcare locations.

This case study documents a feasible approach for LMICs to use to establish/ leverage district-wide production and distribution of ABHR—a critical prevention measure—in the middle of the response to an outbreak. Results from this case study, combined with future research, can improve access to and use of ABHR for both future preparedness and response contexts.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Disclaimer:

The findings and conclusions of this paper are those of the authors and do not necessarily represent the official position of the U.S. Centers for Disease Control and Prevention (CDC) and Infectious Diseases Institute (IDI).

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Highlights

This case study established a centralized approach for local production of quality-controlled, affordable alcohol-based handrub (ABHR) at a district-level during infectious disease outbreaks/health emergence.

Centralized, district-wide local production of ABHR is feasible and enables Healthcare facilities (HCFs) and priority community locations to have regular access to quality-assured ABHR to support hand hygiene during a health emergency.

Production units meeting World Health Organization standards were operational within 11 days after production site selection and ABHR costs were less than $5/L.

This study established estimates for ABHR consumption rates in small, medium, and large healthcare facilities and in community locations during a health emergency.

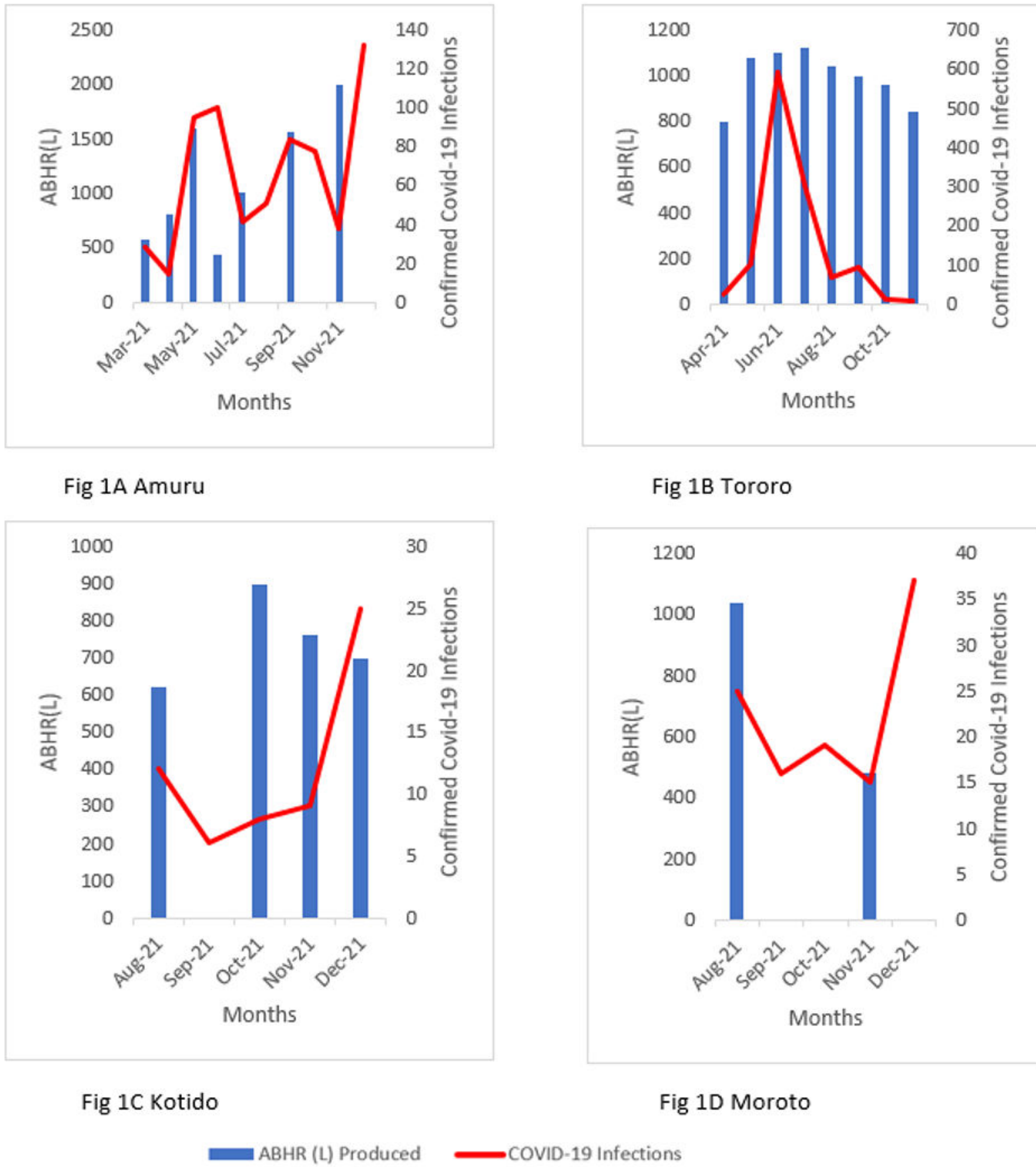

Figure 1.

ABHR (L) Production by District and Concurrent COVID-19 Infections

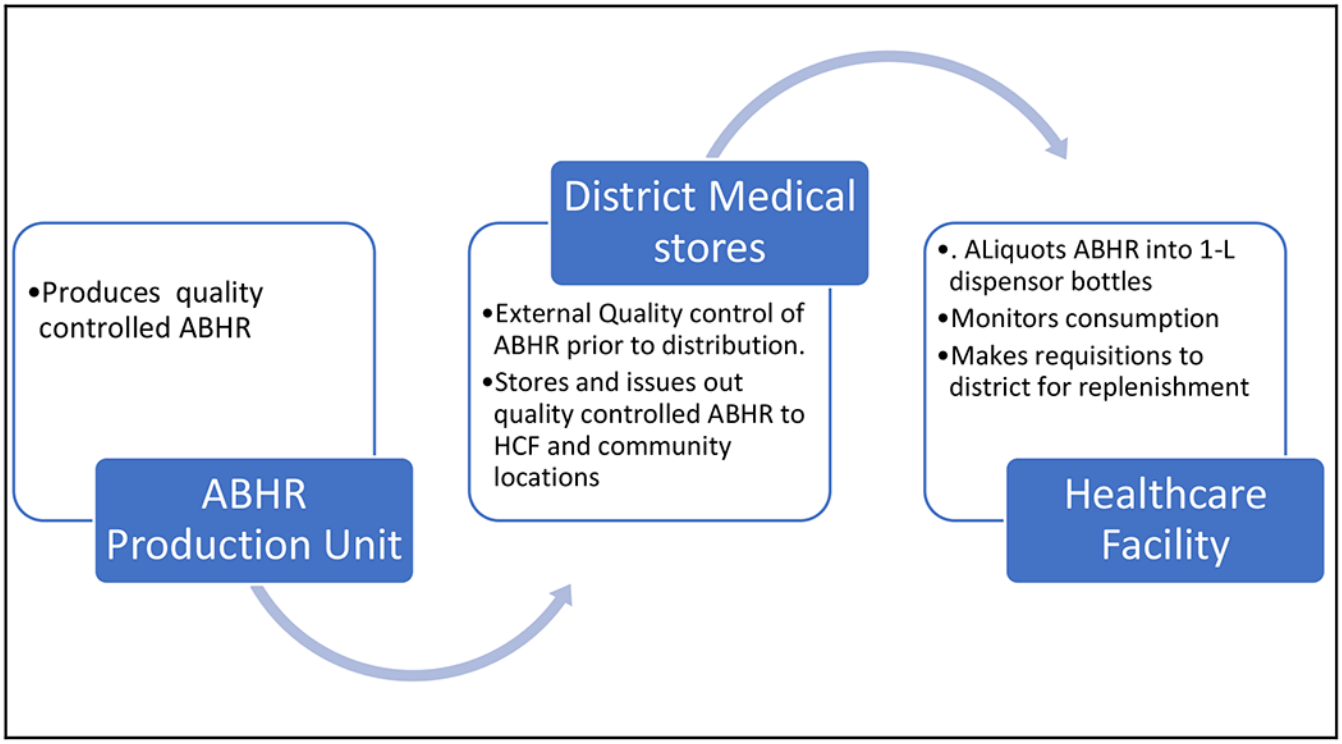

Figure 2.
ABHR Production, Distribution and Consumption Monitoring Cycle

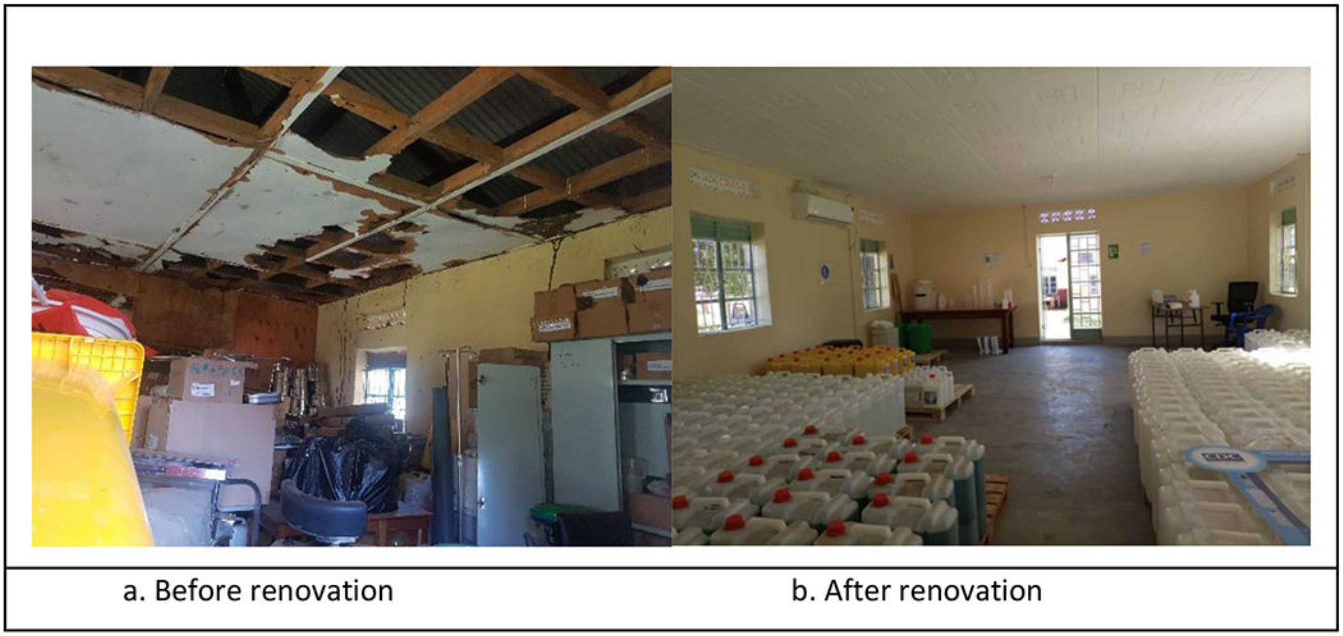

Photo 1.

Renovation and setup of the Kotido ABHR Local production unit

Table 1.

Prioritized locations for ABHR Distribution

Location	Level/Type	Number	Daily Population Estimates (Medical and Non-medical staff)	Daily Total population estimates reached
Healthcare facilities[1]	II	26	12	312
	III	25	55	1,375
	IV	08	53	424
	Hospital	04	130	520
Schools	Primary	02	400	800
	Secondary	06	600	3,600
Markets	Daily	08	300	2,400
Places of worship	Church	06	200	1,200
	Mosque	01	200	200
Point of entries[2]	N/A	03	12000	36,000
Guest Houses	N/A	11	15	165
Truck check points	N/A	07	300	2,100
Police Stations	N/A	04	200	800
Prisons	N/A	02	300	600

[1]HCFs within the Uganda healthcare system are classified into levels based on their catchment areas and the services they provide. The levels of HCFs include Health Center (HC) II, which provides community-based, outpatient service having Target population of 5000 people, HC III, which additionally includes simple diagnostic and maternal health services, with Target population 20,000 people. HC IV, which additionally includes surgical services with target population 100,000 people., and hospital, which has specialized services in addition to all other services provided by lower-level HCFs with target population 500,000 people (Munabi-Babigumira et al., 2019; Namaganda et al., 2015).

[2]Data on estimated populations passing through points of entries were not captured within this project and are estimated from the International Organization for Migration (IOM).

Table 2.

Roles and responsibilities of partners in alcohol-based hand rub (ABHR) district-wide approach.

District Health Office	Implementing Partners	District Stores/National Medical Stores
• Provide space for ABHR production unit and storage • Identify district staff to be trained in ABHR production • Produce ABHR, packaging, and branding • Conduct internal quality control • DHT conducts external quality control • Manage ABHR supplies • Strengthen ABHR use through mentorship programs in HCF	• Supply needs and purchase of raw materials • Establish and functionalize production units including SOPs • Train district staff on ABHR production • Technical support supervision • Monitor consumption at HCFs • Engage the Ministry of Health for the provision of supplies through NMS to enhance sustainability	• Store ABHR raw materials Monitor stock levels • Store final ABHR product and manage issuance to HCFs • Support distribution of ABHR to HCF using NMS distribution networks

ABHR = Alcohol-Based Hand Rub

DHT = District Health Team

HCF = Healthcare facility

NMS = National Medical Stores

Table 3

Alcohol-Based Handrub Internal and External Test Results

		ABHR Quality Control						
					95% Confidence Interval of the Difference			
	District	*N	Mean (%)	Std. Error Mean	Lower	Upper	Minimum (%)	Maximum (%)
	Amuru	201	79.79	.028	79.72	79.86	78	80
	Tororo	211	79.80	.029	79.73	79.87	78	81
	Kotido	75	79.89	.051	79.81	79.97	79	81
	Moroto	48	79.90	.057	79.79	80.00	79	81

*ABHR Batches for both internal and external quality checks

Table 4

a. Costs of Alcohol-Based Handrub Production at a district-wide scale during health emergencies

District-Wide ABHR Costing	**Amuru**[1]	**Tororo**[1]	**Kotido**[2]	**Moroto**[2]
ABHR produced (L)	7,980	8,720	2,980	1,920
Cost of raw materials ($)	10,900	12,083	4,583	3,583
Cost of one-off supplies[3] ($)	4,850	4,400	7,710	6,083
Cost of staff salaries ($)	13,714	10,286	0	0
Overhead costs[4]	400	400	400	400
Distribution Costs	3,600	3,600	1,000	1,000
Cost per liter ($)	4.19	3.50	4.59	5.76
Cost per ABHR liter without Salaries and distribution costs (recurring cost, $)	2.00	2.00	4.13	5.03

[1] ABHR production in Amuru and Tororo commenced in March and April 2021 Respectively

[2] ABHR production in Moroto and Kotido commenced in August 2021

[3] One-off supplies included [graduated cylinders, mixing tanks/buckets, alcoholmeters, air conditioning system, working benches, chairs, refurbishing of facilities and personal protective equipment]

[4] Overhead costs included stationery, ABHR production Unit maintenance, Transport and lunch allowance to district producers.

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b. Advantages, and Potential Limitations of Alcohol-Based Handrub Production at a district-wide scale during health emergencies

Advantages of District-wide ABHR Production
• 12 District Laboratory Technicians and Health inspectors, 3 in each district, were trained to sustain production and quality control.
• Raw materials for Formulation 1 (96% Ethanol, 3 or 6% Hydrogen peroxide, Distilled water, 98-100% Glycerol) were readily available on the local market.
• Districts are in full control of ABHR production and distribution.
• Feasible to be introduced or scaled up during a public health emergency
Potential Challenges to District-Wide ABHR Production
• ABHR production requires that there are enough trained staff to conduct routine production as part of their regular job duties
• Currently, districts may not have budgets to sustain production (Procurement of raw materials).
• In most community locations, reprocessing ABHR dispenser bottles was a challenge.
• The challenge for last-mile delivery of ABHR to non-HCF as there is no clear supply system to leverage for sustainability.