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Challenges and Capacity in Health Product Storage: Cold Chain and Dry Storage Assessment in Northwestern Nigeria

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Abstract. *Objectives: The study assesses the capacity and efficiency of health facilities in Katsina State, Northwestern Nigeria, to store health products that require both cold chain and dry storage. Study Design: This survey-based research was conducted across randomly selected health service delivery points in all 34 Local Government Areas (LGAs) in Katsina State. Methodology: Eleven data collectors, trained on the adapted USAID|DELIVER Project's Logistics Indicators Assessment Tool (LIAT), evaluated storage conditions at 314 health facilities. Results: Six cold chain and seventeen dry storage indicators were assessed. Findings reveal better infrastructure for dry storage than cold storage. While 72-91% of facilities met most dry storage indicators, only 39% had accessible fire safety equipment. For cold storage, just 23% of facilities had electricity during the visit, 36% had functional refrigerators, and 13% maintained liquefied petroleum gas supplies for backup. Conclusion: Health facilities in Katsina State face challenges, particularly in cold chain storage. Investments in reliable power sources and fire safety are recommended to improve storage conditions and safeguard public health.*

Keywords: *Cold chain, storage conditions, health products, public health, Africa*

I. INTRODUCTION

Optimal storage conditions are essential to maintaining the efficacy, potency, and safety of health products throughout their shelf life (Ahmed et al., 2022; Fadiji et al., 2023). While the loss of potency in drugs is widely recognized, the potential harm from degradation products, including adverse events and carcinogenic effects, is often overlooked (Yang & Kar, 2023; Hackman et al., 2020; Glorieux et al., 2024). The need for proper storage practices becomes even more pressing in regions like Northern Nigeria, where populations are large and healthcare infrastructure can be limited (Ezeudu et al., 2022; Abubakar et al., 2022; Aghaji et al., 2021). Katsina State, one of Nigeria's most populous regions, is characterized by numerous health facilities across its 34 LGAs, underscoring the importance of efficient storage systems to meet the state's health demands (Abubakar et al.2022; Chukwuemeka et al., 2023; Ammani and Barau, 2023).

Several factors impact the storage of health products, including the structural integrity of the facility, availability of storage equipment, and environmental controls (Mishra et al., 2022). Cold storage faces unique challenges in Nigeria due to frequent power outages, which disrupt temperature-sensitive supplies such as vaccines (Ogwengo, 2020; Eze, 2022). Dry storage is also affected by environmental conditions like high room temperatures, common in regions such as Katsina (Sabiru et al.2024; Balarabe et al., 2022).

Additionally, the knowledge and practices of healthcare personnel in managing inventory and adhering to best practices—such as the First to Expire, First Out (FEFO) principle—are critical to reducing waste and ensuring product availability (Chisholm et al., 2021; Singh et al., 2022). Previous studies have documented high levels of expired drugs in Katsina, raising concerns about the management of donated health commodities by public health programs (Inyang, 2024; Balogun and Aka, 2022).

This study aims to evaluate the storage capacity of health facilities in Katsina State, focusing on both cold chain and dry storage indicators. Findings will provide insights to guide improvements in storage practices and

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infrastructure, ultimately supporting better healthcare outcomes

II. METHODOLOGY

This cross-sectional survey collected primary data on storage conditions at health facilities through on-site verification and observation. Sample size determination considered the total number of public and private health facilities in Katsina (1,718), with a 95% confidence interval and an assumed 50% "gold-standard" adherence to key performance indicators. This yielded a sample of 314 facilities proportionally distributed across the 34 LGAs.

The USAID|DELIVER Project's Logistics Indicators Assessment Tool (LIAT) was adapted to create a 23-indicator framework, covering both cold chain (6 indicators) and dry storage (17 indicators). Eleven data collectors, each assigned to three LGAs, received extensive training to ensure consistency and accuracy in data collection. Microsoft Excel was used for data aggregation, and qualitative analysis was conducted on observed trends.

Ethical clearance was obtained from Pôle Universitaire Euclide's Institutional Review Board, and informed consent was secured from facility representatives.

Table 1: Result for the Assessment of Cold Chain Indicators

S/N	Indicator	No. of Facilities that Achieved the Indicator	Percentage Pass
1	Operational electricity on the day of the visit	74	23%
2	Functioning refrigerator(s) to store product needing cold storage	113	36%
3	Cold chain commodities kept in ideal temperature between 0 and +8 degrees centigrade	126	40%
4	Refrigerators located away from any surrounding objects (approximately ½ meter)	130	41%
5	Temperature chart up-to-date (to be up-to-date, there must be an entry for the day before the visit)	120	38%
6	Supply of paraffin or LPG for cold chain and sterilization purposes	41	13%

III. RESULT

Cold Chain Storage Indicators

Data on cold chain storage reveal substantial gaps in facilities' ability to maintain ideal storage conditions. Table 1 summarizes the performance of health facilities against each cold chain indicator:

These results indicate that less than half of the facilities met key requirements for cold storage. Only 23% had consistent electricity access, and just 36% had operational refrigerators, compromising the viability of temperature-sensitive products.

Dry Storage Indicators

Dry storage performance was more promising, with most indicators achieved by a large percentage of facilities (Table 2):

While 16 out of 17 indicators met high standards (72-91% compliance), only 39% of facilities had accessible fire safety equipment, highlighting a critical area for improvement in health facility preparedness.

IV. DISCUSSION

The results of this study reveal a complex landscape of health storage capabilities in Katsina State, where dry storage requirements are largely met, but cold chain conditions fall significantly short. These findings align with broader challenges documented across Nigeria and Sub-Saharan Africa, where infrastructural limitations, power instability, and resource constraints

Table 2: Result of the Assessment for Dry Storage Conditions (Indicators)

S/N	Indicator	No. of Facilities that Achieved the Indicator	Percentage Pass
1	Products that are ready for distribution are arranged so that identification labels and expiry dates, and/or manufacturing dates are visible	281	89%
2	Products are stored and organized in a manner accessible for First-to-Expire, First Out (FEFO) counting and general management	285	90%
3	Cartons and products are in good condition, not crushed due to mishandling	283	90%
4	The facility makes it a practice to separate damaged and/or expired products from usable products and removes them from inventory	279	88%
5	Products are protected from direct sunlight	286	91%
6	Cartons and products are protected from water and humidity	288	91%
7	The storage area is visually free from harmful insects and rodents	284	90%
8	The storage area is secured with a lock and key, but is accessible during regular working hours; access is limited to authorized personnel	285	90%
9	Products are stored at the appropriate temperature according to product temperature specifications	283	90%
10	The roof is maintained in good condition to avoid sunlight and water penetration	280	89%
11	The storeroom is maintained in good condition (clean, all trash removed, sturdy shelves, organized boxes)	278	88%
12	The current space and organization is sufficient for existing products and reasonable expansion (i.e., receipt of expected product deliveries for the foreseeable future)	283	90%
13	Fire safety equipment is available and accessible (any item identified as being used to promote fire safety should be considered)	124	39%
14	Products are stored separately from insecticides and chemicals	286	91%
15	Products are stacked at least 10 cm off the floor	265	84%
16	Products are stacked at least 30 cm away from the walls, and other stacks	249	79%
17	Products are stacked no more than 2.5 meters high	227	72%

impede optimal healthcare service delivery, especially in resource-limited regions. This discussion will elaborate on each major finding, compare it with related literature, and explore potential implications for healthcare policy and practice.

Cold Chain Storage Challenges

Cold chain storage presented substantial issues, with only 23% of facilities having operational electricity on the day of the visit and just 36% equipped with functioning refrigerators. This aligns with studies from other Nigerian states, such as Ogun and Lagos, where facilities reported similar struggles in maintaining consistent power for cold storage in the absence of reliable electricity; temperature-sensitive products like vaccines face a high risk of degradation, which could render them ineffective and even harmful if administered. The limited use of backup energy sources, such as liquefied petroleum gas (LPG), further underscores the fragility of the cold chain infrastructure, as only 13% of facilities reported adequate LPG supply.

Comparative studies in low-resource settings, such as rural health centers in Kenya and Uganda, also reveal similar cold chain issues, citing power instability and inadequate refrigeration facilities as barriers to effective vaccine storage. Unlike some countries where solar-powered refrigeration has gained traction as a sustainable solution, Katsina State and similar regions have yet to fully adopt these technologies. Solar-powered systems have shown promise in rural African settings, where they have improved vaccine viability by maintaining consistent temperatures without dependence on grid electricity. This suggests that the use of alternative energy sources could address a significant portion of Katsina's cold chain deficiencies, a recommendation that is reinforced by the existing literature on sustainable health interventions in similar climates.

Dry Storage Conditions and Fire Safety Deficiencies

In contrast to the cold chain, dry storage conditions met or exceeded expectations in most areas, with 72–91% of facilities achieving compliance with essential indicators. Nearly 90% of the facilities maintained products with visible identification labels and expiry dates, organized items for First-to-Expire, First-Out (FEFO) management, and protected health products from sunlight and moisture. These findings are consistent with studies from Ethiopia and Tanzania, where dry storage facilities were similarly effective at managing non-perishable health products through systematic labeling, organization, and physical protection.

However, the low availability of fire safety equipment presents a critical concern. Only 39% of facilities had accessible fire safety resources, which could expose valuable health supplies to potential fire hazards. This mirrors findings from previous studies in West Africa, where the absence of basic safety protocols often leads to significant losses of health commodities during fire outbreaks. Given that many healthcare facilities in rural Nigeria are constructed with minimal fire-resistant materials, the lack of accessible fire safety measures could exacerbate risks to both healthcare workers and patients. Implementing fire safety protocols—such as regular fire drills, availability of extinguishers, and staff training on emergency response—should be a priority, as these are cost-effective interventions that have been shown to reduce fire-related losses significantly.

Implications of Reliable Stastructure

The high compliance rate for dry storage and the corresponding gap in cold chain infrastructure emphasizes the importance of tailored interventions in improving storage practices. Studies in India and Southeast Asia have demonstrated that simple improvements in storage infrastructure, such as fire safety installations and backup energy solutions, have a profound impact on product quality and supply chain reliability. The World Health Organization (WHO) recommended set of standards for health facility storage, including reliable energy sources for cold chain management and stringent dry storage requirements. Adopting these standards in Katsina could improve t of life-saving medicines and vaccines, thereby reducing the high morbidity and mortality rates associated with treatable and vaccine-preventable diseases in the region.

The Role of Training and Knowledge in Storage Practices

This study also underscores the role of healthcare providers' knowledge and adherence to storage protocols, such as temperature logging and FEFO management. The relatively high compliance rate in dry storage indicates a level of familiarity with best practices among facility staff, which could be attributed to previous training initiatives in Katsina State. However, the inconsistent use of temperature charts in cold storage—observed in only 38% of facilities—suggests a gap in training specific to cold chain management.

Research from Ghana and Malawi indicates that regular training sessions and refresher courses in health facilities can improve compliance with complex storage protocols, particularly in environments with frequent staff

turnover. Furthermore, studies suggest that integrating training on energy usage (e.g., solar energy management) and emergency procedures could enhance the sustainability of storage practices, even in the face of resource limitations. In Katsina, reinforcing training on temperature monitoring, cold chain management, and the operational use of alternative energy sources could help maintain the integrity of temperature-sensitive health products.

Policy Implications and Recommendations

Addressing the storage challenges observed in this study calls for both policy and infrastructural changes. First, there is a need for targeted investments in solar-powered refrigeration units, which could provide a reliable cold chain solution without dependence on the national grid. Solar refrigeration has proven effective in settings with similar environmental and logistical challenges, such as remote clinics in Kenya and Tanzania. Second, integrating fire safety protocols within healthcare policy so that facilities are equipped with necessary protective measures significantly reduces the risk of loss from fire-related incidents.

Policy should also prioritize regular training programs for health facility staff, focusing on both dry storage best practices and the specific requirements of cold chain management. Existing programs could be expanded to include modules on alternative energy systems and emergency management, ensuring that staff are well-prepared to manage both day-to-day storage needs and unexpected challenges.

V. Conclusion

This study highlights critical gaps in storage conditions for health products in Katsina State, with cold chain deficiencies posing a significant threat to public health. While dry storage conditions are generally adequate, improvements in power reliability and fire safety are essential to enhance storage capabilities. Targeted investment in solar-powered refrigeration, enhanced training for facility staff, and prioritizing fire safety equipment would address many of the identified issues, supporting safer and more effective health service delivery in the region.

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Declaration Of Conflict Of Interest

The authors declare no conflicts of interest. This research was conducted independently to provide insights for policy improvement and enhanced healthcare delivery.

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