Texila International Journal of Public Health
ISSN: 2520-3134
DOI: 10.21522/TIJPH.2013.12.04.Art009

Cold Chain Adequacy for Childhood Immunization Coverage in Bolgatanga Municipality, A Study in Upper East Region of Ghana

William Fosu Amankwaa[1*], Michael Jeroen Adjabeng[2]
[1]*Texila American University, Guyana, India*
[2]*Public Health Practitioner, Accra, Ghana*

Abstract

Background: The Expanded Programme on Immunization is an initiative that was introduced by the World Health Organization (WHO) in 1974 to ensure there is equitable access to life-saving vaccines for every child, regardless of their geographic location or socioeconomic status. Availability of cold chain equipment such as vaccine fridges, deep freezers and cold-boxes etc are indispensable. Transportation is and human resource equally important to ensure that vaccines reach their destination. The main aim of the study was to assess the cold chain adequacy for childhood immunization coverage in the Bolgatanga Municipality of Ghana. This cross-sectional study employed quantitative methods. A total population sampling method was used to include all the 56 facilities in the Municipality in the study. Some selected health staff were interviewed. The results show that only 28.6% of health facilities had adequate cold chain arrangements in the study area. The study results showed that the majority (87.5%) of facilities had means of transport to support immunization activities however, 53.6% of facilities covered more than 5 kilometres to reach their nearest cold chain site. Again, 57.1% of facilities had only one staff to manage cold chain and immunization activities which was statistically significant (p-value =0.005). The study concluded that cold chain equipment for the maintenance of vaccine potency and to influence immunization uptake in the Bolgatanga Municipality was inadequate. However, means of transport which aided in the collection and distribution of vaccines were not a challenge. Low staffing to manage cold chain and immunization activities was a predictor of low immunization. The study recommends Ministry of Health/Ghana Health Services (MOH/GHS) and partners to procure and distribute vaccine storage equipment to all health facilities in the Municipality. More staffs should be trained in cold chain and immunization activities.

Keywords: *Bolgatanga, Cold Chain Equipment, Coverage, Childhood, Vaccine.*

Introduction

The Expanded Programme on Immunization (EPI) is an initiative that was introduced by the World Health Organization (WHO) in 1974 to ensure there is equitable access to life-saving vaccines for every child, regardless of their geographic location or socioeconomic status. Since its inception, most countries have made efforts to develop context specific implementation processes and over the past five decades, the EPI has evolved into a robust public health intervention that has achieved remarkable milestones and has reshaped the global health landscape [1]. The programme started with only six vaccines, which focused on protecting children against the prevailing six childhood "killer diseases", namely Tuberculosis, Diphtheria, Tetanus, Pertussis, Polio, and Measles. The WHO reports that about 25 new vaccines were introduced in 2021, and this shows the

Received: 10.09.2024 ***Accepted: 07.11.2024*** ***Published on: 27.12.2024***
****Corresponding Author: amankwaawilliams84@gmail.com***

continuous dependence on vaccinations to protect children across the world [2]. In Ghana, the EPI was launched in 1978. However, it only became operational in all regions of the country in 1985. EPI is one of the priority health interventions in the Ministry of Health (MOH) Programme of Work that delivers routine immunization services from health facilities free of charge [3].

Even though vaccines are very critical in child health, the availability of the support structures are necessary to ensure that vaccines get to the target population in potent states and hence an efficient cold chain system is important at every level of the immunization chain. Considering the fact that vaccines require complex handling and storage requirements due to their sensitivity to temperature and light, equipment availability and effective management of the vaccine cold chain system at all levels cannot be overemphasized. Availability of cold chain equipment such as fridges, freezers, cold boxes and carriers as well as the needed transport to move vaccines around are critical determinants of the sustainability and effectiveness of immunization programs all over the world [4]. Its objective is to ensure the uninterrupted availability of quality and potent vaccines from manufacturer to service-delivery levels, so that opportunities to vaccinate are not missed because vaccines are unavailable due to equipment challenges [5]. A study in Uganda indicated that, the stock-outs of vaccines were not due to shortages but rather due to distribution problems within the district mainly influenced by storage facilities [6].

Cold chain maintenance and temperature monitoring are still a major challenge, especially in developing countries, where only around 56% of health institutions adhere to vaccine-keeping requirements [7]. It has also been documented that several African countries lack dedicated vaccine refrigerators, temperature-monitoring loggers, and other necessary equipment for ensuring the viability of vaccines. The Global Alliance for Vaccines and Immunization (GAVI) has noted that Vaccine cold chain storage errors cost huge sums of money in terms of wasted vaccine, revaccination, and specialized transportation [7].

A study in Ghana to assess the cold chain system for vaccines reported that healthcare providers are facing challenges such as power supply, lack of cold chain logistics and transportation and this has affected the ability to maintain vaccines at suitable temperature to ensure their biological potency [8]. Also, a study conducted in the year 2018 indicated that even though Ghana has made significant progress in improving cold chain infrastructure across the country, there are still some lapses about equipment maintenance, staff training, and vaccine wastage due to equipment breakdown. Another study conducted to assess Ghana's cold chain system also identified challenges such as inadequate storage capacity, poor maintenance of equipment, and lack of backup power supply [9].

Problem Statement

The Bolgatanga Municipality used to be one of the high-performing districts until the last three years when performance has been declining compared with set targets of 95% for all antigens by the Expanded Programme on Immunization. (E.g., Penta 1 for 2020=86%, 2021= 79.7%, and 2022= 80.9%; Measles Rubella 1 coverage for 2020= 88.7%, 2021= 81.3% and 2022=79.8%). Secondly, the Upper East region with Bolgatanga Municipality as its regional capital and central district has started recording confirmed cases of vaccine-preventable diseases which serve as a major source of worry; thus the Upper East Region saw 5 confirmed cases of measles, 4 confirmed cases of yellow fever and two compatible polio cases between 2020 and 2022. These low coverages and case confirmation, which needed immediate solutions, could be caused by different factors as already documented in

other research [10] and specific factors in the Upper East Region. Some of these factors may include inadequate cold-chain equipment, old and nonfunctional cold-chain equipment, inadequate transport, difficulty in reaching communities, and inadequate community engagement. This poor performance put the Municipality's progress towards the global vaccine action plan target of achieving 90% in all districts by 2020.

The Bolgatanga Municipality is the second populated district of the Upper East Region of Ghana, targeting over 5,000 children a year and with 56 health facilities [11]. This thus creates a higher demand for vaccines as well as adequate cold chain infrastructure to ensure effective vaccine distribution. Over the years, there has been no systematic study to gauge the status of the cold chain system in the Municipality and this denies stakeholders the needed information about cold chain equipment to improve vaccination in the Municipality. It is against this background that this study is being conducted to assess the cold chain adequacy for childhood immunization in the Bolgatanga municipality of Ghana.

Main Objective

To assess the cold chain adequacy for childhood Immunization coverage in the Bolgatanga Municipality of Ghana.

Material and Methods

Study Area, Design and Population

The study was conducted in Bolgatanga municipality in the upper east region of Ghana, an economically vibrant municipality with a population of nearly 143, 000. The municipality lies between 10033l3011N and 10054l011N and longitude 0048l0l1W and 0060l 0l1W located in the Central part of the Upper East region the municipality shares boundaries with, Bongo District to the North, Bolgatanga East District to the East, Talensi District to the South, and Kassena-Nankana Municipality to the West. The Municipality's immunization system has grown progressively ever since it became fully established and re-inaugurated in March 2018. At inception, the EPI program was offering six pediatric vaccines across the Municipality. This number rose to over 13 antigens by 2019, and there are plans in place to introduce more additional vaccines as the years go by. A quantitative cross-sectional study designed to assess the cold chain adequacy for childhood immunization in the Bolgatanga Municipality of Ghana. The study population included all health facilities in the Bolgatanga Municipality. Selected health staff working in the various health facilities for the study area were included. They included Community Health Nurses (CHN), Community Health Officers (CHO) and Disease Control Officers (DCO). These staff categories were those who were directly involved in immunization activities and could best address the service factors that hindered immunization activities in the Municipality.

Study Variables

Study variables included type of health facility, type of cold chain equipment, availability of motorbikes, etc. The main dependent variable is cold chain adequacy defined by the availability of a vaccine storage fridge, deep freezer, or cold box, and source of power, Availability of a motorbike for transportation of vaccines was also considered.

Sampling Technique and Sample Size

Total population sampling was used, thus all 56 health facilities were assessed. One health staff was selected in each health facility and was interviewed on cold chain and the challenges associated with it in the facility.

Data Collection Tool and Technique

The Data Collection Tool was adapted to align with Ghana's cold chain system. In addition, the tool was slightly adjusted to meet the requirements of the Gavi Cold Chain Equipment Optimization Platform (CCEOP) a

US$250 Million funding scheme that was established in 2015 to support Gavi-eligible countries in transforming their cold chain systems. The final tool, which was pretested and validated by the principal investigator in the Navrongo Municipality, contained questions on health facility/health district background and type of cold-chain equipment and functionality (e.g., equipment type, energy source, functional status, and temperature monitoring devices, transport availability amongst others). The checklist was put on a Kobo mobile data collection tool. Kobo Collect enables one to design surveys, collect data offline, store data securely and export data into various forms (like Excel, CSV, and Google sheet) from the Kobo Toolbox website. A maximum of ten (10) days was used for data collection in June 2023. This study involved the use of smartphones that had the Kobo Collect app downloaded and installed on them.

Statistical Analysis

Data was analysed using Microsoft Excel and IBM SPSS Statistics software version 23. Descriptive statistics were summarized as frequencies and proportions for all variables using Pivot Tables. Second, IBM SPSS Statistics software version 23 was used to run a general linear model univariate and bivariate analysis for the cold chain adequacy to find the linear association between the dependent and independent variables and chi-square (R^2) to measure the variation if the dependent variable can be attributed to the independent variables.

Ethics Approvals and Permissions

Ethical approval was received from the Navrongo Health Research Centre Institutional Review Board (NHRCIRB). Permission was also received from the Bolgatanga Municipal Health Directorate and the authorities at the selected health facilities through written letters by the Municipal Director of Health Service.

Results

Cold Chain Equipment Characteristics

The results showed only 16 (28.6%) had refrigerators in their facilities of which most (87.5%) of the refrigerators were functioning. For deep freezers, 14/56 facilities, representing 25.0% had them. There were 16 (100%) fridge monitoring charts used in monitoring vaccine temperature in both refrigerators and cold boxes as indicated in Table 1.

Table 1. Status of Cold Chain Equipment

Equipment/logistics	Category	Frequency (n=56)	Percentage (%)
Refrigerator	Yes	16	28.6
	No	40	71.4
Functionality of refrigerator	Yes	14	87.5
	No	2	12.5
Deep freezer	Yes	14	25.0
	No	42	75.0
Functionality of deep freezer	Yes	14	100
	No	0	0
Cold box	Yes	13	23.2
	No	43	76.8
Vaccine carriers	Yes	16	100
	No	0	0
Ice packs	Yes	16	100

	No	0	0
Fridge monitor	Yes	16	100
	No	0	0

Note: Data presented as frequency and percentages.

Adequacy of Cold Chain Equipment in Health Facilities

From the data analysis, only 28.6% of health facilities had adequate cold chain equipment in the study district whilst the majority (71.40%) of health facilities did not have cold chain equipment in place as indicated in Figure 1 below.

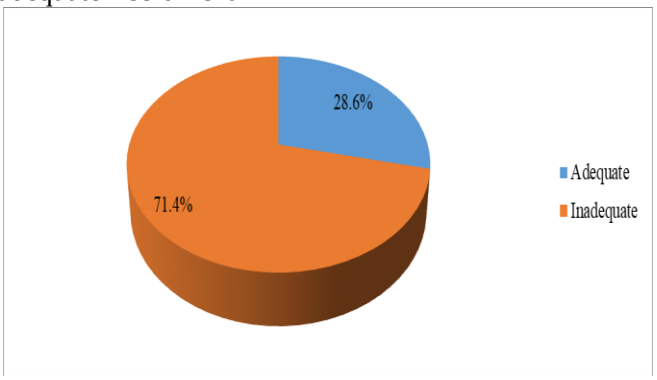

Figure 1. Adequacy of Cold Chain Equipment

Availability of Transport System to Support the Cold Chain System in Bolgatanga Municipality

From Figure 2, most (87.5%) health facilities indicated that they have means of transport for collecting and sending vaccines to the nearest cold chain centre or vaccination point respectively. Only 12.5% did not have transportation in the health facilities to collect and distribute vaccines from the nearest vaccination point.

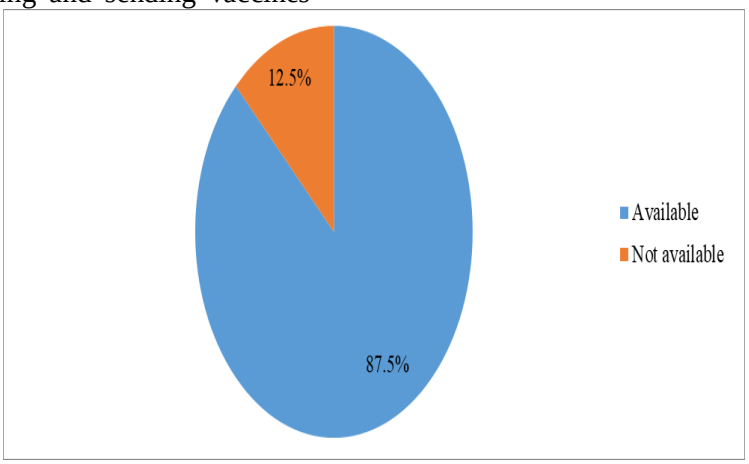

Figure 2. Transport Availability in Health Facilities

Distance to Nearest Cold Chain Site

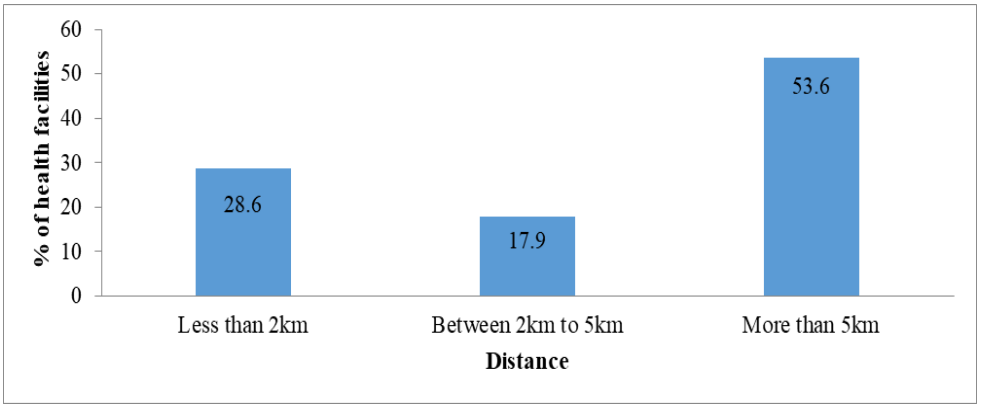

Figure 3. Distance to Nearest Cold Chain Centre

The study showed that 53.6% of all facilities cover a distance of more than 5 kilometres to reach their nearest cold chain site whiles 17.9% cover 2-5 kilometres and 28.6% cover less than 2 kilometres as stated in Figure 3.

From the analysis of the data, 42.9% of the facilities travel more than one hour to the nearest cold chain centre whilst 30.4% travel less than 30 minutes to collect vaccines for routine services as depicted in Figure 4.

Travel Time to Nearest Cold Chain Site

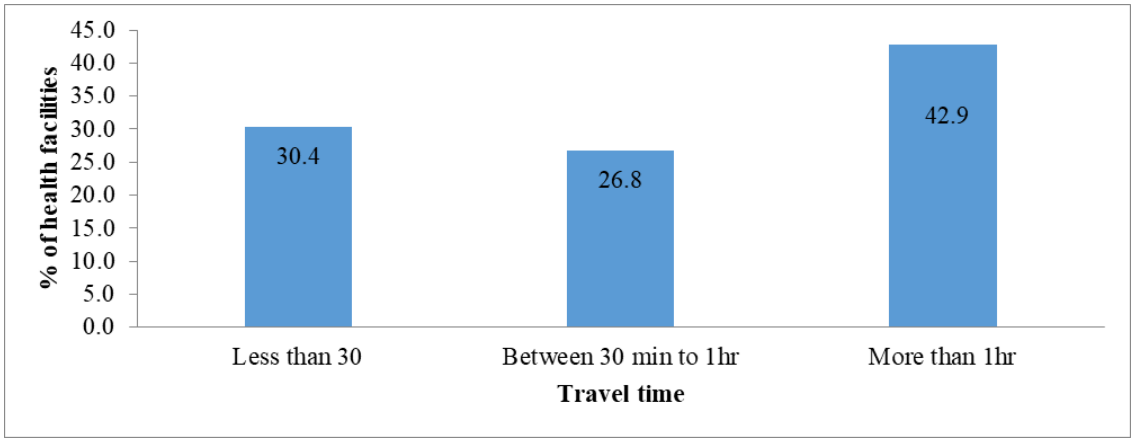

Figure 4. Travel Time to Nearest Cold Chain Centre

Bivariate Analysis of Availability of Cold-Chain Equipment and Transport Availability to Support Immunization Services

From Table 2 results, there are 56 health facilities in the municipality offering EPI services. Only 28.6% of health facilities had adequate Cold Chain Equipment. In addition, 87.5% had motorbikes, and 53.6% travelled more than five kilometres (5km) to the nearest cold chain centre to pick up vaccines for vaccination services routinely. The majority (57.2%) of the health facilities were managed by one trained health staff involved in vaccination.

Table 2. Bivariate Analysis of Availability of Cold-Chain Equipment and Staff Availability to Immunization Services

Variable	Number(n=56)	Percentage (%)	p-value
1. Cold chain equipment adequacy			0.123
Adequate	16	28.6	
Inadequate	40	71.4	

2. Distance to a nearest cold chain centre			0.157
Less than 2km	16	28.6	
Between 2km to 5km	10	17.9	
More than 5km	30	53.6	
3. Transportation availability			0.058
Yes	49	87.5	
No	7	12.5	
5. Staffing Availability			**0.005**
1	32	57.1	
2	10	17.9	
>3	14	25.0	

Note: Data presented as bivariate and p-values.

Discussion

The study revealed that majority of health facilities did not have functioning refrigerators and deep freezers and this clearly affects the storage and distribution of vaccines to vaccination points in the Municipality. The study findings indicated that; only 28.6% of health facilities offering immunization services had refrigerators for immunization services in the Municipality. This means all the remaining 71.4% of health facilities had to pick up vaccines from the nearby vaccine storage centre on their scheduled days and this could cost them much in terms of time and money thereby affecting the successful running of immunization services. It was observed that the study finding is similar to a study conducted in central Ethiopia which saw only 19.0% of facilities with functional refrigerators which impacted negatively on immunization coverage; however, it contradicts a similar study in Ghana which found that more than 50% of health facilities in the Sekyere Central District had functional refrigerators [9]. Again, the findings are inconsistent with another study conducted in the East Gojam zone of the Amhara region in Ethiopia which saw 76.6% of the facilities having refrigerators [12] and another study in Cameroon which also found 75% of facilities had refrigerators for immunization services [13]. The findings of this study also contradict the findings of an Ethiopian study which saw 97.8% of facilities having refrigerators for vaccine storage [14].

Per manufacturer's guidelines, Vaccines are sensitive biological products and require safe handling to safeguard potency. Availability of refrigerators would help maintain vaccines at the correct temperature usually between 2°C to 8°C for most vaccines [15]. It is also necessary for all health facilities to have refrigerators because to the Ghana Public Health Act, immunization services are supposed to be provided daily at health facilities and hence it is proper to have static storage equipment. This helps to avoid wasting vaccines due to heat damage (Public Health Act 2012). Having sufficient refrigerators allows cold chain managers in various health facilities to stock the various required vaccines without the risk of cross-contamination during transportation over longer distances or temperature excursions that could render vaccines unusable [16].

The inadequacy of cold chain equipment is also contrary to a survey in India where it was found that Ice-lined refrigerators and deep freezers were available in almost all (98.6%) health facilities assessed. However, Fridge monitors were present in all facilities with refrigerators which is similar to the study in India [17].

The inadequacy of cold chain confirmed in health facilities (28.6%) calls for efforts of the health authority and the relevant stakeholders

to take action to improve the immunization programme in Bolgatanga Municipality. The current situation will not only affect infant immunization but will impair the capacity of the district to respond to outbreaks and emergencies. Immunization programs often experience fluctuations in demand for vaccines based on factors such as outbreaks of vaccine-preventable disease, seasonal variations, and the conduct of supplemental immunization activities. Sufficient refrigeration capacity therefore allows for storing additional vaccine doses during such peak demand periods [18]. Again this inadequate CCE in the facilities has caused the government and partners many untoward consequences as they struggle to support the national immunization. This is due to high economic losses in the case of the usage of fuel by motorbikes to pick up and use vaccines from nearby cold chain centres. A study in Uganda revealed that a monthly cost of $170.8 was incurred by 19 health facilities for picking vaccines from the nearest vaccine storage centre with a median cost of $8.1 per facility [19]. This study finding is again similar to findings by Ashok, which stated that cold chain equipment inadequacy had affected national immunization [20]. The inadequate cold chain equipment (28.6%) contributed to vaccines running out of stock in some facilities whilst some other facilities had them in stock. Usually, the facilities with vaccine storage always collect vaccines and store them for other nearby facilities to pick on their immunization days, so if for any reason the facility is not able to pick vaccines from the vaccine storage facility, it will result in a vaccine shortage at the immunization site leading to miss opportunities. This result is similar to a study in Ghana, which stated that vaccine stockout because of inadequate storage systems leads to missed opportunities, and contributes largely to low immunization coverage [21]. This result is again similar to a study in Uganda, which indicated that the stock-out of vaccines was not due to shortages but rather due to distribution problems within the district mainly influenced by storage facilities [6].

Secondly, the study revealed that most (87.5.0%) health facilities have a means of transport for their work with only 12.5% declaring a lack of transport for their work. This result contradicts the study which stated that less than half of the facilities lacked transport and picked vaccines using hired motorcycles [19]. The majority (53.6%) travel over 5 kilometres and spend more than one hour (1 hour) to collect vaccines from the nearest vaccine cold-chain centre and hence the availability of means of transport was necessary. The fact that more than half of the facilities travel more than five kilometres and more than one hour to collect vaccines from the nearest health centre, affects immunization uptake. This is similar to results in a study which stated that, the pickup of vaccines by health staff imping their time for delivering immunization services which would lead to missed opportunities. This result is again similar to studies in Nigeria which stated that between 1- 6 hours are saved by the health workers per week if they are not to pick up vaccines from the nearest cold chain centre [22]. Reliable means of transport such as motorbikes and cars are essential for ensuring that immunization services are taken to the doorstep of clients. Transport facilitates the mobility of healthcare workers who administer vaccines and provide immunization services. It allows them to reach remote communities, conduct outreach activities, and participate in vaccination campaigns. In the Bolgatanga Municipality, health facilities in turn have community outreach points that they must reach with immunization services every month, thus making functional transport bikes a necessity [23]. The 12.5% who have no transport in the current study must therefore be looked at as a matter of urgency. Aside from the routine delivery of vaccines, situations such as disease outbreaks or natural disasters

may arise and this requires the rapid transport of vaccines to affected areas. When there are outbreaks of vaccine-preventable diseases, efficient transport infrastructure allows for the quick deployment of vaccines to prevent further spread of diseases among vulnerable populations, including children [23]. Transport enables health workers to conduct community outreach programs, educate caregivers about the importance of immunization, address concerns or myths related to vaccines, and encourage families to bring their children for vaccination. This promotes trust in the immunization program and increases vaccine acceptance among parents and caregivers. By the Community Health Planning and Services (CHPS) concept in Ghana, every CHPS compound must be provided with a functional motorbike as part of the requirements for operating that facility. [24]. This availability of motorbikes is a motivating factor for nurses to run all their outreaches in the community no matter the distance. This study finding is contrary to findings in Ethiopia, which saw less than half (46.6%) of the facilities had cars/motorbikes for transportation of vaccines to support immunization activities [12].

Finally, Cold chain management is not complete without having human resources to manage the equipment. In this study, the majority 51.7% of the facilities had only one trained health staff managing the cold chain which indicated low trained staffing. Thus, most of the staff that supported cold chain management in the study area were without full cold chain management training. This is similar to studies that have shown that poor vaccine handling is associated with technically untrained stakeholders [25]. Again, from this study, the handling of cold chain and immunization in the health facilities in the Municipality was by one trained staff (51.7%) that is supported by other staff like clinicians. This situation forces the trained staff to run to the cold chain center to pick vaccines for immunization which takes some useful time away and puts pressure on them. This study is similar to the findings of a study in Kenya which stated that health workers prefer to work at static facilities rather than travelling to collect vaccines from the vaccine cold store which takes some useful working time away [26]. The constraint of low staffing in health facilities is not novel to the cold chain and immunization but has widely been documented in several scholarly articles as affecting vaccination services [27].

Conclusion/Recommendations

The study concluded that cold chain equipment for the maintenance of vaccine potency in the Bolgatanga Municipality was inadequate. Less than one-third of health facilities were found to have functional cold chain equipment such as refrigerators. However, the majority of health facilities had means of transport and this aided in the collection and distribution of vaccines and rendering immunization services.

The study recommended that the Ministry of Health/Ghana Health Service (MOH/GHS) and partners should procure and distribute vaccine storage refrigerators to all health facilities in the Municipality. The Municipal Health Directorate should also work on securing means of transport for the remaining facilities and adopt regular maintenance schedules to ensure that those who have transportation continue to use them without setbacks.

Conflict of Interest

The author declares no conflict of interest.

Acknowledgements

I thank the almighty God for his mercies during the period of this study. My heartfelt gratitude goes to Dr. Michael Jeroen Adjabeng (Supervisor), for his guidance and corrections during the research period. I also appreciate the commitment of my lovely wife (Mrs. Regina Osei Ferkah) for her encouragement and proofreading during the difficult times of

the study. Finally to all my mentors from the Texila American University who guided me since admission to the end of the course. God bless you all.

References

[1]. WHO, "2023 WHO Global Vaccine Market Report; Agenda, Policy & Strategy (APS), Immunization, Vaccines and Biologicals (IVB)," 2024. https://doi.org/10.2471/

[2]. World Health Organization and others 2022, Vaccines and immunization for monkeypox: interim guidance, https://www.who.int/publications/i/item/WHO-MPX-Immunization

[3]. Ghana Health Service, "Ghana Health Service Annual Report," Ghana, 2007. http://www.ghanahealthservice.org/

[4]. Hanson, K. E. et al., 2023, Safety of measles, mumps, and rubella vaccine in adolescents and adults in the vaccine safety Datalink. Vaccine X, 13, doi: 10.1016/j.jvacx.2023.100268

[5]. WHO, "Measles and rubella strategic framework," 2021. https://www.who.int/publications/i/item/measles-and-rubella-strategic-framework-2021-2030

[6]. Dowling, A. J., 2013, Novel gain of function approaches for vaccine candidate identification in Burkholderia pseudomallei. Front Cell Infect Microbiol, 2, p. 139, https://pdf.usaid.gov/pdf_docs/PA00MKKG.pdf

[7]. Feyisa, Z. T., 2021, Factors limiting youths' practice of preventive measures toward the outbreak of COVID-19 in Oromia special zone surrounding Finfinnee, Ethiopia. PLoS One, 16(3), p. e0248495. . https://doi.org/10.2147/PHMT.S312039

[8]. Le Gargasson, J. B., F. K. Nyonator, Adibo, M., Gessner B. D., Colombini, A., 2015, Costs of routine immunization and the introduction of new and underutilized vaccines in Ghana. Vaccine, 33, pp. A40–A46, doi: 10.1016/j.vaccine.2014.12.081

[9]. Asamoah, D., Agyei-Owusu, B., Andoh-Baidoo, F. K., Ayaburi, E., 2021. "Inter-organizational systems use and supply chain performance: Mediating role of supply chain management capabilities," Int J Inf Manage, vol. 58, p. 102195, doi: 10.1155/2021/7559984

[10]. Russo, G. et al.., 2015, "Vaccine coverage and determinants of incomplete vaccination in children aged 12–23 months in Dschang, West Region, Cameroon: a cross-sectional survey during a polio outbreak," BMC Public Health, vol. 15, pp. 1–11, https://doi.org/10.1186/s12889-015-2000-2

[11]. Bolgatanga Municipal, 2023, Bolgatanga Municipal Health Directorate Annual Report, Bolgatanaga,.

[12]. Bogale, H. A, Amhare, A. F., Bogale, A. A., 2019, Assessment of factors affecting vaccine cold chain management practice in public health institutions in east Gojam zone of Amhara region. BMC Public Health, 19, pp. 1– 6, https://doi.org/10.1186/s12889-019-7786-x

[13]. Yauba, S. et al., 2019, Availability and Status of Vaccine Cold Chain Equipment in Cameroon, Journal of Vaccines & Vaccination. 10, pp. 1- 6, doi: 10. 24105/2157-7560.10.400

[14]. Erassa, T. E., Bachore, B. B., Faltamo, W. F., Molla, S., Bogino, E. A., 2023, Vaccine cold chain management and associated factors in public health facilities and District Health Offices of Wolaita Zone, Ethiopia. Journal of Multidisciplinary Healthcare, 16, pp. 75–84, https://doi.org/10.2147/JMDH.S385466

[15]. Centers for Disease Control and Prevention, 2024, Vaccine Storage and Handling Toolkit. https://www.cdc.gov/vaccines/hcp/admin/storage/toolkit/storage-handling-toolkit.pdf

[16]. UNICEF and others, 2022, Prospects for Children in 2022. https://www.unicef.org/eca/media/19796/file/Prospects%20for%20children%20in%202022:%20a%20global%20outlook%20.pdf

[17]. Rao, S., Naftar, S., Unnikrishnana, B., et al, 2012, Evaluation, awareness, practice and management of cold chain at the primary health care centers in Coastal South India. Journal of Nepal Paediatric Society, 32(1), pp. 19–22, DOI:10.3126/jnps.v32i1.5946

[18]. Lindstrand, A., Cherian, T., Chang-Blanc, D., Feikin, D., O'Brien, K. L., 2021, The world of immunization: achievements, challenges, and strategic vision for the next decade, J Infect Dis, 224(4), pp. 452–S467, https://doi.org/10.1093/infdis/jiab284

[19]. Bakkabulindi, P. et al., 2023, Improving the last mile delivery of vaccines through an informed push model: experiences, opportunities and costs based on an implementation study in a rural district in Uganda. medRxiv, pp. 2011–2023, https://doi.org/10.1101/2023.11.03.23298045

[20]. Ashok, A., Brison, M., LeTallec, Y., 2017, Improving cold chain systems: Challenges and solutions. Vaccine, 35(17), pp. 2217–2223, https://doi.org/10.1016/j.vaccine.2016.08.045

[21]. Kremer, P., Haruna, F., Sarpong, R.T., Agamah, D., Billy, J., et al, An impact assessment of the use of aerial logistics to improve access to vaccines in the Western-North Region of Ghana. Vaccine, 41(36), pp. 5245–5252, https://doi.org/10.1016/j.vaccine.2023.06.036

[22]. Sarley, D., Mahmud, M., Idris, J., Osunkiyesi, M., Dibosa-Osadolor, O., et al. 2017, Transforming vaccines supply chains in Nigeria. Vaccine, 35, pp. 2167–2174, doi: 10.1016/j.vaccine.2016.11.068

[23]. Ouédraogo, Ouédraogo, H. S., Kabore, Y. L. B., Sawadogo, A. G., Bakouan, M., Sawadogo, N., Mano, M., Zongo, A., Sanou, S., & Kaboré, L. 2023, Task-Shifting Immunization Activities to Community Health Workers: A Mixed-Method Cross-Sectional Study in Sahel Region, Burkina Faso. Global health, science and practice, 11(5), e2300044, DOI: 10.9745/GHSP-D-23-00044

[24]. Ahoto, A. T., Giri L. M., Koirala, S., et al, 2021, "Ghana National Community Health Planning and Services (CHPS) policy; gaps between policy and implementation, the need for policy review to address specific gaps," Magna Scientia Advanced Biology and Pharmacy, 2(1), pp. 26–34 DOI:10.30574/msabp.2021.2.1.0013

[25]. Pambudi, N. A., Sarifudin, A., Gandidi, I. M., Romadhon, R. 2022, Vaccine cold chain management and cold storage technology to address the challenges of vaccination programs. Energy Reports, 8, pp. 955–972, https://doi.org/10.1016/j.egyr.2021.12.039

[26]. Zhu, F.C. et al., 2020, Safety, tolerability, and immunogenicity of a recombinant adenovirus type-5 vectored COVID-19 vaccine: a dose-escalation, open-label, non-randomised, first-in-human trial," The Lancet, 395(10240), pp. 1845–1854, https://doi.org/10.1016/ S0140-6736(20)31208-3

[27]. Nabirye, J. et al., 2020, "Health system factors influencing uptake of Human Papilloma Virus (HPV) vaccine among adolescent girls 9-15 years in Mbale District, Uganda," BMC Public Health, 20, pp. 1–11, . https://doi.org/10.1186/s12889-020-8302-z