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A Study on Knowledge of Health Workers on Vaccine Storage, Distribution, and Cold Chain Management in Yemen

Victor Sule[1*], Bilikisu Alatishe[2], Adekunle Ganiyu Salaudeen[3]
[1]*School of Public Health, Texila American University, Georgetown, Guyana, South America*
[2]*Kwara State Ministry of Health, Ilorin Nigeria*
[3]*Department of Epidemiology and Community Health, University of Ilorin Teaching Hospital, Ilorin, Nigeria*

Abstract

The success of the Expanded Programme on Immunization (EPI) over the years is attributed to the immunization supply chain, effective logistics systems, and the health professionals who run them. Gaps in knowledge and practices still exist in developing countries and countries with conflict. Due to the paucity of information regarding the subject in humanitarian settings, this study was carried out. This descriptive cross-sectional study was carried out among health workers at the four levels of the healthcare system in 6 governorates in Yemen. A total of 536 health workers provided responses to the online questionnaire between February and May 2022. The study showed that 515(96.1%) and 521(97.2%) of the respondents, respectively, knew the recommended temperature range for storage of Rota and pentavalent vaccines at the health facility. Most respondents, 415(77.4%) and 413(77.0%) knew the recommended storage temperature for measles and BCG, respectively, and 466(86.9%) knew they could be stored at a negative temperature when the need arises. Over two-thirds of respondents only receive vaccines 411(76.7%), and 124(23.1%) receive and distribute vaccines. Vaccine distribution included the use of refrigerated vehicles (15.2%), cold boxes (32.8%), and vaccine carriers (41.6%), both with conditioned ice packs. Despite the protracted and complex humanitarian situation in Yemen, Health workers demonstrated good knowledge and practices of vaccine storage, distribution, and cold chain management, which contributed to the sustenance of immunization services. There is a need for required investment in a cost-effective and sustainable last-mile vaccine distribution approach to ensure equitable availability of vaccines at health facilities and prevent any missed opportunity.

Keywords: *Cold chain, Distribution, Vaccine storage, Knowledge.*

Introduction

Immunization programmes depend greatly on efficient and effective supply chain systems to store, transport, and distribute these vaccines and health commodities, which ensures that the right products are available at the right place, at the right time, and in the right condition to provide efficient health services to the communities [1]. Evidence has shown that an effective vaccine supply chain system is one of the most vital elements of any immunization programme, which ensures that vaccines reach recipients in their potent form [1]. The success of the Expanded Programme on Immunization (EPI) over the years is attributed to the immunization supply chain and logistics systems and the professionals who run them [2]. Their role is to guarantee as efficiently as possible the uninterrupted availability of vaccines all the way to service delivery levels,

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****Corresponding Author: vsules@gmail.com***

safeguarding vaccine potency from damaging heat and freezing temperatures in a cold chain system [2].

A well-run vaccine storage and distribution system should maintain a constant supply of vaccines, injection equipment, and waste management supplies; keep vaccines, injection equipment, and waste management supplies in good condition; minimize vaccine wastage attributable to spoilage and expiry; maintain accurate inventory records; rationalize the locations where vaccine and other supplies are stored; use available transport as efficiently as possible; monitor the performance of the storage and distribution system and provide information that will help with the forecasting of vaccine and other supplies requirements [3].

A cold chain is a temperature-controlled supply chain that includes all vaccine-related equipment and procedures. The cold chain begins with the cold storage unit at the manufacturing plant, extends to the transport and delivery of the vaccine and correct storage at the provider facility, and ends with the administration of the vaccine to the patient [4].

Vaccines must be stored properly from the time they are manufactured until they are administered. Potency is reduced every time a vaccine is exposed to an improper condition. This includes overexposure to heat, cold, or light at any step in the cold chain. Exposure to any inappropriate conditions can affect the potency of any refrigerated vaccine, but a single exposure to freezing temperatures can destroy potency. Liquid vaccines containing an adjuvant can permanently lose potency when exposed to freezing temperatures [4].

Gaps in knowledge and practices of vaccine storage and distribution involving cold chain logistic systems still exist in many developing countries and countries with a conflict situations. A study in north-western Nigeria showed that only 3.8% of the respondents had good knowledge of cold chain management [5]. A similar study among health workers on vaccine cold chain management in public health facilities in Ethiopia showed that more than 50% of vaccinators and vaccine handlers had satisfactory knowledge and practice [6].

A study of the Evaluation of the Application of Effective Vaccine Management in Wassit Governorate, Iraq, in 2020 assessed distribution comprising the transport of vaccines between each level in the supply chain is effective, including the correct use of passive containers (cold boxes), packing practices with coolant packs (conditioned icepacks or cool water packs), temperature indicators, and maintaining transport contingency plans [7]. A low score indicator was reported in this study because ice packs conditioning and packing are not done in accordance with World Health Organization (WHO) guidelines in 85%, and only 22% reported the use of freeze indicators. [7] However, a similar study in 2018 on Effective vaccine management and Oman's healthcare system's challenge to maintain high global standards in 16 different sites showed a very impressive performance of 99% on distribution criterion as against the standard of 80% set by WHO for the EVM assessment [8].

In 2014, 20% of health facilities in low- and lower-middle-income countries did not have any cold chain equipment to store vaccines and protect them against heat damage. Of the equipped health facilities, only 2% had a functional cold chain that used optimal cold chain technologies. The remaining 78% of facilities were equipped with cold chain equipment that was either not functional or that used obsolete technology, putting vaccines at risk of temperature damage [2].

Cold Chain and Vaccine Management (CCVM) remains an exceptionally challenging component of EPI [4, 9]. These challenges are highly faced, especially in lower levels of the health system, for different reasons like: problems related to vaccine storage, lack of temperature measurement devices, lack of continuous temperature documentation, inadequate refrigerators, impropriate storage

practices, lack of designated personnel, and insufficient staff training [9].

There is the paucity of information regarding the knowledge of health workers on vaccine storage and distribution in humanitarian settings. Therefore, this study was carried out to determine vaccine storage and distribution knowledge of health workers in Yemen.

Materials and Methods

Description of the Study Area

Yemen is situated at the southwestern corner of the Arabian Peninsula and shares a border with Saudi Arabia and Oman. It has a total population of about 32 million people, with 23 governorates, 333 districts, and about 4,500 health facilities providing routine immunization services [10]. The country there has is ongoing conflict of over eight years, making the country one of the world's worst humanitarian crises, with over 68% of the population (including 12.9 million children and 5.2 million women) in need of humanitarian assistance.

The crisis has affected both the delivery of and access to essential services. Over four million people, including two million children, are internally displaced. Many are in a situation of protracted and multiple displacements, straining their resources and exacerbating vulnerabilities. The influx of large numbers of internally displaced persons (IDPs) puts an additional burden on resources in hosting communities, many of which are conflict-affected with significant humanitarian needs.

The country has four immunization supply chain levels, including the central level with a cold store equipped with walk-in Cold and freezer rooms (WICR and WIFRs) where the vaccine for routine immunization and campaigns from offshore are stored and managed by the team led by vaccine and cold chain manager. This level is involved in quarterly vaccine distribution to the governorate level. The governorate level equipped with WICRs for vaccine storage undertakes monthly distribution of vaccine to the districts and districts level equipped with solar direct drive (SDD) refrigerators for vaccines storage, distributes to health facilities or facilities pull vaccines from there on a monthly basis. Both governorate and district cold stores are managed by the EPI focal persons. The Health Facility, which is the service delivery point, is equipped with SDD refrigerators and managed by the facility manager under whom the vaccinators work as focal persons for vaccine management.

Study Design

This descriptive cross-sectional study was carried out among health workers working at the four levels of governance/health care system. Fisher's formula was used to determine the minimum sample size [11]. A total of 536 health workers participated in the study between February and May 2022. Out of the 23 governorates in the country, six governorates, Aden, Lahj, Hajjah, Sanaa, Amran and Dhamar, were randomly selected by balloting. For a better coverage and responses, the health workers at the different levels of service, including central, governorate, districts, and health facilities in the selected six (6) districts were reached with the online research tool to harvest their responses.

A structured questionnaire adapted from WHO and UNICEF documents on vaccine management documents [12] was used to elicit information on knowledge of vaccine storage and distribution among the health worker-respondents. The questionnaire was developed in English and translated to Arabic for the ease of understanding of the respondents because the official language in Yemen is Arabic. The questionnaire thus had questions in both English and Arabic languages so that respondents had the option of responding in either language convenient to them. A set of 20 questions was used to determine knowledge, and each is assigned a score of one point correct or appropriate response. Additionally, key informant interviews were conducted with 5

staff of MoPHP and partners involved in immunization supply chain management at the national and sub-national level.

The questionnaire was pre-tested among health workers in Raymah governorate, which was not part of the study areas. The pre-testing helped identify ambiguity and gaps, which after corrections, led to improving the tool. Questionnaire was distributed online to health workers. Participant information and guide was provided alongside of the questionnaire. The online responses were compiled, cleaned, and imported into the Statistical Package for Social Sciences (SPSS) platform for relevant descriptive analysis of measures of frequency and the result was presented in a frequency table. The analysis also included knowledge scoring of the respondents on vaccine handling and storage into Poor, fair and good.

Results

The respondents' age ranged from 24 to 59 years with a mean of 29 ± 2.6 years. Two hundred and ninety-six (55.2%) were female. Most respondents (424(79%) had diploma certificates as the highest level of education and majority were nurses by profession (61.4%).

Table 1. Socio-demographic Characteristics of the Respondents (N=536)

Variables	Frequency	Percentage (%)
Age group (Years)		
≤30	196	36.6
31 - 40	226	42.2
41 - 50	97	18.1
51 - 60	17	3.1
Sex		
Male	240	44.8
Female	296	55.2
Highest Level of qualification		
High school certificate	27	5.0
Diploma	424	79.1
Bachelor's degree	81	15.1
Master's degree	4	.7
Professional background		
Nursing	329	61.4
Midwifery	105	19.6
Pharmacy	37	6.9
Medicine	10	1.9

Most of the health workers knew the correct temperature range for storage of the Rota vaccine (96%), pentavalent vaccine (97%), and PCV (97%) at the facility level. Although just a little above three-quarter (77%) Correctly knew the temperature range for storage of MR and BCG vaccines, most of them (86.9%) knew that MR and BCG vaccines can be stored in the freezer if the need arises or in an emergency.

Table 2. Knowledge of Temperature for Vaccine Storage at Facility Level (N= 536)

Knowledge of vaccine storage temperature	Frequency	Percentage (%)	Remarks
Rota vaccine storage temperature			
-15^{o}c to - 25^{o}c	2	0.4	
+2^{o}c to +8^{o}c	515	96.1	Correct response

-2ºc to - 8ºc	19	3.5	
MR vaccine storage temperature			
-15ºc to - 25ºc	46	8.6	
+2ºc to +8ºc	415	77.4	Correct response
-20ºc to - 25ºc	75	14.0	
Pentavalent vaccine storage temperature			
-15ºc to - 25ºc	1		
+2ºc to +8ºc	521	97.2	Correct response
-2ºc to - 8ºc	14	2.6	
BCG vaccine storage temperature			
-15ºc to - 25ºc	48	9.0	
+2ºc to +8ºc	413	77.0	Correct response
-2ºc to - 8ºc	75	14.0	
PCV storage temperature			
-15ºc to - 25ºc	3	0.6	
+2ºc to +8ºc	521	97.2	Correct response
-2ºc to - 8ºc	12	2.2	
Storage of MR & BCG in freezer if need arises			
Yes	466	86.9	Correct response
No	50	9.1	
Don't know	21	3.9	

Only 234(43.7%) knew that vaccine forecast as the first step of vaccine management, while the majority 321 (60%), knew that conditioned icepack is the recommended icepack for vaccine transportation and distribution. Over three-quarters of the respondents had correct knowledge of tool showing vaccine exposure to heat (79.3%) and discarded point of VVM stages (81.7%).

The overall categorization of the respondents on knowledge of vaccine handling and storage was good 429 (80.0%), fair 63 (11.8%), and poor 44 (8.2%).

Table 3. Knowledge of Vaccine Storage and Distribution (N = 536)

Knowledge variables determined	Frequency	Percentage (%)	Remarks
First step of vaccine management			
Vaccine Distribution	23	4.3	
Vaccine Temperature Monitoring	182	33.9	
Vaccine Forecasting need	234	43.7	Correct response
Vaccine storage	97	18.1	
Kind of ice pack use for vaccine transportation & distribution			
Frozen	200	37. 3	
Conditioned icepacks	321	59.9	Correct response
Ordinary water icepacks	8	1.5	
No need for icepacks	7	1.3	
Most important tool in vaccine stock management at level			
Early expiry first out (EEFO)	208	38.8	Correct response
First in first out (FIFO)	213	39.7	
Any of above	115	21.5	

Tool that shows vaccine exposure to heat			
VVM	425	79.3	Correct response
Fridge tag 2	23	4.3	
Freeze watch	54	10.1	
Remote temperature monitoring device (RTMD)	34	6.3	
Discard point VVM Stage			
Stage 1 & 2	19	3.5	
Stage 2 & 3	76	14.2	
Stage 3 & 4	438	81.7	Correct response
All stages are good & vaccine should not be discarded.	3	0.6	
Test for frozen vaccine			
Shake test	507	94.6	Correct response
Temperature check	19	3.6	
Melting test	6	1.1	
No test is needed	4	0.7	

A total of 392(73%) reported having functional SDD refrigerators; 9(1.7%) claimed that their SDD refrigerators were non-functional, while about 61% had functional electrical refrigerators. The majority of them said SDD refrigerators (77.8%) have been in use in the last 5 years, as against 187(43.4%) respondents that said their electrical refrigerators have been in use for about the same period.

Table 4. Availability and Functionality of Vaccine Storage Facility

Variables	**Frequency**	**Percentage**
Status of SDD refrigerator (N=536)		
Available and functional	392	73.1
Available but not installed	127	23.7
Not available	8	1.5
No longer functional	9	1.7
Status of electrical refrigerator (N=536)		
Available and functional	330	61.6
Available but not installed	67	12.5
Not available	105	19.6
No longer functional	34	6.3
How old is SDD refrigerator (n=519)		
0-5years	404	77.8
6-10years	74	14.3
11-15years	34	6.6
>15years	7	1. 3
How old is electrical refrigerator (N=431)		
0-5years	187	43.4
6-10years	135	31. 3
11-15years	85	19.7
>15years	24	5.6

Main source of energy for vaccine storage (N=536)		
Solar	351	65.5
Electricity	185	34.5
Availability of backup generator (N=536)		
Yes	280	52.2
No	256	47.8

More than two-thirds of the respondents only receive vaccines, 411(76.7%), 124(23.1%) receive and distribute vaccines, while only one (0.2%) only distribute the vaccine. A total of 364(68.4%) receive the vaccine on a monthly basis while 98(78.4%) distribute vaccine weekly. The mechanism of vaccine distribution included the use of refrigerated trucks (15.2%), cold boxes conditioned with ice packs (32.8%), and vaccine carriers with conditioned ice packs (41.6%).

Table 5. Frequency and Approach to Effective Vaccine Distribution

Variables on frequency and approach to vaccine distribution	Frequency	Percentage
Role in vaccine handling, storage & distribution (N=536)		
Receive vaccines only	411	76.7
Distribute vaccines only	1	0.2
Receive and distribute vaccines to other level	124	23.1
Frequency of receiving vaccine (n=535)		
Weekly	114	21.3
Monthly	364	68.4
Quarterly	57	10.7
Frequency of vaccine distribution (n=125)		
Weekly	98	78.4
Monthly	15	12-0
Quarterly	12	9.6
How vaccines are Received (N=536)		
Refrigerated truck	25	4.7
Cold boxes conditioned with icepack	272	50.7
Vaccine carrier with conditioned icepacks	224	41.8
Vaccine carrier without conditioned icepacks	15	2.8
How vaccines are Distributed (n=125)		
Refrigerated truck	19	15.2
Cold boxes conditioned with icepack	41	32.8
Vaccine carrier with conditioned icepacks	52	41.6
Vaccine carrier without conditioned icepacks	13	10.4
Experienced stock out (N=536)		
Yes	432	63.8
No	194	36.2

The vaccine stock management tool mostly used is manual vaccine ledger 520(97%), while only 3% used electronic VSSM. A total of 424(79.1%) had updated cold chain inventory, while over 90% carried out temperature monitoring checks/ charts on refrigerators twice a day.

Table 6. Availability of Vaccine Management Data

Variable	Frequency	Percentage
Vaccine stock management tools		
Manual vaccine ledger	520	97.0
Electronic VSSM	16	3.0
Frequency of physical vaccine stock take		
Monthly	458	85.4
Quarterly	28	5.2
Yearly	45	8.4
Not usually done	5	0.9
Status of cold chain equipment inventory		
No cold chain inventory	61	11.4
Inventory not updated	51	9.5
Inventory updated	424	79.1
Frequency of monitoring chart on refrigerator		
Once a day	29	5.4
Morning and evening	497	92.7
No temperature chart	6	1.1
Temperature chart not updated	4	0.7

Reported mean wastage rate for the pentavalent vaccine in the previous year was ≤10% among 357(66.6%) of the respondents. Multi-dose vial policy was observed by 93.8% of the respondents, and the duration for observing the policy on opened vials was ≤4 weeks by most of them (81.3%).

Table 7. Vaccine Wastage

Variables on vaccine wastage	Frequency	Percentage
Mean wastage rate for Pentavalent vaccine N=536		
0-10%	357	66.6
> 10%	23	4.3
Wastage not recorded	156	29.1
Factors causing wastage N=536		
Vaccine expiry	138	25.7
Vaccine breakage	71	13.2
Opened vials not finished	239	44.6
VVM change to discard point	88	16.4
Multi-dose vial policy (MDVP) Observed N=536		
Yes	503	93.8
No	33	6.2
Duration of observing MDVP N=503		
≤4 weeks	409	81.3
>4 weeks	94	18.7

Discussion

Vaccine storage and handling as well as the knowledge of cold chain handlers, are important components of the logistic requirements of immunization programs [13, 14]. In this study, 429(80%) of the health workers had good knowledge of vaccine management, this was found to be higher than the result of a similar study in the Tigray region, northern Ethiopia (48%) [9]. Most of the health workers knew the recommended temperature range for storage of routine vaccines at the health facility, including 515 (96.1%) for the Rota vaccine and 521(97.2) for both the Pentavalent vaccine and the Pneumococcal conjugate vaccine. These findings are consistent with the results of the studies conducted in Oromia, Ethiopia (96.9%) [15], Malaysia (95.5%) [16], and Tigray, Ethiopia (80%) [9]. However, the results are higher than those reported in studies done in Bale and Gurage zone, Ethiopia (67.8% and 71.1%) [17,18], Cameroon (68.5%) [19], Mozambique (52%) [20] and Nigeria (52%) [13]. The study also showed that most of the respondents 415(77.4%) and 413(77.0%) knew the recommended storage temperature for freeze-dried vaccine (measles and BCG) and a total of 466(86.9%) knew that measles and BCG vaccine could be stored at negative temperature when need arises. This knowledge is consistent with WHO revised policy that no longer recommends that freeze dried vaccines be stored at -20°C. [21].

The use of conditioned ice packs has long been recommended by the WHO to avoid freezing vaccines [22]. The finding from this study revealed that more than half, 321(59.9%) of the respondents knew conditioned icepacks are required for vaccine transportation and distribution. Emphasis has long been placed on keeping vaccines cold, with less attention devoted to the prevention of vaccine damage from freezing. Freezing of vaccines in the cold chain is commonplace, potentially resulting in the widespread delivery of vaccines whose potency has been compromised [14].

To effectively maintain an adequate supply of life-saving vaccines in low- and middle-income countries, where electricity supplies can be capricious, the WHO currently recommends solar refrigerators for regions with less than four hours of electricity per day, on average, and electric mains powered ice-lined refrigerators (ILRs) for areas with more reliable electricity. Gavi recommends solar refrigerators for locations with fewer than eight hours of electricity per day or power outages that last more than 48 hours [23]. A new refrigerator technology, named “solar direct-drive” (SDD), eliminates the need for batteries and therefore has the potential to resolve battery-powered vaccine refrigerator problems and help extend the cold chain into areas that might otherwise be underserved [24]. The study's finding showed that 392(73.1%) of the respondents reported the availability of functional SDD vaccine refrigerators and 330(61.6%) reported the availability of functional electric refrigerators at the facility. These findings are consistent with the result from similar study in Italy (76.5%) [25]. The result is lower compared to the finding in similar study in Tigray region of northern Ethiopia, where 100% reported at least one functional refrigerator [9], **(**81.5%) in North-West Region of Cameroon [26], and (92%) in another study in District of Silt’e Zone, Ethiopia [14] but higher than the finding from the study in North central Nigeria with 8.2% functional SDDs and 6.1% electrical refrigerator [13].

In 2015, Gavi, the vaccine alliance assessed that up to 90% of health facilities in some countries are equipped with old, obsolete, or broken refrigerators with high freezing or temperature excursion risks or, not equipped with any temperature monitoring device at all [27] which contributed to informing the establishment of the Cold chain Equipment Optimization Platform (CCEOP). The study revealed an impressive number of respondents,

404(77.8%) reporting the availability of functional SDDs of 0-5 years old and a total of 482 (92.1%) reporting functional SDDs between 6 and 10 years old. This finding is corroborated by the decision of the Ministry of Health authority following the comprehensive cold chain inventory in 2017 to invest in the new technology of solar energy, given the challenge with power supply amidst the conflict in the country. This also informed the country's application to the Gavi CCEOP in 2018, for which country led service bundle was considered in 2020 [28]. The study also showed a total 312(75%) of respondents that reported the availability of electrical refrigerators 0-10 years of age. These could be available at some governorates as well as districts and HFs where SDDs have already been provided to replace the electrical equipment. The impact of such investment in solar powered are tremendous including the elimination of use of fossil fuels by relying on solar energy and the beneficial use of Ice bank 'batteries' instead of lead batteries which are vulnerable due to degradation and theft [29].

Vaccine and immunization supply distribution and transport are critical components of the cold chain system [30]. Adequate and timely distribution of the vaccines and injection devices is important as any delay in the distribution of vaccines or error in calculating vaccine needs may potentially result in stockouts and missed opportunities for the intended recipients [31]. This study showed a high proportion (76.7%) of respondents only receive vaccines, while 23.1% receive and distribute the vaccine to other levels. Of those that receive the vaccine, 68.4% do so on a monthly basis. The high number is an indication that most of these respondents function at the health facility level, which is the last mile for vaccine distribution in immunization services. A total of 103(90.4%) of the respondents involved in distribution do so weekly and monthly. The finding of regular distribution practice agrees with the report of timely and regular supply of vaccines to all levels as strength in vaccine security and logistics that keeps immunization running despite the complex emergency in Yemen [10].

A few of the respondents 12 (9.6%) distribute quarterly, which is likely to be happening only from the primary store at the central level. The practice of using the refrigerated vehicle for vaccine distribution was shown in this study by a total of 19(15.2%) of respondents that are involved in vaccine distribution and 25(4.7%) responsible for receiving vaccines. 272(50.7%) and 224(41.8%) of the respondents receiving vaccines do so with cold boxes and vaccine carriers with conditioned icepacks while 41(32.8%) and 52(41.6%) involved in vaccines distribution do with cold boxes and vaccine carrier with conditioned icepacks.

These findings are collaborated by the current system in Yemen where quarterly vaccine distribution from the primary store at the central level to the governorates is supported by UNICEF using its transport LTA with refrigerated trucks while from the governorate to the district level, UNICEF supports with funds to distribute monthly with cold boxes and vaccine carriers with conditioned icepacks. The last-mile distribution to the health facilities usually involves health facilities picking vaccines from the district store, which is supported now in less than 50% (about 2000 HFs) of the health facilities benefitting from the operational cost through the world bank project.

Conclusion

Despite the protracted and complex humanitarian situation in its eightieth year in Yemen, the Knowledge of Health workers on vaccine storage, distribution and cold chain management is still optimum. The MoPHP has sustained effective and efficient vaccine storage across the immunization supply chain levels in the country which has contributed to the

sustenance of immunization services through the conflict.

The plan to equip every health facility offering routine immunization, and solarization of the central and governorate cold stores are achievable through concerted resource mobilization. There is a need to provide the required investment in a cost-effective and sustainable last-mile vaccine distribution approach to ensure equitable availability of vaccines at the service delivery points and prevent any missed opportunity.

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Declaration of Conflicting Interest

The Author(s) declare(s) that there is no conflict of interest.

Reference

[1] Osei, E., Ibrahim, M., & Kofi Amenuvegbe, G., 2019, Effective Vaccine Management: The Case of a Rural District in Ghana. Advances in preventive medicine, 2019, 5287287. https://doi.org/10.1155/2019/5287287.

[2] WHO., & UNICEF., 2016, WHO/UNICEF joint statement: Achieving immunization targets with the comprehensive effective vaccine management (cEVM) framework https://apps.who.int/iris/bitstream/handle/10665/254717/WHO-IVB-16.09-eng.pdf.

[3] World Health Organization. (WHO)., 2017, Guideline for establishing or improving primary and intermediate vaccine stores. https://apps.who.int/iris/bitstream/handle/10665/67807/WHO_V-B_02.34_eng.pdf.

[4] Centre for Disease Control and Prevention. (CDC)., 2021, Vaccine Storage and Handling Toolkit https://www.cdc.gov/vaccines/hcp/admin/storage/toolkit/storage-handling-toolkit.pdf.

[5] Nwankwo, B., Joga, S.J., Olorukooba, A.A. et al., 2018, Knowledge, attitude, and practice of cold chain management among primary health care workers in Giwa, Northwestern Nigeria. Arch Med Surg 2018; 3:71-6. https://www.archms.org/text.asp?2018/3/2/71/254575.

[6] Mohammed, S.A., Workneh, B.D., & kahissay, M.H., 2021, Knowledge, attitude and practice of vaccinators and vaccine handlers on vaccine cold chain management in public health facilities, Ethiopia: Cross-sectional study. PLoS ONE 16(2): e0247459. https://doi.org/10.1371/journal.pone.0247459.

[7] Zayer, J., & Chiad, I., 2020, Evaluation of Application of Effective Vaccine Management in Wassit Governorate, Iraq. International journal of pharmaceutical quality assurance. 11. 242-246. https://www.researchgate.net/publication/348780491_Evaluation_of_Application_of_Effective_Vaccine_Management_in_Wassit_Governorate_Iraq.

[8] Al Abri, S., Al-Rawahi, B., Abdelhady, D., & AL abaidani, Idris., 2018, Effective vaccine management and Oman's healthcare system's challenge to maintain high global standards. Journal of Infection and Public Health. 11. 10.1016. https://www.researchgate.net/publication/325210133_Effective_vaccine_management_and_Oman's_healthcare_system's_challenge_to_maintain_high_global_standards/citation/download.

[9] Gebretnsae, H., Hadgu, T., Ayele, B. et al., 2022, Knowledge of vaccine handlers and status of cold chain and vaccine management in primary health care facilities of Tigray region, Northern Ethiopia: Institutional based cross-sectional study. PLOS ONE. 17. e0269183. 10.1371/journal.pone.0269183.https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0269183.

[10] Ministry of Public Health & Population, Yemen., 2016, Comprehensive Multi-year Plan (cMYP) 2016-2020.

[11] Charan, J., & Biswas, T., 2013, How to calculate sample size for different study designs in medical research? Indian journal of psychological medicine, 35(2), 121–126. https://doi.org/10.4103/0253-7176.116232.

[12] World Health Organization (WHO)., 2005, Vaccine Management Assessment. http://apps.who.int/iris/bitstream/handle/10665/69616/WHO_IVB_05.02_eng.pdf?sequence=1.

[13] Ameen H.A., Salaudeen A.G., Bolarinwa O.A. et al., 2014, Vaccine Storage and Handling Practices among routine immunization service providers in a metropolitan city of North-Central Nigeria. Journal of Community Medicine and Primary Health Care. 26 (2) 18–28. https://www.ajol.info/index.php/jcmphc/article/view/125356.

[14] Feyisa, D., Ejeta, F., Aferu, T. et al., 2022, Adherence to WHO vaccine storage codes and vaccine cold chain management practices at primary healthcare facilities in Dalocha District of Silt'e Zone, Ethiopia. Trop Dis Travel Med Vaccines 8, 10. https://doi.org/10.1186/s40794-022-00167-5.

[15] Mohammed, S.A., Workneh, B.D., & kahissay, M.H., 2021, Knowledge, attitude and practice of vaccinators and vaccine handlers on vaccine cold chain management in public health facilities, Ethiopia: Cross-sectional study. PLoS ONE 16(2): e0247459. https://doi.org/10.1371/journal.pone.0247459.

[16] Daud, Norwati., 2014, Knowledge, Attitude and Adherence to Cold Chain among General Practitioners in Kelantan, Malaysia. https://internalmedicine.imedpub.com/knowledge-attitude-and-adherence-to-cold-chain-amonggeneral-practitioners-in-kelantan-malaysia.php?aid=6257.

[17] Woldamichael, B., Bekele, D., & Esmael, A., 2018, Cold Chain Status and Knowledge of Vaccine Providers at Primary Health Care of Units Bale Zone, Southeast Ethiopia: Cross-sectional Study. Immunome Research. 14,152. https://www.readcube.com/articles/10.4172/1745-7580.1000152.

[18] Zeyneba, J. Y., Habtamu, Y.N., Behailu, T. D. et al., 2019, Knowledge of Health Professionals on Cold Chain Management and Associated Factors in Ezha District, Gurage Zone, Ethiopia, Scientifica, vol. 2019, Article ID 6937291, 7 pages. https://doi.org/10.1155/2019/6937291.

[19] Ebile Akoh, W., Ateudjieu, J., Nouetchognou, J.S. et al., 2016, The expanded program on immunization service delivery in the Dschang health district, west region of Cameroon: a cross sectional survey. BMC Public Health 16, 801. https://doi.org/10.1186/s12889-016-3429-7.

[20] Mavimbe, J.C., Bjune, G., 2007, Cold chain management: Knowledge and practices in primary health care facilities in Niassa, Mozambique. Ethiopian Journal of Health Development, 21(2): 130-135. https://www.ajol.info/index.php/ejhd/article/view/10040.

[21] WHO., & UNICEF., 2016, WHO-UNICEF Effective Vaccine Store Management Initiative: Modules 1-4. https://apps.who.int/iris/bitstream/handle/10665/68993/WHO_IVB_04.16-20.pdf?sequence=1.

[22] PATH Optimize., Aug.2013, Preventing in cold boxes and vaccine carrier. https://media.path.org/documents/TS_opt_handout_freeze_safe.pdf.

[23] Haidari, L. A., Brown, S. T., Wedlock, P., Connor, D. L., Spiker, M., & Lee, B. Y., 2017. When are solar refrigerators less costly than on-grid refrigerators: A simulation modeling study. *Vaccine*, *35*(17), 2224–2228. https://doi.org/10.1016/j.vaccine.2016.11.103.

[24] WHO., & UNICEF., 2015, Introducing solar powered vaccine refrigerator and freezer system: A guide for managers in national immunization programmes https://apps.who.int/iris/bitstream/handle/10665/195778/9789241509862_eng.pdf.

[25] Grasso, M., Ripabelli, G., Sammarco, M. L., Manfredi Selvaggi, T. M., & Quaranta, A, 1999, Vaccine storage in the community: a study in central Italy. Bulletin of the World Health Organization, 77(4), 352–355. https://pubmed.ncbi.nlm.nih.gov/10327715/.

[26] Yakum, M.N., Ateudjieu, J., Walter, E.A. *et al.* Vaccine storage and cold chain monitoring in the Northwest region of Cameroon: a cross sectional

study. *BMC Res Notes* **8**, 145 (2015). https://doi.org/10.1186/s13104-015-1109-9.

[27] UNICEF Supply Division., July 2018, Cold Chain Equipment - Solar Direct Drive and Mains Powered Refrigerator Systems: Product Profiles, Availability, and Guidance UNICEF Supply Division. https://www.unicef.org/supply/sites/unicef.org.supply/files/2019-06/cold-chain-equipment-sdd-drive-and-mains-powered-refrigerators.pdf .

[28] Ministry of Public Health & Population, Yemen. (2020). Application for Country led service bundle under Cold Chain Equipment Optimization Platform (CCEOP) Application.

[29] UNICEF Supply., 2015, Using the Sun to Keep Vaccines Cool: A collaboration to develop an environmentally-friendly, affordable, battery-free refrigeration system: Solar Direct Drive Technology https://www.unicef.org/innovation/stories/using-sun-keep-vaccines-cool.

[30] WHO., & UNICEF., 2017, Evidence brief Solar power refrigerator and Freezer https://apps.who.int/iris/bitstream/handle/10665/254715/WHO-IVB-17.01-eng.pdf;sequence=1.

[31] Department of Health., National Immunization Program Manila, Philippines., 2018, Vaccines, Cold Chain and Logistics Management Manual of Operations 5th edition. https://doh.gov.ph/sites/default/files/publications/NIP-MOP-Booklet%2010.pdf.