UNIVERSITY of RWANDA

EAC REGIONAL CENTRE OF EXCELLENCE FOR VACCINES, IMMUNIZATION AND HEALTH SUPPLY CHAIN MANAGEMENT (EAC RCE VIHSCM)

ASSESSMENT OF MEDICINES COLD CHAIN STORAGE CONFORMITY WITH THE REQUIREMENTS OF THE WORLD HEALTH ORGANIZATION IN HEALTH FACILITIES IN THE EASTERN PROVINCE- RWANDA

A Dissertation submitted to the College of Medicine and Health Sciences, University of Rwanda, in partial fulfillment of the Requirements for the program of a Master's degree of Sciences in Health Supply Chain Management (MSc HSCM)

By***: NYIRIMANZI Joseph Désiré***

Reg Nº: 220014814

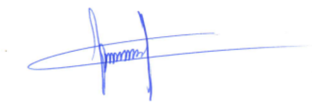
Supervisor: ASS.PROF KAYITARE Egide

Co-Supervisor: BIZIMANA Thomas

February 2022

DECLARATION

I, **NYIRIMANZI** Joseph Désiré, to the best of my knowledge, hereby declare that the thesis entitled **"Assessment of the Medicines Cold Chain Storage Conformity with the Requirements of the World Health Organization in Health Facilities of the Eastern Province-Rwanda"** is my original work and has never been presented in any University for any academic purposes.

Signature  Date: 20/02/2022

Student Name: **NYIRIMANZI Joseph Desire**

Approved by Supervisor

Signature  Date: 20/02/2022.

Name: Prof. Egide Kayitare

DEDICATION

This work is dedicated to

My beloved wife, Jacqueline,

My beloved daughters Thecla, Balbine and Ritha.

ACKNOWLEDGMENT

I thank God, who has continuously given me the strength and resources to do this research.

I will forever remain grateful for the Scholarship by the EAC Regional Center of Excellence for Vaccines, Immunization, and Health Supply Chain Management (RCE-VIHSCM) that catered for all training expenses

My sincere gratitude goes to my supervisors, Professor Egide KAYITARE and Mr. BIZIMANA Thomas, who agreed to walk with me step by step. Their kind and limitless guidance and remarks illuminated and directed me throughout the entire completion process of this study.

My gratitude is extended to the University of Rwanda staff for the guidance that enhanced my knowledge and skills throughout my training.

I sincerely thank Rwanda Medical Supply (RMS Ltd), Expended Program for Immunization of Rwanda, and Eastern Province-based health facilities for allowing me to collect data in selected public, faith-based, and private health facilities for their time to participate in this research.

Finally, I want to thank my family for their support and patience until the success of this program. My colleagues and classmates who have been a source of support and morals remain indelible in my heart.

ABSTRACT

Background: Health actors who manage pharmaceutical supply chain systems must follow established global regulations to handle properly, store, and distribute temperature-sensitive products. These requirements highlight cold chain temperature devices usability and storage facilities to ensure that the products mentioned above are stored accordingly throughout the supply chain. Various studies have shown that the storage and transport of products in the cold chain are inefficient, leading to poor product quality and thus public health problems. Therefore, it was worth identifying how Rwanda has developed its cold chain supply systems from central medical stores to the end-users of Eastern Province that register high temperatures.

Methodology: This study was carried out in selected health facilities in Eastern Province (public, faith-based and private). Prospective, cross-sectional, and observational design with quantitative and qualitative approaches were adopted, and forty-four health facilities were selected using convenience, stratified and purposive sampling techniques. The respondents were the cold chain technicians managing vaccines and other cold chain products in the selected health facilities. The researcher created a checklist and questionnaire for data collection, and temperature data loggers were mounted in refrigerators to measure MKT. The University of Rwanda provided ethical approval, and health facilities were permitted to conduct a study in their premises voluntarily. Key informants consented to participate in the study voluntarily as well.

Results: In vaccination programs in public and faith-based facilities, the recorded MKT conformed to the WHO standards. Nevertheless, at public, faith-based, and private pharmacy storage, the cold chain storage conformity deviated from the required temperature of 2–8 °C. The performance of cold chain storage conformity of refrigerators used in pharmacy stock of public health facilities was 18(56%), in faith-based facilities was 4(57%), and in private retail pharmacies was 7(70%). WHO pre-qualified refrigerators were available at 62(97%). Factors affecting storage conformity were the lack of a contingency plan in the power outage (54,5%) and limited calibration of cold chain equipment (42%). This study also pointed out insufficient knowledge of cold chain technicians and a distribution gap of products from central medical stores to service delivery points.

Conclusion: The study found cold chain equipment status, temperature monitoring system, quality management system, and transportation management to be the significant factors that affect the WHO

storage temperature conformity in health facilities in the study area. Hence, there is a need to harmonize the supply chain of both vaccines and other temperature-sensitive medicines.

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ABBREVIATIONS AND ACRONYMS

CCT:	Cold chain Technician
CMS:	Central Medical Store
DRC	Democratic Republic of Congo
EPI:	Expanded Programme for Immunization
HF:	Health Facility
LMICs:	Low and middle-income countries
MKT:	Mean Kinetic Temperature
QMS:	Quality Management System
Rwanda	FDA: Rwanda Food and Drug Authority
RBC:	Rwanda Biomedical Center
RMS Ltd:	Rwanda Medical Supply Limited
RSB:	Rwanda Standards Board
SDP:	Service Delivery Point
SPSS:	Statistical Package for Social Science
TMD:	Temperature Monitoring Devices
UK:	United Kingdom
UNICEF:	United Nations Children's Fund
WHO:	World Health Organization

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

The supply chain of medicines is the cornerstone of the pharmaceutical business worldwide. Supply chain management had gradually expanded since the early 1980s when the companies discovered the benefit of collaboration within their organizations and beyond, promoting their supplies and attaining their goal efficiently (1). Warehousing is pivotal in the supply chain systems as it links good flows between suppliers and customers. The primary operations of warehouse management rely on receiving material and controlling associated movement, including shipping and putting away these materials or goods (2). Transportation control of medicines requiring a cold chain is vital to maintain product quality and protect end-users against ineffective pharmaceutical products (3). Lack of suppliers' awareness in distributing cold chain medicines may negatively impact product quality and potency.

In 2011, the World Health Organization (WHO) established guidelines for storing and transporting temperature-sensitive medicines (4). They aim to provide cold chain management of pharmaceuticals, ensuring the health product's efficiency, quality, and efficacy, and detailed information on temperature-controlled transport. In addition, pharmaceutical industries pinpoint the conditions in which vaccines and temperature-sensitive pharmaceuticals should be handled and warn of the potential hazard to the consumer if not handled accordingly. Eventually, the reliable organs validate the related guidelines to guarantee the safety and effectiveness of the cold chain products in the pipeline up to the end-users (5).

Despite guidelines for properly storing medicines requiring cold chains, the World Health Organization (WHO) estimated that fifty percent of all vaccines were wastage worldwide before being administered to the end beneficiaries. At the same time, 25% of them were degraded during the transport before reaching the destination (6). Besides, global warming negatively affects supply chain operations during transport, distribution, and storage, especially cold chain medicines stored in inappropriate conditions (7).

The assessment of effective vaccine management carried out by WHO, and the United Nations Children's Fund (UNICEF) in 2016 showed inefficiencies in vaccine management. The challenges observed included storage conditions, transportation management systems, and temperature monitoring. In addition to that, the results pointed out incoherencies in distribution systems and cold chain equipment status, especially in limited-resource countries (8).

1.2 Problem statement

Cold chain monitoring is a significant challenge in most low- and middle-income settings due to inefficient cold chain infrastructure, limited transportation, unreliable power supply, and limited trained staff and equipment to maintain the cold chain(9). These drawbacks weaken cold chain conformity strategies. Njuguna and collaborators, in the study carried out in Kenya on the effective management of vaccines in 2015, revealed that improper transportation of cold chain vaccines might compromise products' quality and culminate public health safety. The transportation vans were calibrated poorly along the supply chain, and specialized vehicles only existed in 48% (6).

The study carried out in Ethiopia pointed out the inefficiencies in storage practices of health commodities. These drawbacks include temperature recording, storage capacity, insufficient knowledge in cold chain handling, and lack of generators as backup systems during a power supply failure (10).

The study conducted in Tanzania highlighted non-compliance with cold chain storage temperature. The findings revealed that 48.5% of assessed health facilities deviated from WHO recommendations in temperature monitoring. The factors associated with this low compliance to WHO guidelines resulted from insufficient knowledge of cold chain technicians and unreliable cold chain infrastructure and equipment. The recorded Mean Kinetic Temperature (MKT) exceeded the upper limit of the normal range of cold chain product storage, and more affected health facilities are located in remote areas (11). The challenges mentioned above culminate in low potency of products and thus public health risk.

Bizimana T and collaborators, in the study on the efficacy of misoprostol and oxytocin distributed in Rwanda in 2021 to manage a postpartum hemorrhage, highlighted the challenges of cold chain medicines kept on ambient temperature, deviating the World Health Organization requirements. This observation indicates that cold chain medicines are not always kept at the required storage temperature, resulting in losing medical potency and increasing medical costs and waste (12).

In Rwanda, climate change impacts the Eastern Province considerably. This region counts long dry spells characterized by rainfall deficit throughout the year, raising the temperature abnormally (13). Rwanda's cold chain system encompasses two parallel supply chain dimensions: vaccines and other temperature-sensitive medicine cold chains. These cold chain storage status regarding the WHO standards remains unknown. This study evaluated how 44 health facilities in the Eastern Province of Rwanda currently store medications at temperatures that comply with WHO guidelines.

1.3 Research objectives

1.3.1 General objective

To assess the storage temperature conformity in Health Facilities selected from the Eastern Province of Rwanda regarding the WHO requirements for medicines requiring cold chain storage.

1.3.2. Specific Objectives

1. To examine storage temperature conformity in the Eastern Province Health Facilities
2. To assess how the health facility infrastructure affects the storage of cold chain products in the Eastern Province Health Facilities.
3. To evaluate the knowledge of cold chain technicians on storing medicines requiring cold chains in the Eastern Province Health Facilities.
4. To assess the storage conditions of medicines requiring cold chain during transportation from the central level to the Eastern Province Health Facilities.

Research Questions

The following questions are important and pertinent to this study.

- To what extent does storage temperature conform to WHO requirements in health facilities in the Eastern Province of Rwanda?
- What are the healthcare infrastructure conditions of cold chain medicines in the health facilities of Eastern Province?
- Are cold chain technicians knowledgeable in storing medicines requiring cold chains in health facilities of the Eastern Province?
- What is the storage condition of medicines requiring cold chain during transportation from the central to the service delivery points in Eastern Province?

1.4 Justification of the study

The study assessed the storage temperature for medicines requiring cold chains in public, faith-based, and private health facilities in the Eastern Province of Rwanda. The research generated significant data that will improve the cold chain monitoring system. The enhancements relied on storage, health facility infrastructure, cold chain technician knowledge, and distribution of cold chain medicines. The findings will inform Rwanda's health actors (Ministry of Health, Rwanda Biomedical Centres, assessed health facilities) on the status of the cold chain system and make the appropriate decision accordingly to ensure conformity with World Health Organization requirements. This study will enable the Rwanda Ministry of Health and intended health facilities to be informed on cold chain equipment and knowledge of cold chain technicians for further decision making and planning. This study's findings will also boost the awareness of cold chain infrastructures.

1.5 Delimitations

This study assessed cold chain storage and transportation for temperature-sensitive - medicine, precisely storage and transport for medicines requiring a cold chain. It was carried out in selected Eastern Province-based health facilities in Rwanda starting from August 2021 to February 2022

1.6 Limitations

There are limited documents related to cold chain medicines storage in Rwanda to which to refer. Owing to time constraints, the length of this study was too short. Furthermore, it did not cover all factors associated with a cold chain instead of storage and distribution characteristics. The results of this study were limited to the health facilities assessed in Eastern Province in Rwanda, not generalized to the entire country. These findings were limited to public health facilities and excluded private health institutions. The areas of interest were cold chain storage conformity, cold chain technician knowledge, cold chain infrastructure, and related transportation policies. There was no assessment of the impact of non-conformity of cold chain storage in Eastern province health facilities.

CHAPTER TWO: LITERATURE REVIEW

This chapter explores the resources currently available for cold chain medicine storage across the whole supply chain system. This section comprises technical operation definitions used in storage temperature monitoring systems, temperature measurement, health professional knowledge in cold chain management, equipment, and transportation policies and guidelines.

2.1 Operational definition of terms

Cold chain - the system ensures temperature-sensitive medicines are maintained within a specified temperature range to avoid damage due to temperature fluctuations (14).

Data loggers - Long-life electronic devices that record measurements continuously over a set period.

Health Facilities-Owned either by the National government, religious-based, or private health institutions.

Mean Kinetic Temperature – an expression of the effect of temperature variations during the storage or distribution of cold chain products.

Shake test: This method is used to check those freeze-sensitive vaccines are frozen; it is performed on suspected vaccines rather than vaccines that are frozen.

Temperature Monitoring -monitoring and recording temperature as per WHO guidelines (14)

Temperature data Loggers-Temperature monitoring device used to record temperature continuously and store data for 30 days. The researcher checks the temperature from it after 30 days. Data recorded and stored can be downloaded using USB into a computer for further analysis.

VVM (Vaccine Vial Monitor)- Depending on vaccine types, it is a thermal indicator on the side of the vaccine vial or the top cover that monitors if the vaccine's vial was exposed to excessive heat over time. That indicator changes the color as the vaccines continuously expose abnormal temperatures. The VVM records the extreme temperature in 4 stages (I, II, III & IV). Phases I & II are ready for use, while III & IV are discarded.

2.2 Cold chain management

Cold chain management is defined as maintaining vaccines and other temperature-sensitive medicines, such as insulin, oxytocin, etc., between refrigerated temperatures (2ºC to 8ºC) along the supply chain.

Keeping these products outside the acceptable range reduces their potency and leads to poor quality and wastage (15).

The reliable cold chain storage is entitled to fulfill essential requirements, including cold chain equipment, infrastructure, and human resource capabilities. The latter comprises cold chain technician knowledge and skills to maintain the entire system in the normal range. The storage conformity should have a continuous temperature monitoring system using temperature monitoring devices (TMD) to ensure product potency. This monitoring system should calculate Mean Kinetic Temperature (MKT)(3).

2.3 Storage temperature conformity of cold chain medicines

The quality of cold chain medicines relies on storage and handling strategies. Thus, temperature fluctuations of the products described above during entire supply chain processes should be managed under a comprehensive approach (16). In the health system, cold chain products encompass vaccines and other temperature-sensitive medicines such as oxytocin insulin, human immunoglobulins, blood products, etc. These medicines require special handling to maintain their potency throughout the supply chain. Exposing these products outside the temperature range may culminate in the loss of quality and inefficiency (17).

Once temperature-sensitive medicines are manufactured, the pharmaceutical firms also establish their storage temperature range guaranteeing their potency throughout their life cycle. However, these products may be exposed to temperature variability due to the environmental profile during transportation from the manufacturer to the end-users. These variabilities may be due to the seasonal temperatures, transportation modes, routes, temperature at the origin and destination, or transit duration (18). Or refrigerators may lose their capacity to keep set temperature, especially in settings with fluctuating electric power. Thus, having analytical means to measure temperature exposures that impact product quality is worth it. The Mean Kinetic Temperature was proposed as a reliable method to evaluate temperature variations during the shipment and storage of the products (19).
The Mean Kinetic Temperature ascended from the International Conference on Harmonization (ICH). It was defined as “a single derived temperature, which, if maintained over a defined period, would afford the same thermal challenge to a pharmaceutical product as experienced over a range of higher

and lower temperatures for an equivalent defined period." The MKT illustrates cumulative thermal stress that heat products over various temperatures during storage, shipping, and distribution of temperature-sensitive medicines(20).

2.4 Health risks for non-storage conformity of cold chain medicine

Temperature-sensitive medicines require special handling to maintain potency throughout the cold chain, resulting in potential hazards if stored in unpredictable conditions. This section focused on vaccines that prevent lethal diseases in childhood, oxytocin that controls postpartum hemorrhage, and insulins widely used to monitor diabetes, a deadly non-communicable disease.

2.4.1 Vaccines

Vaccines are biological products that contain antigens used to prevent and control specific diseases. Vaccines are produced through killed pathogen (pertussis used to produce DTP), weakened micro-organism (polio-virus), or inactivated toxin (tetanus toxoids) (21). The treated pathogen weakens its toxicity and retains its immunogenicity. The administration of vaccines produces memory cells that stimulate the body to produce the immune response in specific antibodies during pathogen exposure. The latter empowers the faster immune response to the pathogen re-exposure in the preliminary stage of infection (22).

Vaccines lose potency rapidly when exposed to outside recommended temperature ranges as they are biologically temperature sensitive. Thus, vaccine storage at the recommended temperature throughout the cold chain is vital to maintain potency and quality (23). The study carried out in Nigeria in 2016 highlighted the challenges in vaccine handling due to insufficient cold chain equipment and storage facilities' limited knowledge of cold chain storage. These bottlenecks may culminate in loss of vaccine potency and consequently be hazardous for the population (24).

2.4.2 Oxytocin

Oxytocin, from the Greek word 'oxutokia' meaning "sudden delivery, "is a neuropeptide secreted from within the brain and released into the circulation via the posterior pituitary. This primordial role of this hormone refers to the regulation of reproductive and psychosocial. Oxytocin plays a vital role in childbirth through uterine contractions during labor to prevent bleeding. Furthermore, oxytocin acts in interpersonal relations such as empathy and generosity (25).

The uterus may lack the proper tonicity of contracting or tightening after parturition during labor. This uterus atonicity is the common cause of postpartum hemorrhage culminating in fatal maternal mortality. These health issues are prevented and treated by administering oxytocin or misoprostol, the prostaglandin analogue (26).

However, the oxytocin is degraded at high temperatures, leading to losses of its potency. This challenge has been observed primarily in resource-limited settings where the cold chain infrastructure is unreliable, especially in the tropical region. A study in the DRC in 2018 found that 80% of oxytocin ampoules were substandard. The analysis revealed that the product initially met all requirements but was degraded during improper storage (27). The results from WHO and UNICEF support these findings conducted in Ghana, where the storage temperature attained 30.1^{o}Cduring distribution from central medical stores to health facilities. The WHO recommends storing oxytocin at refrigerated temperatures (2^{o}C and 8^{o}C) to maintain potency.

2.4.3 Insulin

Insulin (from Latina insula=island) is a pancreatic hormone secreted by the islets of Langerhans of the pancreas. This hormone regulates blood glucose levels in the body. The insulin metabolizes carbohydrates, fats, and starches and converts them into glucose that the body uses to produce energy. The body cannot use glucose effectively if the pancreas does not produce the required insulin due to the destruction of beta cells. On the other hand, the insulin produced becomes resistant to effectively regulating glucose levels in the blood. These two options culminate in fatal and deadly Diabetes Mellitus types 1 and 2, respectively (28).

Given the above statements, patients with severe diabetes must be administered insulin to control the disease. Nevertheless, insulin requires injection as a mode of administration as it is partially digested if administered orally due to the characteristics of the protein. On the other hand, insulins are labile drugs sensitive to extreme temperature and direct sunlight. This protein decreases its potency if stored under uncontrolled temperature (29). Hence, the insulins must be stored under cold chain conditions to maintain quality. Alternatively, the insulin can be stored at ambient temperature when opened and used between 10 days and 8 weeks. It is also unlikely to store insulin in household refrigerators as they risk being frozen as their refrigerators are designed to keep food between 0°C and 4°C (30).

2.5 Health Facility Infrastructure

Health facility infrastructure comprises physical, technological, and organizational elements or resources to deliver healthcare services. The cold chain infrastructures are one of the seven components of health facility infrastructure. This includes the facility management, the physical health assets, the supply facility, disposal systems, medical equipment, ICT system, and outreach services (31).

Cold chain equipment comprises refrigerators, cool packs, freezers, cold boxes, vaccine carriers, temperature monitoring charts, and temperature monitoring devices (32). Cold boxes can store cold chain products for more than two days without electricity or a refrigerator's breakdown. They are also used in the monthly active distribution of vaccines from the district stores to service delivery points.

Nevertheless, sustaining these functional components in settings with limited resources is a substantial concern (31). WHO advises calibrating the above equipment annually to maintain its measurement accuracy). The calibration should be done against the recognized, traceable, and certified standards (33). The report from WHO estimated about 20-40% of wastage, and among the causes was poor handling and inappropriate infrastructure (34).

The WHO and UNICEF assessment results on cold chain equipment in LMICs were disheartening. The findings revealed that only 2% of assessed facilities had a reliable cold chain technology, 23% used outmoded cold chain technologies, and 14% had a nonfunctional cold chain equipment. Moreover, the results revealed that 41% had poor-performing cold chain equipment, while 20% had no equipment (9).

In Cameroon, the study conducted by Martin N.Y in 2015 showed that equipment breakdown is the main cause of temperature excursion in the cold chain system. About 11.33% of health facilities involved in the study had refrigerator breakdowns within two months (35). A study carried out by Mangeni M.N in 2009 in two districts of Uganda on cold-chain logistics management showed poor performance of various indicators, including insufficient storage space and gas shortage to keep refrigerators functioning. This inadequate cold chain system functioning may impact cold chain product storage and increase damages and wastage (36).

2.6 Human resource knowledge on temperature management

Human resource capabilities are a vital enabler of supply chain performance. Organizations should technically equip their human resource through regular capacity building to increase their knowledge and skills to attain objectives and goals. According to the study made by Azira B et al. in 2013 in Malaysia, temperature monitoring was introduced to enhance the knowledge of cold chain technicians. Despite the effort, the result showed that most health workers responsible for vaccines have78.7% knowledge. Their attitude was significantly poor at 79.7% (37).

The recommendations from the study carried out by Martin N.Y in 2015 in North West Cameron suggested the continuous, regular capacity building of cold chain technicians. Although the cold chain maintenance was unreliable, health personnel who monitored it had insufficient knowledge of various cold chain indicators, including recommended vaccine temperature storage. This was obvious as about 43.8% didn't know this in the cold chain requirement (35).

In the study in Amhara in Ethiopia, Hewan Adam Bogale et al. found the knowledge gap among health cold chain technicians. According to these results, only 38.3% of health workers identified cold chain operations sufficiently. The authors recommended regular supervision and training to enhance knowledge and skills in cold chain management (10).

2.7 Transportation of cold chain product

In the cold chain system, controlling temperature from one supply level to another is vital to properly maintain recommended cold chain temperature. According to the WHO, 25% of vaccines reach the last mile in the degraded status during transportation, significantly impacting product quality (6). The study carried out by Walter and collaborators in 2013 on the assessment of cold chain management in West Cameroon found that 54.8% of health facilities assessed didn't have transportation means(38).

The cold chain transportation issues were also observed in developed countries, where the UK recorded 32% of transport inefficiencies. These challenges motivated these countries to set up specific regulations and policies governing the transportation of cold chain products and reduce potential inefficiencies. According to the manufacturer's labels, these regulations state that drugs should be transported in an acceptable temperature range. The regulations stipulate that drugs shipped should consider the transportation mode and climate variability. Temperature-sensitive medicine should be transported with calibrated and temperature-controlled vehicles with temperature and humidity monitoring devices (39).

Because of this, WHO has timely set up and updated global rules and regulations governing the transportation of temperature-sensitive medicines to ensure products' safety and integrity. These regulations include refrigerated vehicles equipped with calibrated temperature monitoring devices such as temperature data loggers with sensors and an alarm system that alerts vehicle drivers during temperature excursions (40).

After being dispatched from a manufacturing plant, the cold chain products undergo the complex supply chain due to many storage locations and various transportation modes before reaching the last mile and being consumed by end-users. The transportation arrangements throughout the journey should be considered as the storage extension. Thus, the shipment should consider seasonal distributions or transportation mode and packing methods to maintain the temperature requirement (41).

2.8 Cold chain medicines

Cold chain medicines are temperature-sensitive medical products requiring special temperature-controlled storage conditions throughout their supply chain to maintain product quality. Temperatures outside this range may reduce the product potency culminating in an inadequate response.

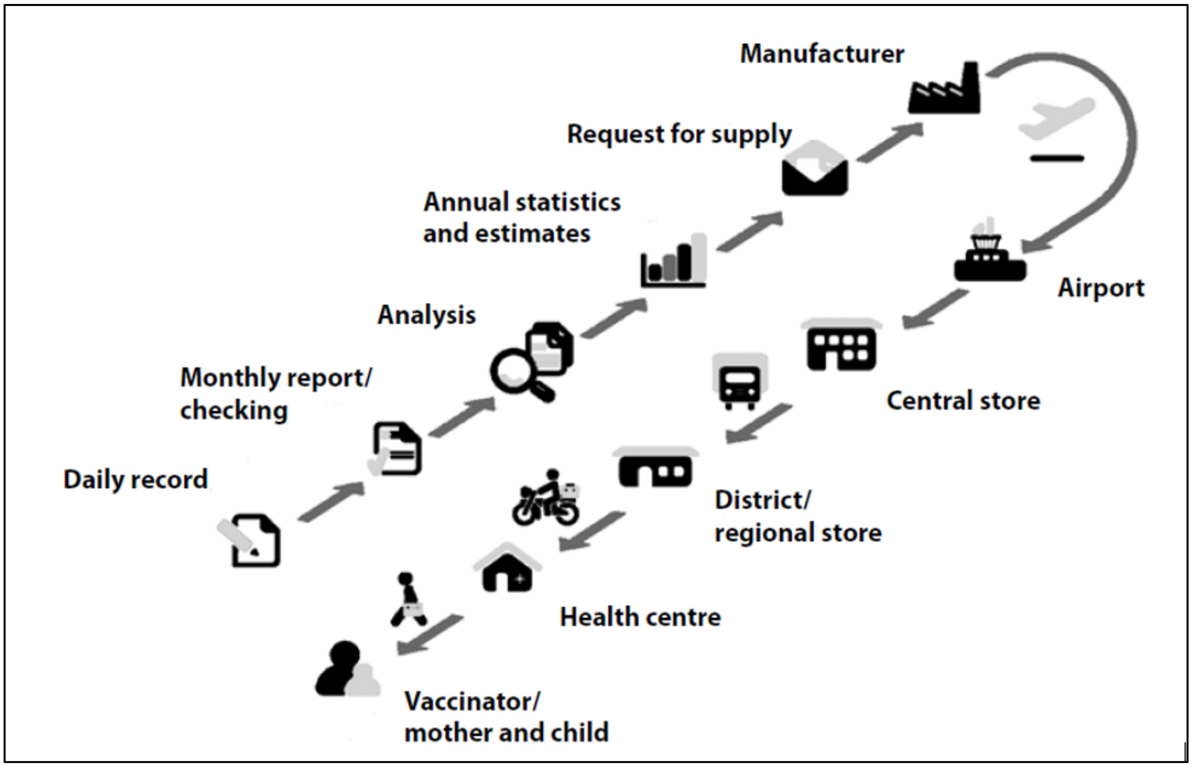


Figure 1: Cold chain system. Source WHO

2.9 Cold chain distribution system in Rwanda

Proper cold chain maintenance requires the medicines always to be maintained between 2^{o}C and 8^{o}C. This requirement comprises shipping from the manufacturer to the central medical stores, storing at district warehouses, and last-mile delivery. These products should be kept at this temperature during the outreach campaigns for immunizations(35).

The mode of delivering cold chain products in Rwanda is the pull system, and two parallel systems are performed at three levels.

2.9.1 Vaccines distribution system

The Expanded Programme for Immunization (EPI) manages all vaccines the government procures or receives from UNICEF or WHO. The refrigerated vehicles are used to distribute them from the EPI to district hospitals. Moreover, the district hospitals receive the vaccine requests from the health centers and set up a distribution schedule. These health centers then come to the hospitals to get their vaccines and carry them in cool boxes. The vaccine beneficiaries get immunization at health centers or during outreach campaigns.

Cold chain of Vaccines in Rwanda

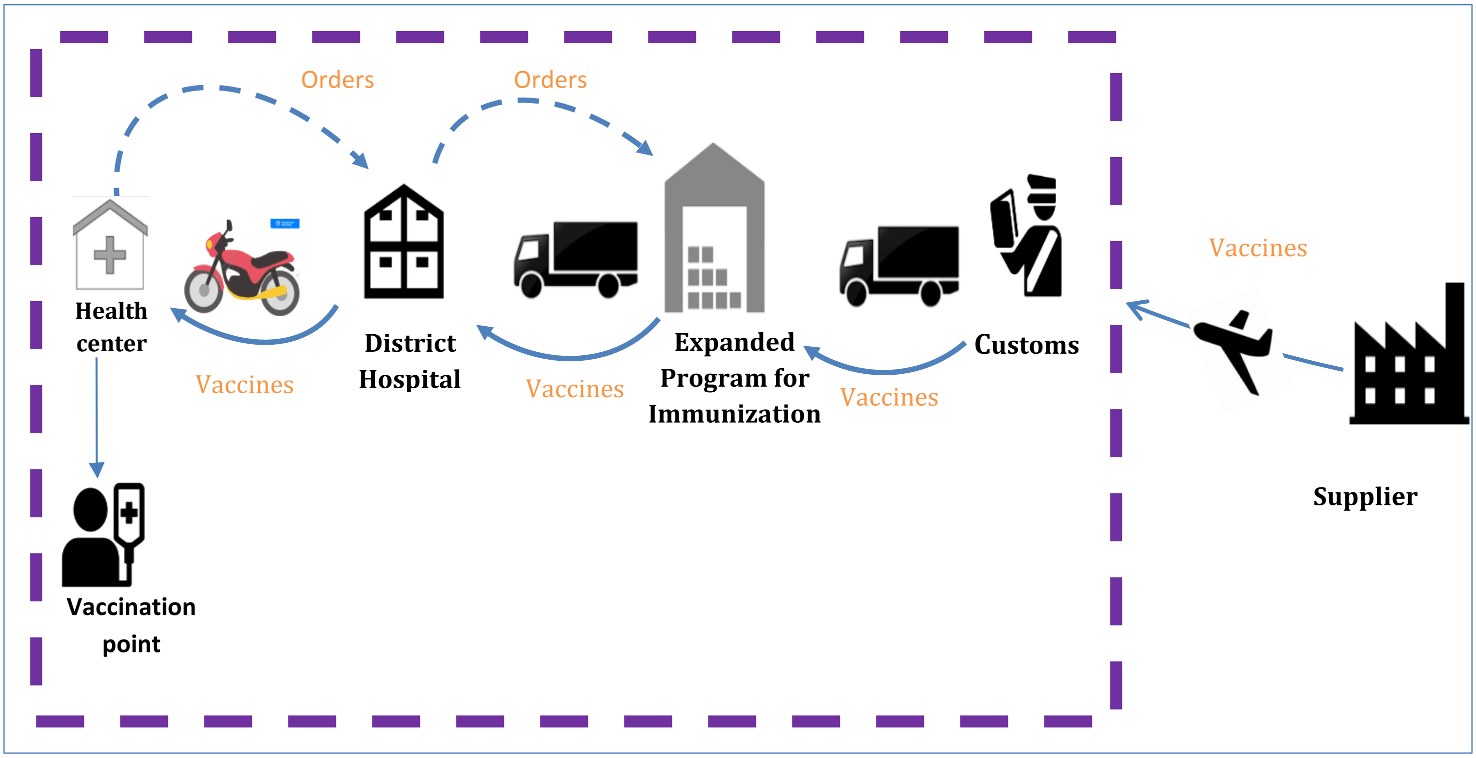


Figure 2: Vaccine distribution in Rwanda. Source: Research

2.9.2 Other cold chain product distribution model

The Rwanda medical supply (RMS Ltd) manages essential medicines, including cold chain medicines. The RMS Ltd procures cold chain medicines (Oxytocin, Insulin, human immunoglobulin) and stores them at the Central Medical Store (CMS). The distribution is done from RMS central medical warehouses to RMS warehouse branches at District levels using Minitrucs and from the RMS branches to health facilities. On the other hand, private pharmacies procure these cold chain products from private wholesalers (Figure 3).

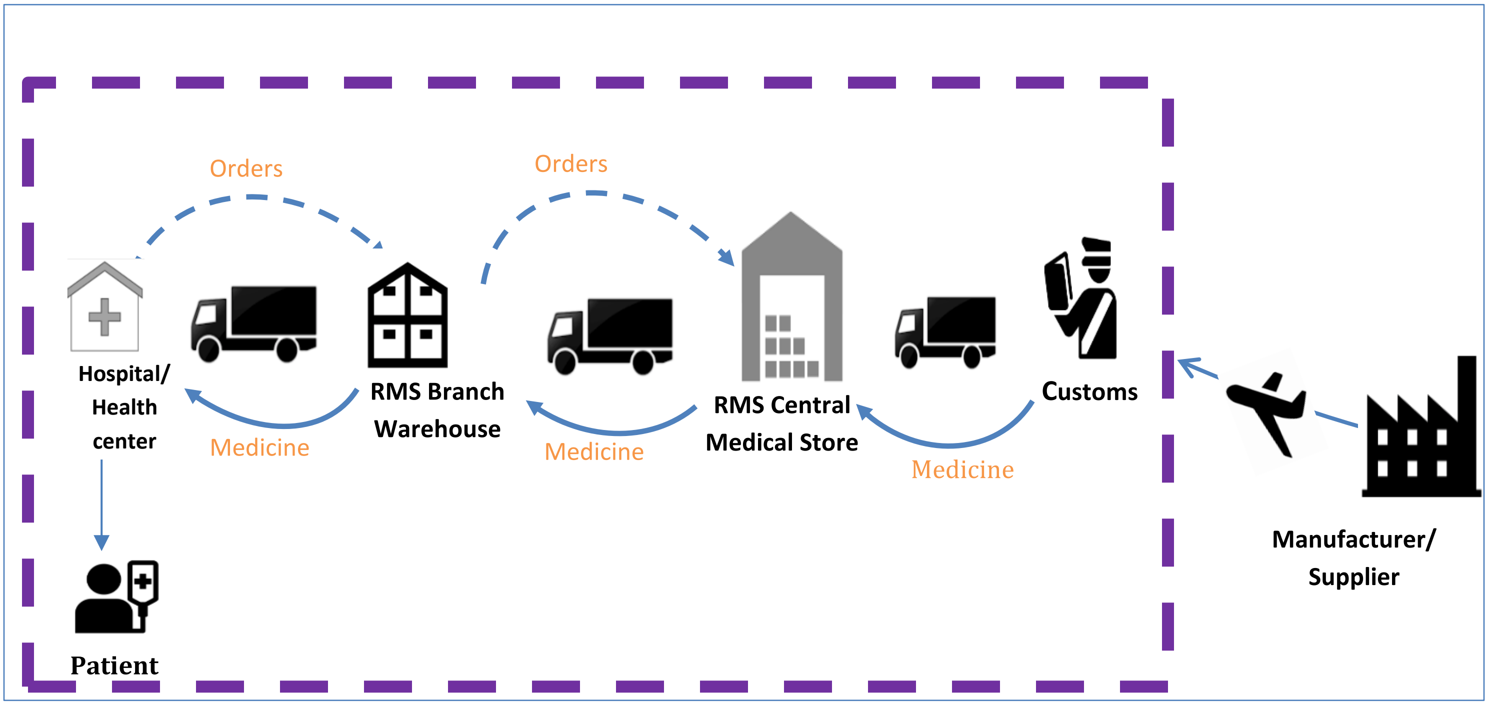


Figure 3: Cold chain distribution in Rwanda

2.10 Storage facilities for cold chain medicines

The storage condition of cold chain products is vital in maintaining a medical product's quality, efficacy, and stability.

2.10.1 Purpose-built pharmaceutical refrigerator

It is a WHO-recommended refrigerator that stores cold chain vaccines and other cold chain products. It is equipped with a fan that enables air to circulate inside to maintain a uniform temperature profile and has an alarm system to alert the temperature deviations(42). Factors to consider when outsourcing such refrigerators rely on how long the devices can maintain the recommended temperatures in the outage power supply. It may also reflect ambient temperature variations such as hot spells and global warming(43).

2.10.2 Temperature Monitoring Devices (TMD)

Data loggers are electronic devices that record measurements continuously over a set period. Researchers and scientists use these instruments as cost-effective because they don't require being on-site and using additional financial expenses. Once deployed in remote areas, these long-life battery instruments can save money and time monitoring various conditions. In addition, such devices are reliable as they are free from human error and withstand any climate or environmental conditions. Other TMD includes thermometers of refrigerators (44).

2.11 Quality management systems of cold chain product

A quality management system (QMS) refers to the processes, methods, responsibilities, procedures, documentation, quality policy, and resources management to implement quality management (45). The QMS for storage ensures a calibration program to maintain temperature monitoring devices in the efficient range. The QMS should also monitor storage facilities, validation of transports arrangements, and a cold chain personnel training program. The QMS should finally ensure the process is in place to monitor the implementation and effectiveness of the cold chain activities(46).

2.12 Conceptual framework

The conceptual framework refers to the overall exhaustive presentation of the researcher's idea raised from the existing studies adapted to fit the current research context. This section illustrates the interaction between variables (dependent and independent), clarifying to what extent the relationship between variables fits the aim of the study. It can be presented narratively or schematically (47). The narrative concept framework describes the relationship between variables, existing theories, and research findings (48). This study developed the conceptual framework based on existing literature concerning cold chain storage conformity to the WHO standards.

In this study, cold chain storage conformity depends on cold chain temperature status at the health facility, cold chain storage infrastructure, cold chain handlers' knowledge of temperature-sensitive medicine, and the cold chain storage conditions during transports from central medical stores to the last mile facilities. The illustration of the conceptual framework is based on research questions identifying key factors that may contribute to the problem. Furthermore, this conceptual framework clarifies the relationship between the problem (Cold chain medicine conformity with WHO requirements) and contributing factors mentioned above.

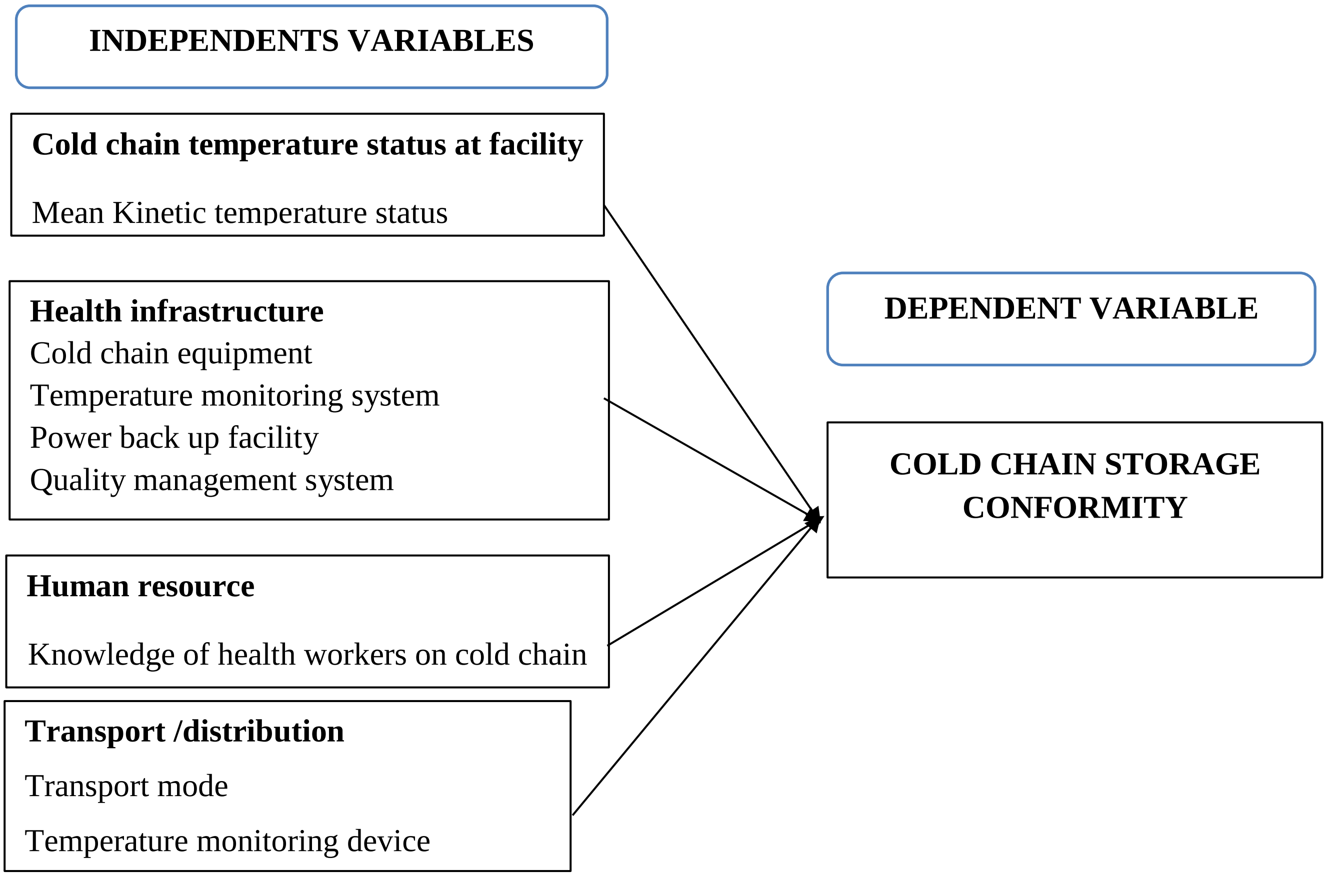


Figure 4: Conceptual framework

CHAPTER THREE: METHODOLOGY

3.1 Study design

This study used quantitative and qualitative methods in a prospective, cross-sectional, and observational design. The quantitative approach provided a comprehensive and detailed assessment of the cold chain product storage situation in the Eastern Province of Rwanda

The qualitative methods collected information about the infrastructure and the storage equipment and the knowledge of storekeepers on the storage of cold chain medicines. Key informants were selected purposively and undertook an in-depth interview to obtain medicine cold chain management practices. The observational approach used the checklist to measure key indicators.

A prospective method was chosen because we monitored the storage devices over time and watched the outcomes. The dependent variable under this research was the cold-chain storage conformity. In contrast, independent variables were: the cold chain temperature status, health infrastructures, knowledge of cold chain technicians, and transportation policy of cold chain products.

3.2 Study location

This study was carried out in the Eastern Province of Rwanda from September 2021 to February 2022. The Eastern Province is one of the five provinces of Rwanda. This province comprises 7 administrative districts namely Nyagatare, Gatsibo, Kayonza, Ngoma, Rwamagana, Kirehe and Bugesera. Eastern Province of Rwanda counts long dry spells with deficit rainfall which raises temperature abnormally. According to the national census of 2012, this is the most populated among Rwanda's five provinces, estimated 2,595,703 inhabitants (49). In addition, it comprises 210 health facilities, four categories: public, faith-based, non-governmental, and private.

3.1 Target populations

This study targeted 210 health facilities comprising: 106 health centers, 17 faith-based facilities, 7 district hospitals, 7 RMS branches, 71 retail pharmacies, 1 RMS head office, and 1 EPI. Rwanda's cold chain system is parallel and divided into three levels. The first is the central level represented by the Expanded Program for Immunization (EPI) and Rwanda Medical Supply (RMS) Ltd. The second level comprises district hospitals representing EPI and District RMS branches representing RMS headquarters. The last level is the peripheral represented service delivery points (SDPs). Expanded Program for Immunization (EPI) procures vaccines from UNICEF and WHO with the support of the Global Alliance for Vaccines and Immunization (GAVI) and distributes them to district hospitals. The latter distributes them to the health centers where immunization takes place.

On the other hand, RMS Ltd procures cold chain products from manufacturers and wholesalers and distributes them to RMS branches. The latter distributes these cold chain products to the hospitals and health centers to deliver them to the clients.

3.2 Samples

In this study, the sample comprised refrigerators and cold chain technicians managing vaccines and other cold chain products from public, faith-based, and private health facilities in the Eastern Province of Rwanda.

3.2.1 Sampling techniques

This study used convenience, stratified random, and purposive sampling techniques. The health facilities assessed (public, faith-based and private retail pharmacies) were grouped into subgroups (strata) according to their types. Private clinics were not selected because they don't manage cold chain products. Two health facilities of each category (public, faith-based, and private retail pharmacies) were considered part of the study participant. The RAND function in Microsoft Excel was performed to select these facilities randomly.

3.4.2. Sample size determination

The RAND function generated 14 health centers, 14 faith-based health facilities, and 14 private pharmacies. In addition, 7 district hospitals, 7 RMS branches, 1 RMS Central Medical Stores (CMS), and an Expanded program for immunization (EPI) were selected purposively to be part of the study as they actively participate in the last mile deliveries. Hence all health facilities considered in this study comprised 58 health facilities.

Considering the target population, each public health facility participating in the study should provide two cold technicians, one managing vaccines and other cold chain products. Private retail pharmacies, RMS branches, RMS head office, and EPI provided 1 technician due to the nature of the facility. Hence 93 cold chain technicians were part of the study.

In each public and faith-based facility, two refrigerators (one for vaccine storage and one for other cold chain products) were considered part of the assessment. The retail pharmacies provided one refrigerator as they didn't manage vaccines. RMS branches should also provide two refrigerators. Hence, the refrigerators considered in this study were 98. The EPI and RMS head office refrigerators were not included as these institutions manage cold chain products in cold rooms.

Nevertheless, due to time constraints and the covid-19 pandemic outbreak, the selected population was not met accordingly. Hence, 44(76%) health facilities were visited, including 25 public and faith-based facilities, ten private retail pharmacies, 7 RMS branches, 1 RMS Head Office, and 1 EPI. Among these health facilities, 42 were assessed to measure the compliance of WHO cold chain storage conformity. Two others (RMS head office and EPI) were visited to assess the compliance of storage of health products during transportation.

Hence, in 25 health facilities mentioned above researcher mounted 1 data logger in each refrigerator that stores vaccines and cold chain products, respectively. Thus, 50 data loggers were mounted. In the private retail pharmacies, 1 data logger was mounted as they usually have one refrigerator, then 10 data loggers were mounted. The last health facilities used to mount data loggers are seven branches in which 2 data loggers were mounted. Hence, 74 data loggers were mounted in 74 refrigerators of 42 health facilities.

As cold chain technicians, 67 participated in the study from health facilities, including 57 public health facilities and 10 private retail pharmacies.

3.5 Data collection

3.5.1 Data collection methods and techniques

3.5.1.1 Mean Kinetic Temperature

Fridge data loggers were programmed to record and save data every ten minutes. These data loggers were connected to the computer with appropriate software to log selected parameters, including sampling intervals and start time, and activate them for starting data recording and saving. Seventy-four data loggers were then mounted in the refrigerators in a secured place. These data loggers immediately began recording temperature for 30 days.

3.5.1.2 Storage, personnel, transportation indicators

Data collected included health infrastructure, cold chain technician knowledge, the quality management system, and the transportation policy of cold chain products in central medical stores and study areas.

3.5.2 Questionnaire

The questionnaires contained important questions aligned with the study's objectives, including the socioeconomic characteristics of respondents who manage cold chain products. It also included close-ended questions to collect relevant information from cold chain management systems in the Eastern Province based-health facilities.

3.6 Data analysis

This study's data analysis was performed per the specified objectives.

3.6.1The conformity of cold chain storage as per World Health Organization requirements

This objective was measured using Mean Kinetic Temperature as described below:

3.6.1.2 Mean Kinetic Temperature

After thirty days, the investigator recollected temperature data loggers mounted in the refrigerators, and the imec Messtechnik software was used to determine the Mean Kinetic Temperature (MKT). The formula to calculate MKT is indicated below:

The formula to calculate MKT is indicated below:

$$T_K = \frac{\frac{\Delta H}{R}}{-\ln\left(\frac{e^{\left(\frac{-\Delta H}{RT_1}\right)} + e^{\left(\frac{-\Delta H}{RT_2}\right)} + \ldots + e^{\left(\frac{-\Delta H}{RT_n}\right)}}{n}\right)}$$

Where:

TK is the mean kinetic temperature in kelvins

ΔH is the activation energy (in kJ mol−1)

R is the universal gas constant (in J mol−1 K−1), i.e., 8.314472 J/mol-K

n = the number of sample periods over which data is collected

T = temperature in degrees K

n = the number of sample periods over which data is collected

ln= is the natural log, and ex is the natural log base.

3.6.2 Knowledge of cold chain technicians about the storage of cold chain products

This objective enabled us to measure the knowledge of cold chain technicians on the storage of cold chain medicines. We conducted an in-depth interview with key informants and know to what extent they know cold chain medicine handling guidelines.

3.6.3 Infrastructure conditions of cold chain products.

This objective is used to analyze cold chain infrastructure through an observational approach. The infrastructure observed comprised cold chain equipment and temperature monitoring devices used in cold chain management

3.6.4 Storage conditions of cold chain products during transportation

This objective analyzed cold chain storage performance while transporting cold chain products from central medical stores, including Expanded Program for Immunization and Rwanda Medical Supply Ltd, to service delivery points. We used this observational approach and interview.

Input, cleanup, editing, and analysis of the corrected data were performed using SPSS V25. Critical variables, including association variables and Chi-square, were analyzed using inferential and descriptive statistics.

3.7 Ethical consideration

Study permission and approval No CMHS/IRB/297/2021 was sought from the University of Rwanda, Institution Review Board (IRB). The interviewees agreed to participate voluntarily and were assured that their information would only be utilized for academic studies. The informed consent form was developed and disseminated to the key informants, who were allowed to ask for clarifications to partake in the research. The participants who agreed to participate in the study signed the informed consent form.

CHAPTER FOUR: RESULTS

This chapter outlines study results concerning cold chain storage conformity, health facility infrastructure, cold chain technicians' knowledge, and cold chain transportation policy from central medical stores for public and private health facilities.

4.1 Storage temperature conformity to the WHO's recommendations

Out of 74 refrigerators assessed, 50(67%) were used in public health facilities, 14(19%) used in faith-based facilities, and 10(14%) used in private retail pharmacies (Figure48).

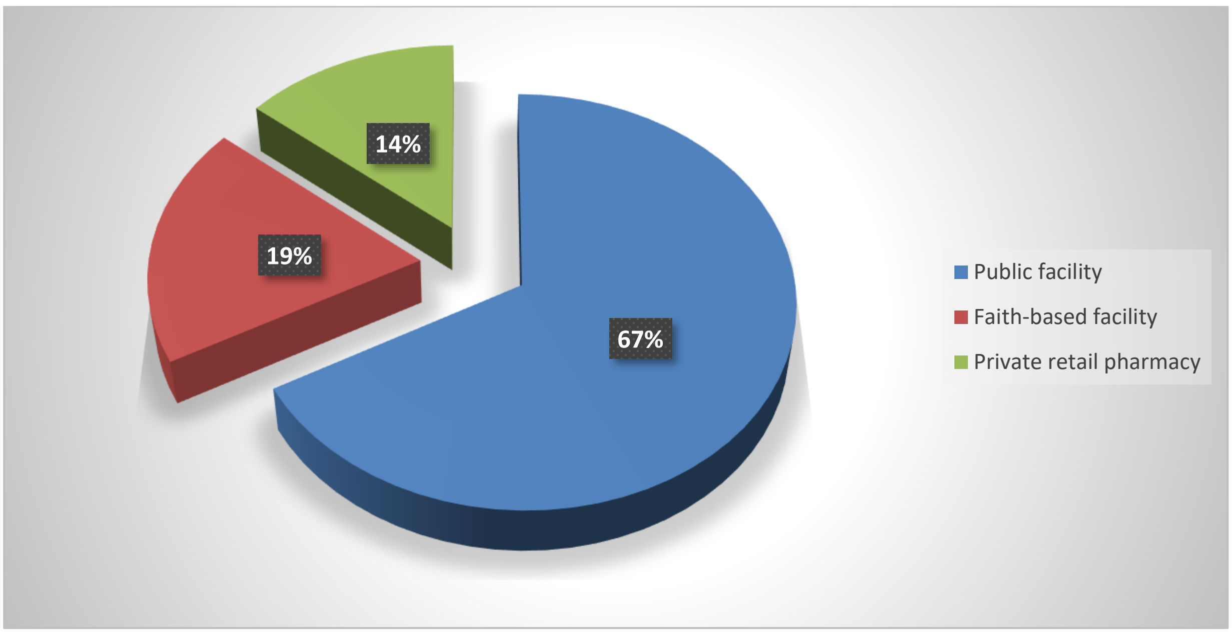


Figure 5: % of health facilities participated in the study

Out of 74 refrigerators assessed, 49(66%) were used to store cold chain products in pharmacy stock, while the vaccination programs covered 25 (34%) in public and faith-based facilities (Figure 5).

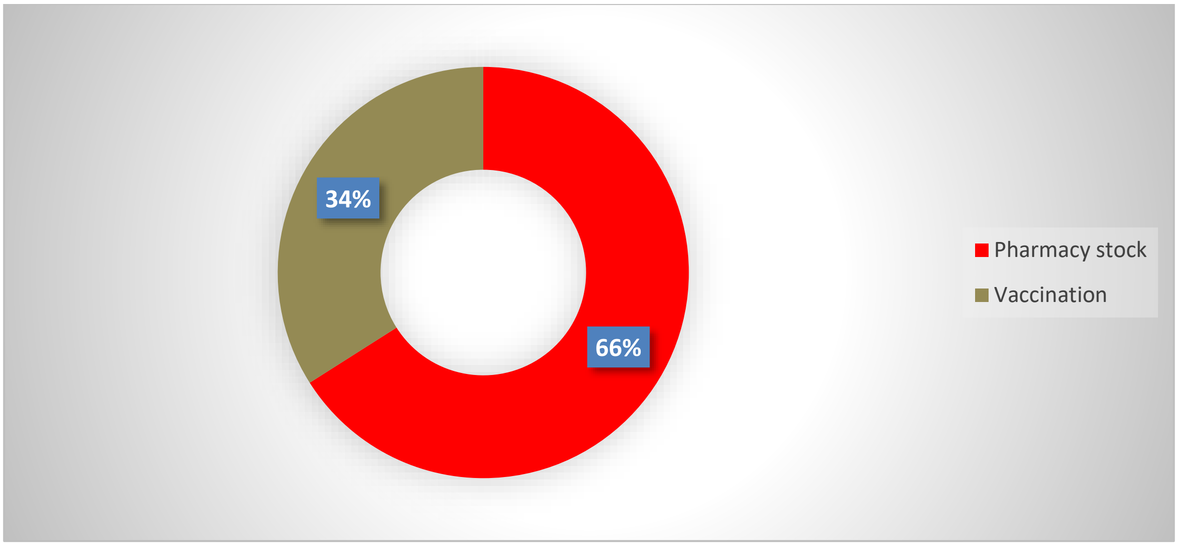
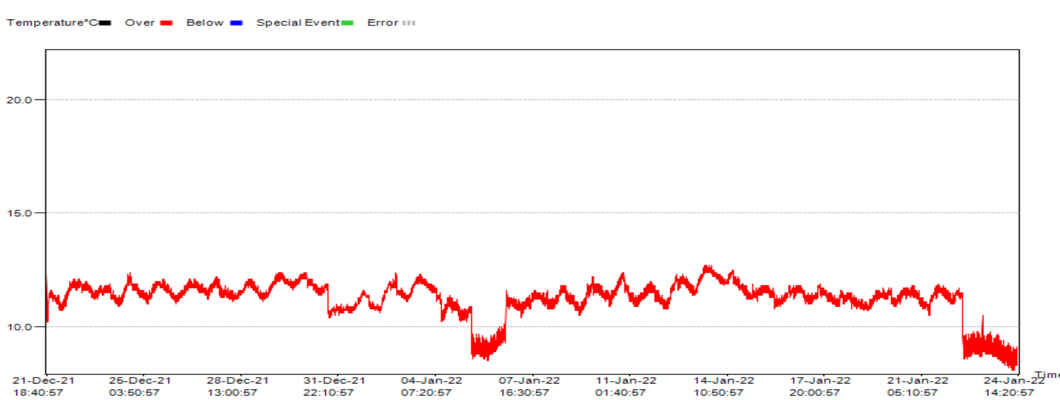


Figure 6: Refrigerators used in vaccination and pharmacy stock

Mean Kinetic Temperature was measured for 74 refrigerators assessed. Deviations from the acceptable temperature ranges defined for products requiring cold-chain storage were found. Our results showed variability in cold chain conformity as per the examples below. Some refrigerators deviated from storage requirements (below 2^{o}C and others above 8^{o}C).

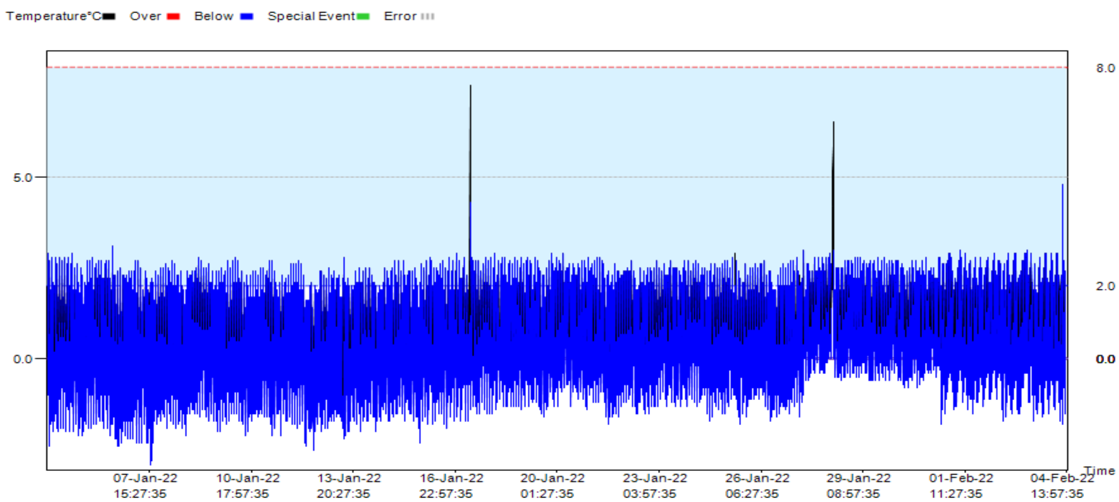
This study discovered the status of refrigerators that stored cold chain products to maintain their potency. The figure below illustrates the refrigerator that recorded temperature above the recommended range. MKT measured in this refrigerator was 11.2^{o}C, and such storage conditions may affect the product quality (Figure 6).



MKT=11.2^{o}C

Figure 7: Recorded MKT with deviations from the recommended storage temperature range.

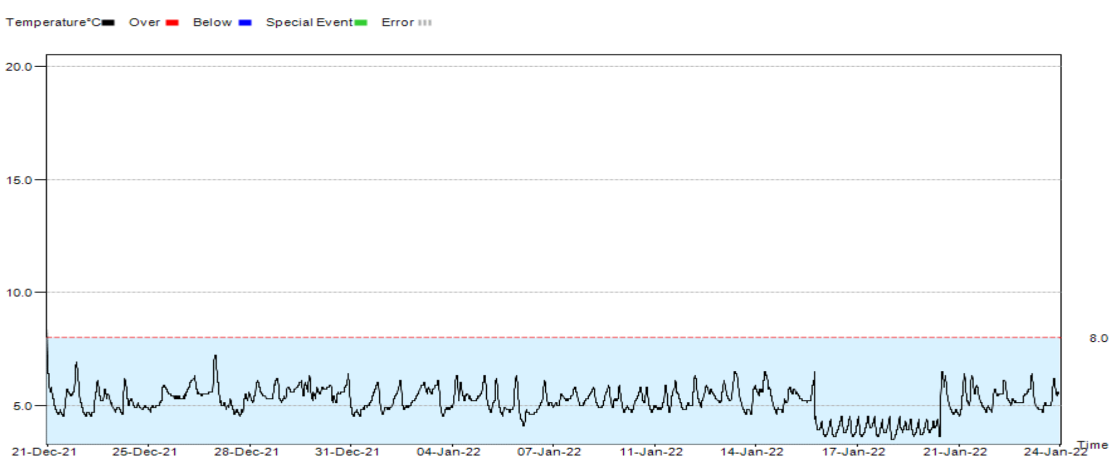
The results of MKT measurements revealed that some refrigerators record temperatures that are below the recommended range. The MKT measured in the below refrigerator was 0.7°C which may impact the potency of cold chain products (Figure 7).



MKT= 0.7°C

Figure 8: MKT registered in a cold refrigerator

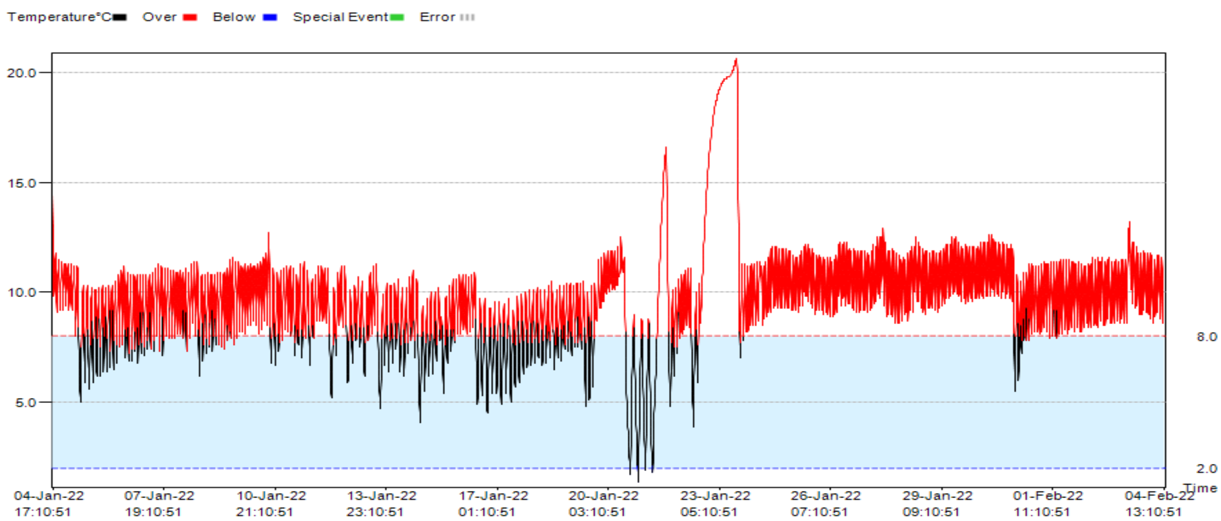
This study also pointed out the refrigerators that meet cold chain storage conformity to the standards. The measured MKT in such fridge ranged between 2°C-8°C. In the example below, the MKT recorded was 5.1°C (Figure 8).



MKT= 5.1°C

Figure 9: MKT recorded in a well-functioning refrigerator

The figure below represents the instability of the refrigerator while storing cold chain products. This case may result from the unstable power supply or limited contingency plans such as lack of function and automated generator. In the example below, the recorded MKT was 10.1ºC, and such storage conditions may negatively impact cold chain products' potency (Figure 9).



MKT= 10.1ºC

Figure 10: MKT recorded in a cool and hot refrigerator

These results revealed that the totality (100%) of refrigerators used in public and faith-based facilities, vaccination programs complied with storage temperature conformity as per WHO requirements. The performance of cold chain storage conformity of refrigerators used in pharmacy stock in public health facilities was 18(56%), in faith-based facilities was 4(57%), and in private retail pharmacies was 7(70%) (Figure 10)

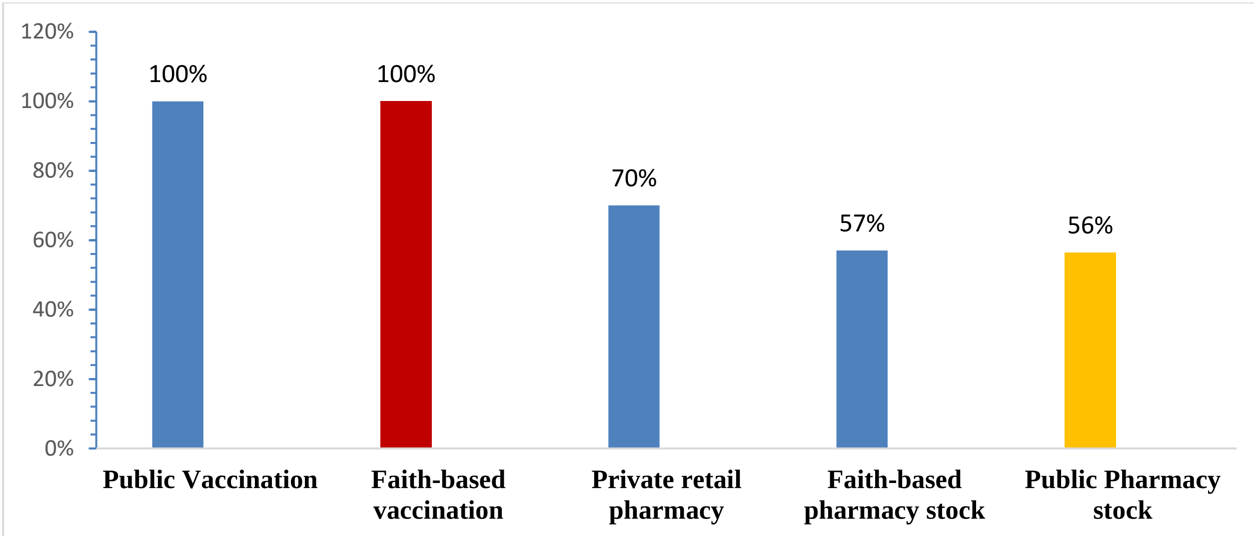


Figure 11: Storage temperature conformity to the WHO's recommendations in health facilities

4.1.1 Mean Kinetic Temperature recorded in refrigerators of pharmacy stock and laboratory

This section indicates the results for storage temperature conformity with the WHO requirements. The unit of measurement was Mean Kinetic Temperature, measured in refrigerators that stored cold chain products in pharmacy stock and laboratory.

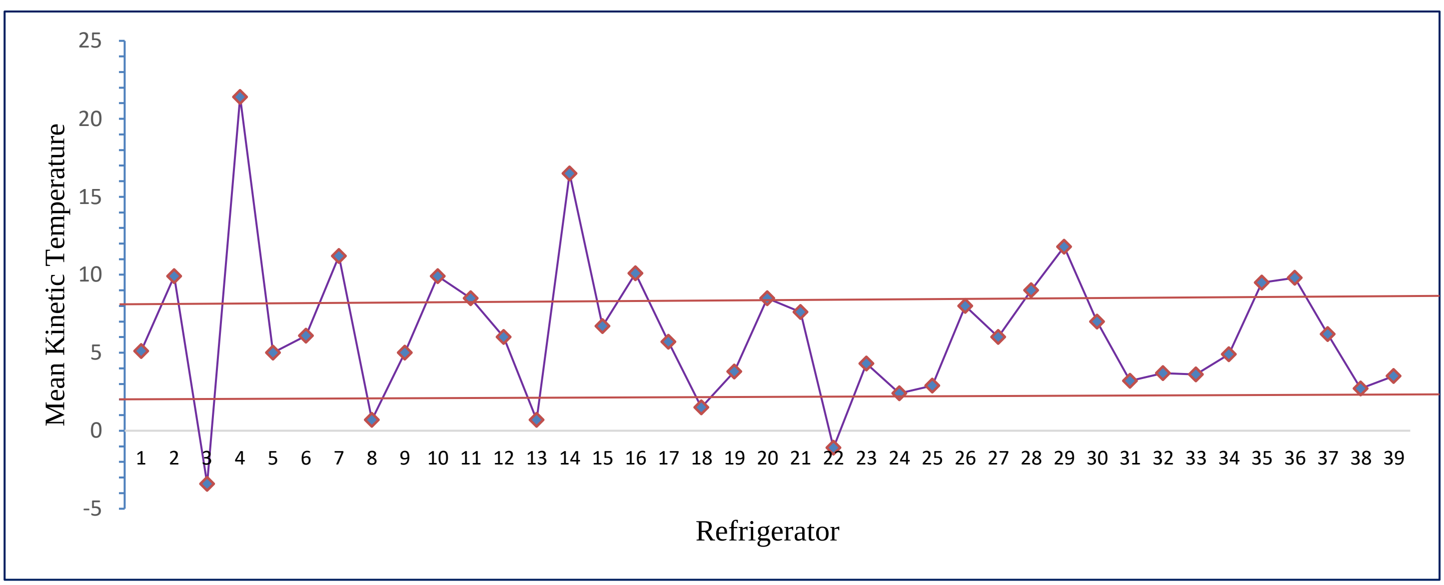


Figure 12: MKT recorded in pharmacy stock and laboratory program

The results pointed out that 17(44%) of refrigerators assessed in both pharmacy stock and laboratory did not comply with the WHO standards of cold chain storage. The high MKT was 21,4°C, while the lowest was -3.4°C (Figure 11).

4.1.2 Mean Kinetic Temperature found in refrigerators of the vaccination program

The cold chain management system in Rwanda is parallel. This section highlights the Mean Kinetic Temperature measured in the refrigerators for the vaccination program. The majority 25(100%) of refrigerators assessed in this program complied with cold chain storage WHO requirements. The MKT recorded ranged between 2°C and 8°C. The highest MKT recorded in these refrigerators is 7.8°C, while the lowest is 4°C (Figure 12).

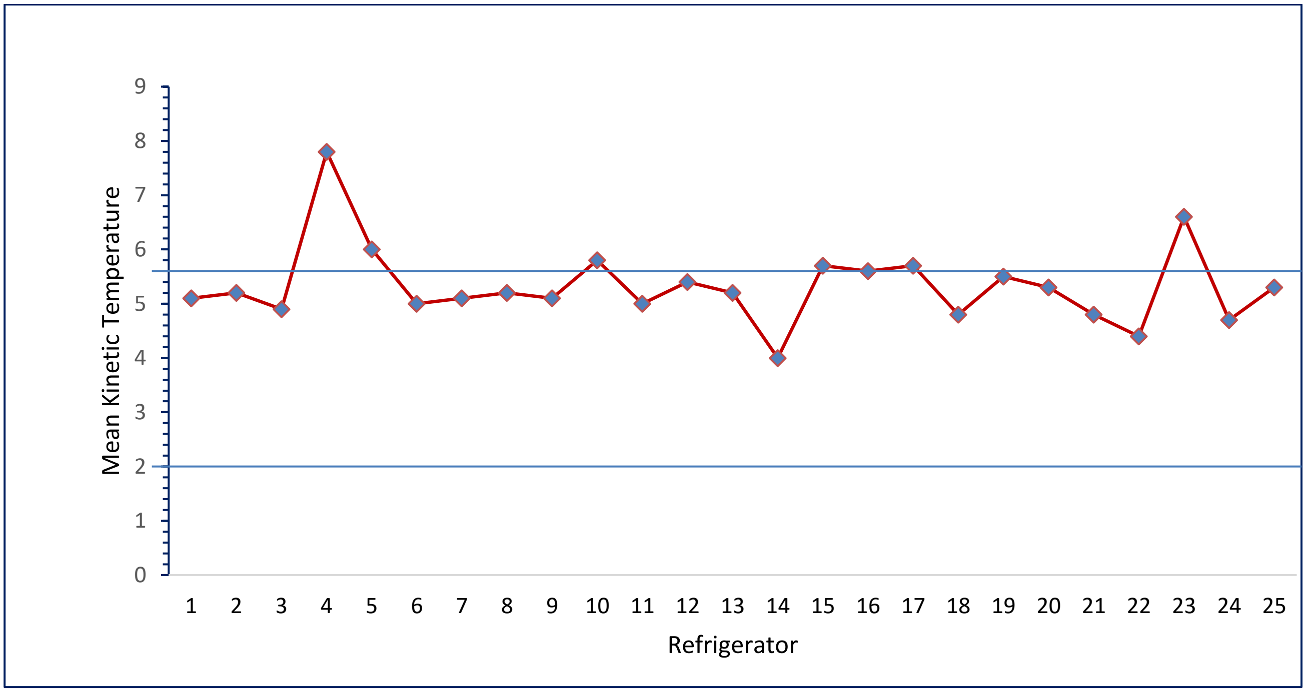


Figure 13: MKT recorded at the vaccination program

4.1.3 Mean Kinetic Temperature found in refrigerators of private health facilities

This study found that of 10 refrigerators assessed in private retail pharmacies, 3(30%) did not comply with WHO requirements. The high MKT was 12,1°C while the lowest was 2.4°C (Figure 13).

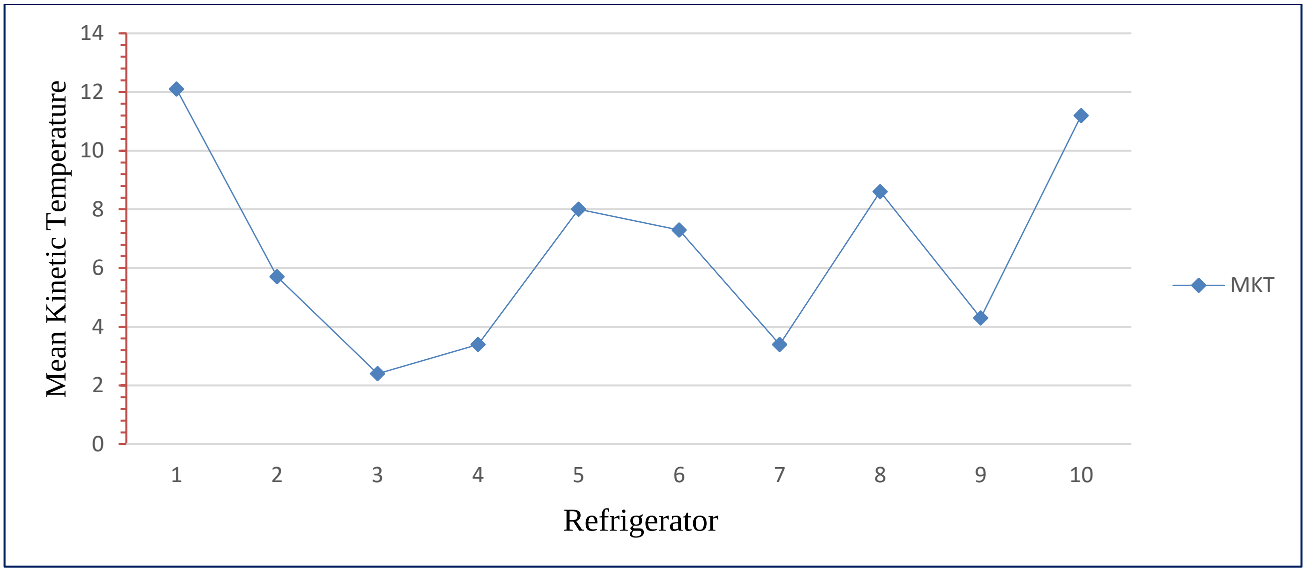


Figure 14:MKT recorded in refrigerators of private health facilities

4.2 Effects of infrastructure on the storage of cold chain products in health facilities

This section highlights how the health facility infrastructure affects the storage conditions of cold chain products. The infrastructures assessed were: cold chain equipment and temperature monitoring devices, temperature monitoring system, and quality management system.

4.2.1 Availability of cold chain equipment for public and faith-based health facilities

The 64 refrigerators were assessed in public and faith-based health facilities. Most refrigerators 62(97%), were pre-qualified and furnished with temperature monitoring devices (thermometers or fridge tags). However**,** 11(17%) store various cold chain products, including cold chain medicines (oxytocin, insulins) and laboratory commodities (laboratory reagents, blood components, and other chemicals) in the same refrigerators. In addition, 2(3%) of public and faith-based health facilities visited used domestic refrigerators for storing cold chain products. 1(2%) of the health facilities visited shared refrigerators storing vaccines with other products as one for vaccines was broken down (Figure 14).

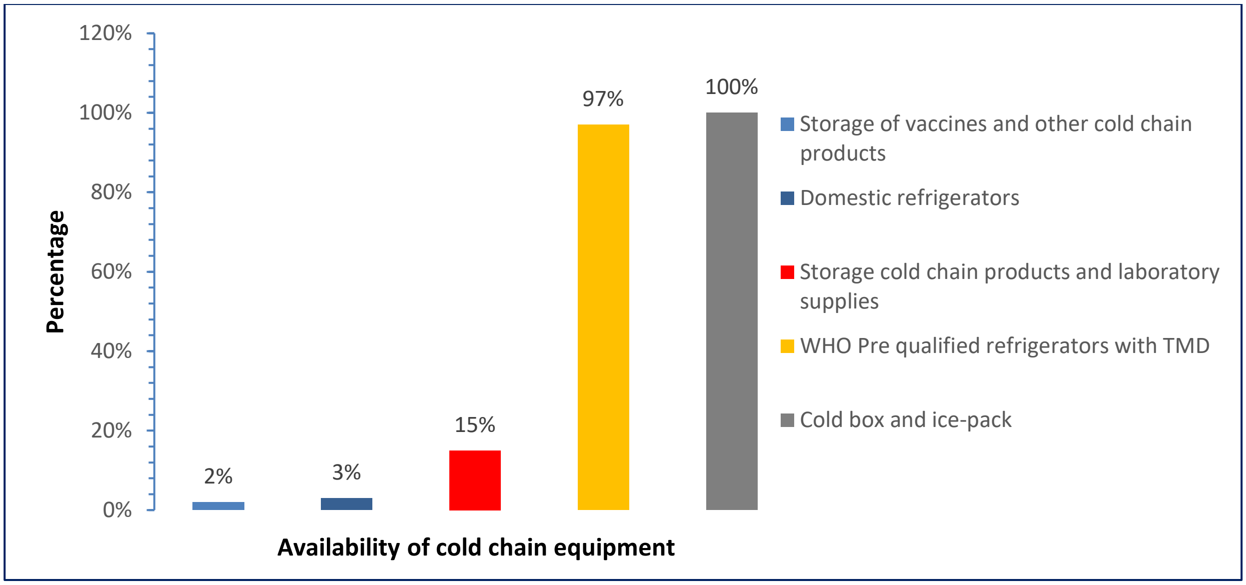


Figure 15:Availability of cold chain equipment in public and faith-based health facilities

4.2.2 Age of cold chain equipment in public and faith-based health facilities

This study revealed that 18(28%) of refrigerators assessed in public and faith-based facilities were aged between 2 to 4 years since their installation, and these refrigerators stored vaccines. Contrarily, 17(27%) and 9(14%) refrigerators were between 8 and 10 years old and more than ten years. These refrigerators are used to store other routine cold chain products (Figure 15)

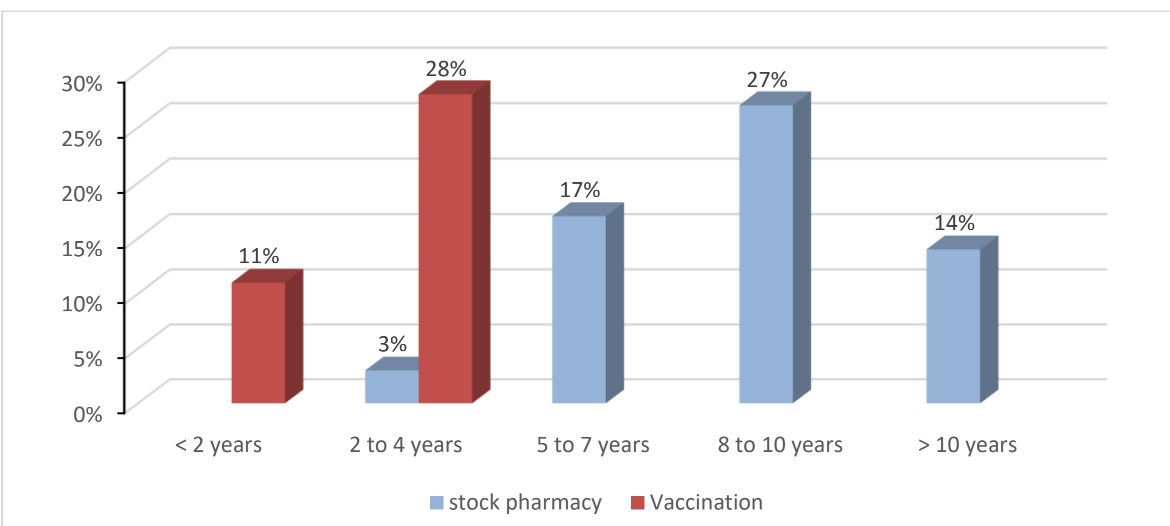


Figure 16: Age of cold chain refrigerators recorded in public and private health facilities

4.2.3 The temperature monitoring systems in public and faith-based health facilities

This study revealed that out of 57 cold chain technicians from public and faith-based health facilities, 51(89%) recorded daily storage temperature. However, 6(11%) did not record temperature many months ago. The reason highlighted was dysfunctional temperature monitoring devices. Temperature data loggers enable cold chain technicians to gather storage temperature information and analysis the case of alarm if it happened on the weekend or at midnight. Of the 64 refrigerators visited, only 25(39%) use thermometers and temperature data loggers for refrigerators used in the vaccination program and can print out the results monthly (Figure 16).

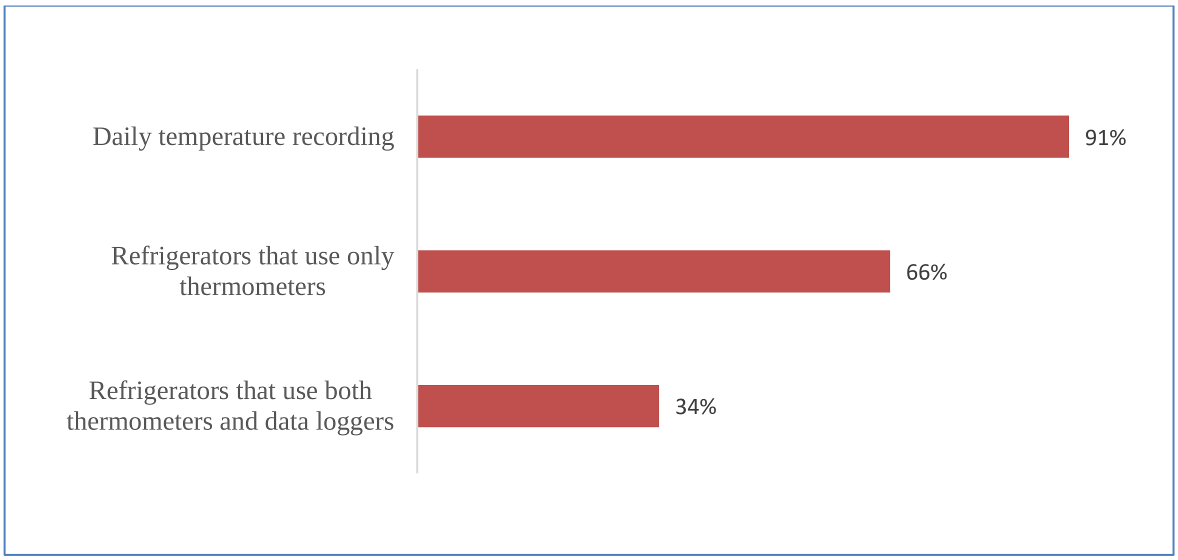


Figure 17: Temperature recording system in the public health facility

4.2.4 Contingency plan for the power outage in public and faith-based health facilities

This study found that 57 cold chain technicians from public and faith-based health facilities visited, and the majority of respondents, 45(79%), confirmed using a generator in a power outage. However, 25(45,5%) were automated (Figure 17).

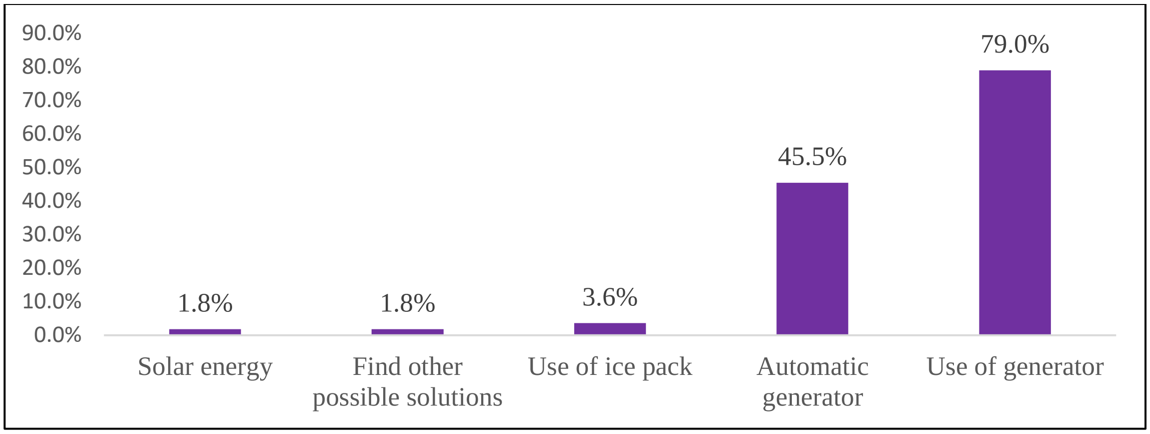


Figure 18: Availability of contingency plan in the event of a power outage

4.2.5 The quality management system of cold chain storage

4.2.6.1The quality management system of cold chain storage in public and faith-based health facilities

This section highlights the calibration of cold chain equipment. QMS ensures that the cold chain equipment is calibrated and validated to maintain cold chain products appropriately in the supply chain management system. Out of 57 cold chain technicians evaluated for this study, 24 (42%) acknowledged having calibrated refrigerators, 14 (25%) underlined calibration of temperature monitoring equipment, and 12 (21%) stated the availability of stickers for the next calibration session, 1(2%) confirmed calibration of the vehicle that distribute vaccines (Figure 18).

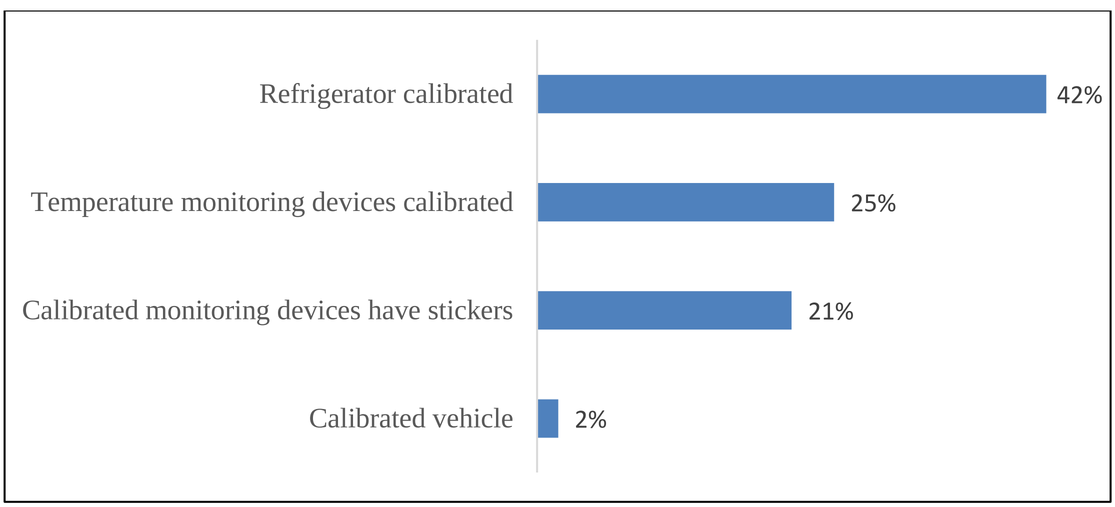


Figure 19: Calibration of cold chain equipment and devices

4.2.6 Availability of cold chain equipment in private health facilities

This study found that all private retail pharmacies visited have refrigerators, 40% have ice packs, and none have cold boxes for transporting cold chain products (Figure 19).

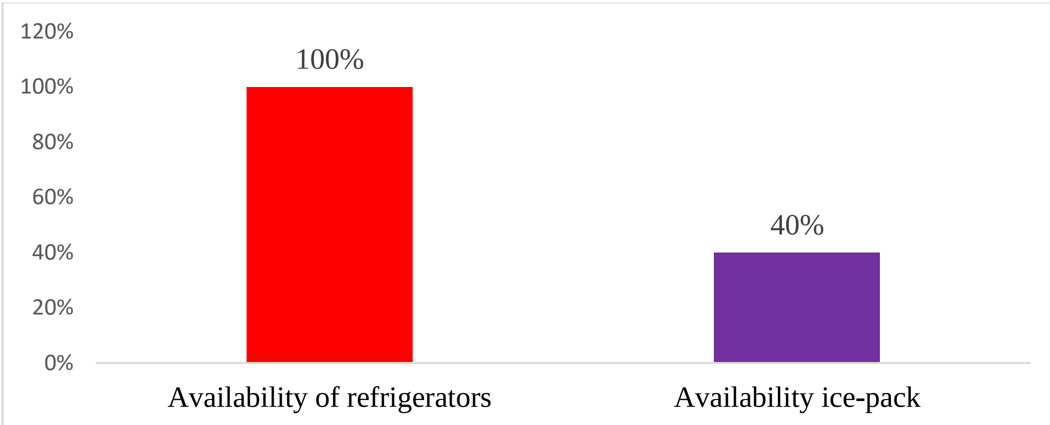


Figure 20:Availability of refrigerators in private retail pharmacies

4.2.7 Age of cold chain equipment found in private retail pharmacies

The findings of this study showed that out of 10 refrigerators assessed from private health facilities, the majority, 7(70%), were between are between the ages of 2 and 4 years, followed by 2(20%) aged between the ages5 to 7 years and 1(10%) that is newly commissioned (Figure 20).

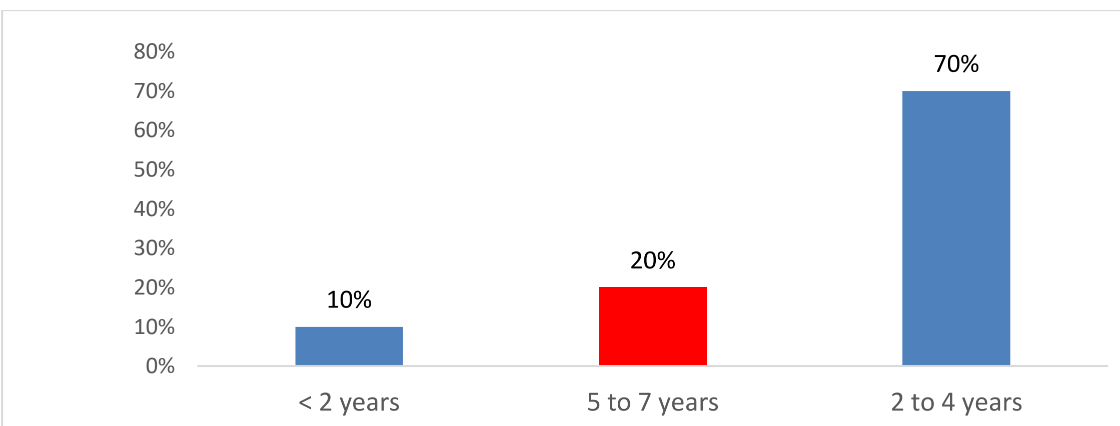


Figure 21: Age of Refrigerators found in private retail pharmacies

4.2.8 Temperature monitoring system in private retail pharmacy

This section comprised the temperature monitoring system found in private retail pharmacies. This study found that in 10 retail pharmacies visited, 9(90%) had thermometers and recorded daily temperature (Figure 21).

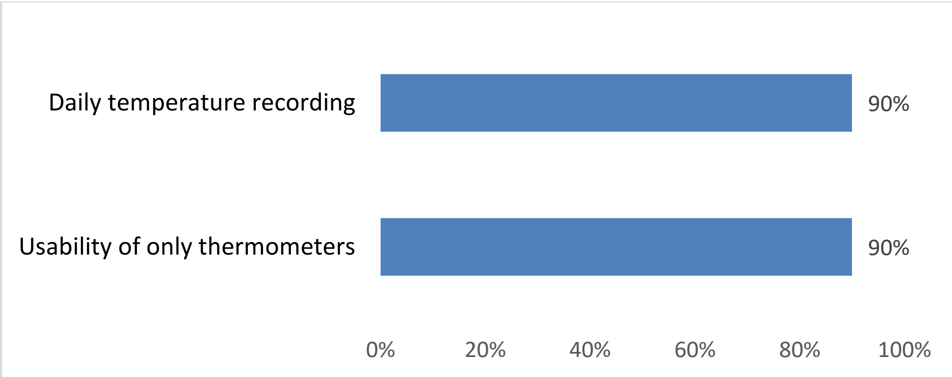


Figure 22: Temperature monitoring system

4.2.9 Availability of contingency plan

The results of this study found that out of 10 private retail pharmacies assessed, the majority 10(100%) have refrigerators, and 9(90%) have working temperature monitoring devices (thermometers). The majority 6(60%) of retail pharmacies visited use generators in the event of a power outage, while 1(10%) use ice packs and 2(20%) do nothing. However, the overall private retail pharmacies assessed didn’t have automated generators (Figure 22).

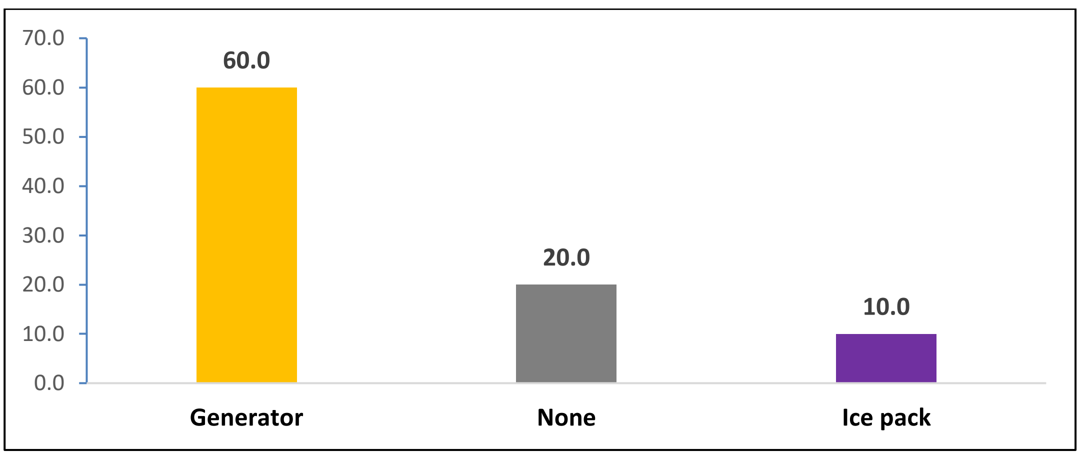


Figure 23: Availability of contingency plan

4.2.10 Quality management system of cold chain storage in private retail pharmacy

All retail pharmacy technicians that participated in the research don’t have information about the calibration of cold chain equipment and monitoring devices. Majority10(100%) do not have calibrated refrigerators, and the thermometers used to record daily temperature are not calibrated.

4.3 Knowledge of technicians on the storage of cold chain products in health facilities

4.3.1 Knowledge of cold chain technicians from the Public and faith-based health facilities

The cold chain technicians' knowledge of cold chain guidelines was assessed through 15 Likert scale questions. This assessment was done with cold chain technicians working in public and faith-based facilities as they managed vaccines and cold chain products in this study. The reliability of the questions was verified beforehand using Cronbach's Alpha (**α**), and it was discovered that **α** =0.7, confirming the reliability of the questions. The questions evaluated the VVM knowledge, storage, and distribution of vaccines.

Cronbach's Alpha (**α**) was pre-tested to ensure the reliability of the questions and found that α=0.7, which indicates the reliability of the questions. The questions focused on vaccine cold chain management and evaluated the VVM knowledge, storage, and distribution.

The Likert scale table indicated that 27(49.1%) cold chain technicians had a problem recognizing the shared responsibility of cold chain actors. The duration of vaccine storage at district hospital is one month, and there was no difference between those who agreed and disagreed(P=0.225). Vaccines storage between 2^oC and 8^oC was known by 44(80%). The majority of respondents, 39(70.9%), knew that VVM is used to measure if vaccines are damaged by heat, 36(65.5%) knew that VVM is not used to perform vaccine freezing and 25 (45,5%) identified the four VVM stages. Few respondents identified the impact of storing cold chain products with vaccines at 16(29.1%). Vaccine transportation in a vaccine carrier with conditioned icepacks was known at required storage (2^oC and 8^oC) should be transported in vaccine carriers with conditioned ice packs to avoid freezing during outreach activities.

Nevertheless, most respondents knew that before administering vaccines, it's better to check all necessaries to ensure safety, including expiry date and VVM status at 81.9% and 85.5%, respectively. Temperature data loggers were known for 40 (73.7%) respondents. This knowledge performance was due to the data collection approach. This study used face-to-face interviews, which created a good environment for the participant to ask for clarifications on the research questions. (Table 2).

Table 1: Knowledge of cold chain technicians on cold chain product

Knowledge of cold chain storage	Disagree No. (%)	Agree No. (%)	Total No. (%)	Chi-square	P-value
The vaccine cold chain maintenance is the responsibility of the hospital that stores the vaccines	27(49.1)	28(50.9)	55(100.0)	30	.000
The duration of keeping vaccines at the hospital is less than 2 months	32(58.2)	23(41.8)	55(100.0)	7.891	.225
All vaccines are stored between 2 and 8°C	11(20.0)	44(80.0)	55(100.0)	19.8	.000
The VVM is used for vaccines damaged by heat	16(29.1)	39(70.9)	55(100.0)	9.618	.002
The VVM is used for vaccines damaged by freezing	36(65.5)	19(34.5)	55(100.0)	5.255	.022
A shake test must be conducted when freeze-sensitive vaccines are visibly seen to be frozen	25(45.5)	30(54.5)	55(100.0)	0.455	.500
Data loggers are used to measure temperature-sensitive medicines in cold chain storage	15(27.3)	40(72.7)	55(100.0)	11.364	.001
The duration of vaccine storage at district hospital is 1 month	34(61.8)	21(38.2)	55(100.0)	3.073	.080
There are four stages of VVM identifying the state of vaccines	30(54.5)	25(45.5)	55(100.0)	0.455	.500
Vaccines and other temperature-sensitive medicines can be kept in the same refrigerator if there is a shortage of refrigerators.	39(70.9)	16(29.1)	55(100.0)	9.618	.002
Vaccines are distributed at -2 and -8°C	37(67.3)	18(32.7)	55(100.0)	6.564	.010
Vaccines can be transported using an ice pack in the cold box to maintain temperature	23(41.8)	32(58.2)	55(100.0)	1.473	.225
During outreach activities, vaccines should be stored in a vaccine carrier with ice pack	24(43.6)	31(56.4)	55(100.0)	0.891	.345
Before distributing vaccines, you should check only the expiry date	45(81.8)	10(18.2)	55(100.0)	22.273	.000
Before distributing vaccines, you should check only VVM	47(85.5)	8(14.5)	55(100.0)	27.655	.000

4.3.2 Knowledge of cold chain technicians from private health facilities

The knowledge of cold chain technicians from private retail pharmacies was focused on insulin storage. In most retail pharmacies, 10(100%) know the correct insulin storage, and 9(90%) know that the insulin can be stored at room temperature for at least one month. However, 6(60%) said that insulin could be stored in a domestic refrigerator, and only 10% have information on the use of VVM while storing vaccines (Figure 23).

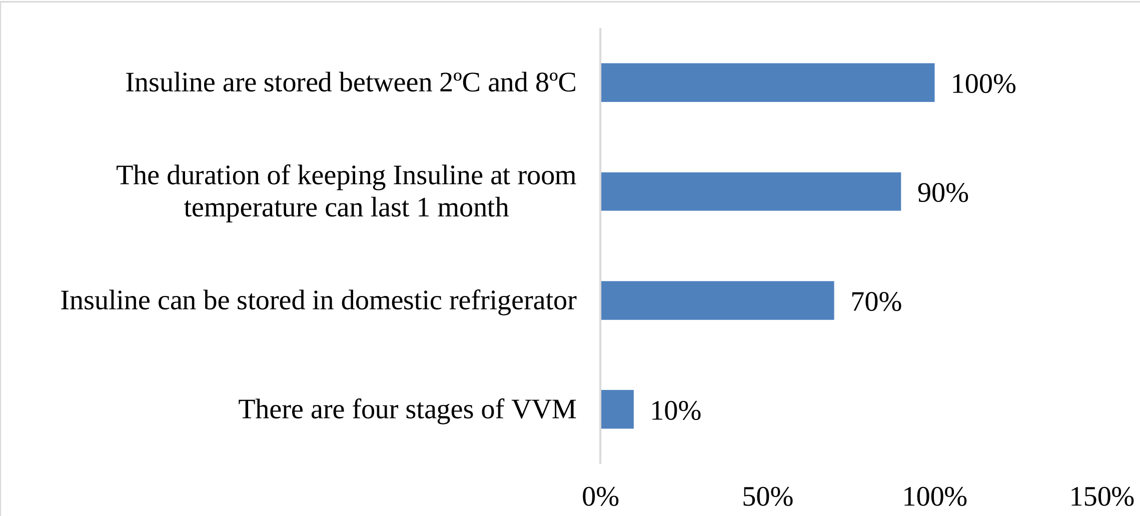


Figure 24: Knowledge of cold chain technicians on cold chain products

4.4 Storage conditions of cold chain medicines during transportation

This section highlights the storage condition while transporting cold chain products from central medical stores (RMS and EPI) to service delivery points. The assessment at this stage focused on the quality of cold chain transportation.

4.4.1 Transportation of cold chain products from RMS Ltd to health facilities

The cold chain products at RMS Ltd are stored in the big cold room. The person-in-charge monitors daily storage temperature using thermometer and data loggers, as testified by CCT: "*We monitor temperature daily using temperature monitoring devices including thermometers and data loggers.*"

The RMS Ltd calibrated temperature monitoring devices (TMD) to ensure reliability in temperature measuring. "*We use the temperature monitoring device calibrated by Rwanda Standard Board (RSB) to ensure the reliability of temperature monitoring.*"

Nevertheless, Rwanda Medical Supply Ltd doesn't have a system to monitor the quality of cold chain storage during transportation. This facility has a limited approach for monitoring cold chain products during transportation. "We *put cold chain products in cool boxes with a conditioned ice pack and distribute them to the RMS branches with other generic health products, which return store them in* *refrigerators." We do not use TMD when transporting cold chain products".* The RMS ltd doesn't have the system to ensure cold chain storage in remote areas. *"We do not have a robust system to monitor regularly cold chain equipment in remote areas."*

4.4.2 Transportation of vaccines from EPI to public and faith-based health facilities

This section highlights the transportation mode of vaccines from Expanded Program for Immunization to the point of vaccination. Before packing vaccines, the cold chain technician monitors daily storage temperature using thermometers and data loggers, as testified by the CCT. "…*We monitor temperature daily using temperature monitoring devices including thermometers, data loggers, VVM check and shake test before delivering them to the vaccination points.*"

The EPI distributes vaccines nationwide using refrigerated and calibrated vehicles to ensure products reach the end-users with guaranteed safety and quality. *"To ensure vaccine potency, the EPI vehicles distribute vaccines countrywide using the refrigerated truck.*

The EPI has disseminated temperature data loggers in each refrigerator that stores vaccines countrywide to ensure distributed vaccines are stored in assured cold chain equipment. These data loggers record temperature daily, and the CCTs at the health center level report the status of refrigerators monthly. *The cold chain equipment is monitored at a peripheral level any time."*

The EPI has an electronic engineer calibrating refrigerated vehicles to distribute vaccines nationwide. *"Our engineer calibrates vehicles and refrigerators to ensure good functionality. At the hospital level, they submit the equipment status report to ensure their refrigerators are in good condition to maintain vaccines accordingly".*

The EPI has an electronic system that enables the program to monitor cold chain equipment in remote areas. "*The electronic system enables us to check temperature even in remote areas. We use Standard Operating Procedures of the program adapted from various WHO documents".*

4.4.3 Transportation condition of cold chain products in private health facilities

4.4.3.1 Reception of cold chain products from suppliers

Out of 10 private retail pharmacies, 6(60%) receive the cold chain products packed in cold chain equipment (conditioned ice park). However, 4(40%) receive cold chain products with other medicines (Figure 24).

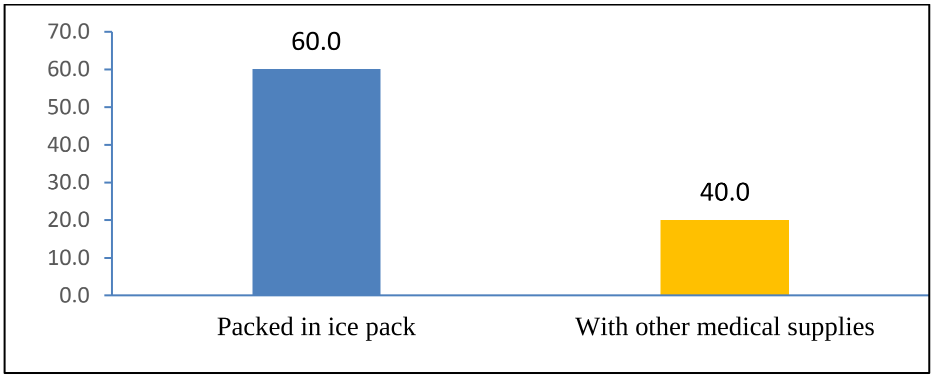


Figure 25: Reception of cold chain products from suppliers

4.4.3.2 Packing insulin for the patient at the retail pharmacy

In the majority of retail pharmacies, 7(70%) pack insulin for the patient in simple envelopes while 2(20%) pack in cold package (ice pack conditioned) and 1(10%) pack in a cool container (Figure 25).

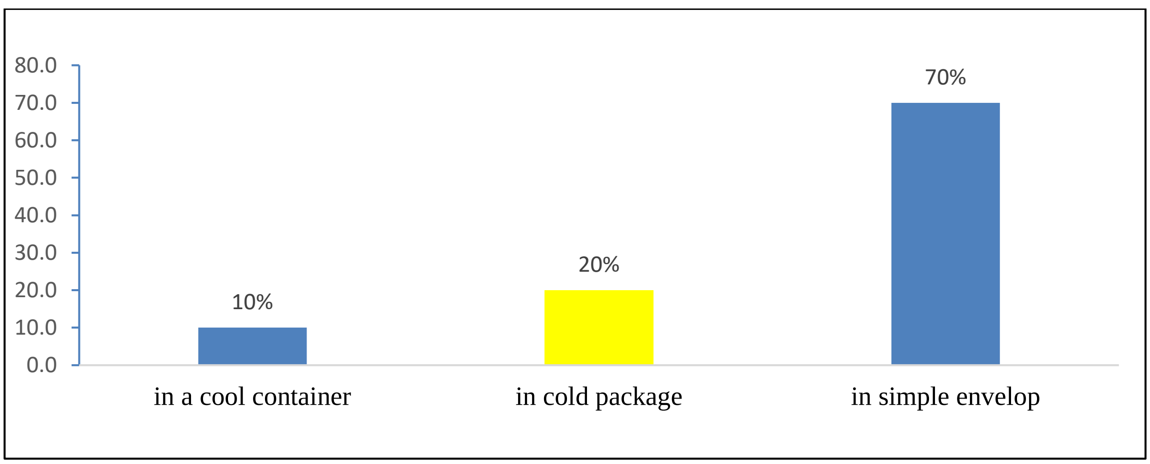


Figure 26: Packing insulin for patients

CHAPTER FIVE: DISCUSSION

Cold chain conformity is a significant achievement in preventing cold chain losses and public health calamities. To improve the cold chain system, reliable infrastructure, available quality management system, and knowledge of cold chain technicians is the cornerstone.

This study showed that almost half of refrigerators storing cold chain products and laboratory commodities did not conform to the WHO cold chain standards. The MKT calculated was below 2^{o}C above 8^{o}C. In contrast, it was observed that the overall refrigerators used in immunization comply with WHO cold chain requirements. The MKT calculated to fit with the storage temperature requirements of cold chain medicines ranged (from 2^{o}C-8^{o}C). The good performance in the vaccination program might result from consistent use of WHO pre-qualified and new refrigerators. The majority, 18(28%), were between 2 and 4 years since their installation.

The cold chain storage conformity in private retail pharmacies was also good. Out of 10 refrigerators assessed, 3(30%) didn't conform to the WHO requirements. This performance might also result in refrigerators' status and regular supervision from Rwanda Food and Drug Authority (RFDA).

Ashok and collaborators narrate the CHAI's experience in monitoring cold chain in 9 African countries and India in 2017. Their study found that many developing countries use obsolete technologies and old equipment, rating between 15% and 50%. This cold chain equipment was susceptible to poor temperature control and breakdown(50). These findings also support the results of this study because two refrigerators were broken down throughout the study before the allotted time ended.

Alemtsehay B.M and collaborators' findings in the study conducted in Ethiopia also pointed out the use of domestic refrigerators as they are cheaper, which may affect the potency of cold chain products because these kinds of refrigerators do not maintain optimal temperature range reliably(51). A study in three African countries (Ghana, Uganda, and Kenya) revealed that Ghana was not conforming to the WHO cold chain standard at 26.2%. The better management observed in Ghana might be attributed to the involvement of cold chain technicians(52).

The study in Tanzania showed that 48,5% of assessed health facilities didn't comply with WHO requirements. They recorded MKT>8^{o}C, and the temperature excursion was attributed to electricity failure and lack of contingency plan (53). These findings of this study support our results. Although most health facilities visited had generators as a backup in the case of electricity failure, almost half aren't automated. One of our respondents supported these results and said: *"our generator is not automated. In the case of electricity failure, if trained staff is not around to put it on, we remain in darkness till morning"* The respondent also pointed out the financial constraint for buying fuel which delays starting the generator when needed and timely.

The WHO and UNICEF assessment of cold chain equipment in LMICs revealed that 23% of health facilities assessed use outdated cold chain technology, with 41% of poor-performing cold chain equipment (9). In contrast, this study showed that 48(96%) have WHO pre-qualified refrigerators in most health facilities. This performance is attributed to the support of the National Vaccine and Immunization program that provides WHO pre-qualified refrigerators to the vaccination program at the health facility level to maintain the quality vaccines and potency.

Cold chain equipment, temperature monitoring system, and contingent plan are vital enablers of an effective cold chain system. In the study conducted in three African countries, the authors pointed out the lack of contingency plan and electricity failure as the primary source of temperature excursion(52).

The potency and quality of the products above are greatly enhanced by the quality management system used to store cold chain products. It guarantees the accuracy of temperature monitoring and cold chain equipment and certifies the procedures used to create a cold chain system. This study showed the low performance of cold chain equipment calibration. Participants of this study had limited information about it, and the said calibrated equipment is not systematic as per WHO requirements. The findings of this study are consistent with the study in Ghana in 2012, where 78% of participants did not have information on calibration policies (46).

Cold chain technicians' knowledge is a vital component of cold chain performance. Martin N.Y and collaborators found the gap in cold chain technicians in 2015 in North West Cameron and suggested continuous, regular refresher training and capacity building (35).

In the study in Amhara in Ethiopia, Hewan Adam Bogale et al. found the knowledge gap among cold chain technicians as only 38.3% were fully skilled in cold chain management. They recommended immediate and regular training and supervision to enhance knowledge and skills in cold chain management (10). The CCTs in this study recommended regular training to update their knowledge and skills on cold chain management. In the entire cold chain management system, monitoring temperature from one supply level to another is the cornerstone to ensuring proper maintenance of recommended temperature.

The results of this study also explored the knowledge of cold chain technicians in private retail pharmacies. Most (100%) knew that cold chain products, including insulins, must be stored between 2oC-8oC and that insulin can remain at least 30 days at ambient temperature. However, 70% believed insulin can be kept in a domestic refrigerator, whereas the latter may compromise its potency.

This study pointed out that the transportation of cold chain management also remains an issue in public health facilities, especially for routine cold chain products, as central medical does not control it throughout the entire chain. In contrast, the EPI Rwanda program monitors vaccines' transport until the end-users via refrigerated and calibrated vehicles, data loggers, and the cold chain report status of the equipment disseminated countrywide. Monicah W and collaborators in the study on the vaccines logistics in 2015 discovered that transport systems were not specialized for cold chain items(6).

This study also showed a gap in the transportation of cold chain products in private retail pharmacies. About 40% of retail pharmacies receive their products packed with other health commodities and do not assess the status of temperature storage at the reception. The distribution of cold chain products is not also reliable as most private retail pharmacies 7(70%) pack insulin in simple envelopes for their clients.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The study showed that the age of refrigerators coupled with the temperature monitoring system, lack of contingency plan, power outage, and quality management system are the significant factors that affect the WHO storage temperature conformity in health facilities of Eastern Province in Rwanda. The study also showed the cold chain technicians' knowledge gap that needs to be handled. Transportation of cold chain products from central medical stores to health facilities was an issue for cold chain products apart from vaccines cold chain system.

6.2 Recommendations

With the finding from this study, the researcher addresses the Ministry of Health, Rwanda Medical Supply, and developing partners with the following recommendations:

- MoH and partners
  - Harmonization of the supply chain of both vaccines and other temperature-sensitive medicines is a need
  - In collaboration with RSB to establish a national team in charge of validating cold chain processes and equipment to capture temperature records accurately
- For Rwanda Medical Supply Ltd and partners
  - Commission updates cold chain equipment and TMD for RMS branches and health facilities in need
  - A backup system to safeguard cold chain products' potency in case of a power failure should be installed in those facilities without them.
- For further Researchers
  - The impact of non-conformity of cold chain storage conditions in Eastern province-based health facilities should be evaluated.
  - To carry out a study on the variation in room storage temperature and the availability of room temperature regulation systems in Rwanda
- For all potential interveners of medicines cold chain storage
  - Technical and systematic handling of cold chain infrastructure to avoid their early breakdown

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Appendix 1. Informed consent form

Assessment of medicines cold chain storage conformity with the requirements of the World Health Organization in health facilities in the Eastern Province-Rwanda

SECTION I: Information Sheet

Introduction

I am pursuing a Master's degree from the East Africa Community Regional Center of Excellence in Vaccine, Immunization, and Health Supply Chain Management at the University of Rwanda. As part of this degree, I am undertaking a research thesis leading to the award of my degree. The main objective of my research is to assess medicines' cold chain storage conformity with the World Health Organization requirements in health facilities in the Eastern Province in Rwanda.

Type of Research Intervention

The research outcomes are expected to provide an insight into the critical challenges in the storage of cold chain medicines in the Eastern Province of Rwanda with a focus on temperature control, cold chain infrastructure, validation of storage systems, monitoring of cold chain facilities, documentation, and oversight responsibilities by the regulatory authority(s).

Selection of participants

Participants were selected for this study based on their values and considering their expertise, perception, ideas, practices, and professionalism.

Participation in the study

Respondents participated in this study voluntarily. It was their choice to adhere to the study. Participants were guaranteed their preference would not affect their professional standing or everyday life.

Procedures

Respondents completed questionnaires at their facilities or institutions (EPI, RMS Lts, district hospitals, health center, and private retail pharmacies). The temperature data loggers were mounted into refrigerators for temperature recording. There was also visual observation will also be made.

Duration

The group discussions took approximately 30 minutes of your time.

Risks and Discomforts

The risk to the participant in this study was minimal. During the group discussion, participants might decide to share information, decline to answer any questions they did not wish to answer, or stop the interview at any time.

Benefits

Participants were explained that there was no direct benefit to them. Nonetheless, their participation would improve cold chain storage.

Sharing of research findings

However, **Joseph Desire NYIRIMANZI**, the researcher of this study, will use the information collected in his dissertation and other publications and not identify participants individually.

Contact address in the case of additional information about the research

If the participants had questions or concerns about their rights to participate as a research subject, or if need to obtain additional information on the research perspective, they could contact the Institutional Review Board (IRB) through the following:

IRB Secretariate

Email: researchcenter@ur.ac.rw

Identification of Investigator

If participants had any questions or concerns about the research, they were free to contact

Mr. Joseph Desire NYIRIMANZI

Principal Investigator

University of Rwanda

Phone: +250 788 659 878

Email: jodeny09@yahoo.fr

<u>SECTION II</u>: Certificate of Consent

I have been requested to participate in the research entitled "Assessment medicines cold chain storage conformity with the World Health Organization requirements in health facilities in Eastern Province- Rwanda."

I reviewed the previously provided details and asked all the questions I had. I voluntarily consent to take part in this research. I'm free to revoke my consent and stop taking part without being penalized. I have not given up my legal rights by agreeing to be in this research.

I freely agree to take part in this study: Yes / No

I give my consent to be recorded/. Yes / No

Participant's name: …………………………………………………..

Participants' signature:..

Date:../...../………

Name of researcher: …………………………………………………

Signature of researcher: …………………..

Date: ……/…../….…

Appendix 2: Questionnaire for Storage of public and faith-based facilities

Survey on the Assessment of medicines cold chain storage conformity with the World Health Organization requirements in health facilities in Eastern Province- Rwanda

I. Demographic characteristics

Please tick [√] as appropriate

1. **Type of facility**
   (a) Public health center [ ]
   (b) Public district hospital [ ]
   (c) Public faith-based facility [ ]
   (d) RMS Branch [ ]
2. **Gender of respondent**
   (a) Male [ ]
   (b) Female [ ]
3. **Age of respondent**
   (a) 20 to 30 years [ ]
   (b) 31 to 40 years [ ]
   (c) 41 and above[ ]
4. **Education level**
   (a) No Education [ ] (b) Primary [ ] (c) Secondary [ ] (d) University [ ]
5. **Profession/ training level**
   (a) Supply Chain specialist [ ]
   (b) Biomedical Engineer [ ]
   (c) Pharmacist [ ]
   (d) Nurse [ ]
   (e) Other...
6. **Since when have you been doing this field?**
   (a) 0 to 3yrs [ ] (b) 4 to 7yrs [ ] (c) 8 to 12yrs [ ] (d) above 12yrs [ ]

II. Facilities and Storage Area

1. Are doors designed to provide security for the product and restrict the entry of unauthorized persons? (a) Yes [ ] (b) No [ ]

2. In a power outage, how do you maintain proper storage conditions?
3. Do you have an automatic generator to handle power outages? (a) Yes [ ] (b) No [ ]
4. Do you record temperature daily? Yes [ ] (b) No [ ]
5. Are the temperature records available for the last three months? Yes [ ] (b) No [ ]

III. Cold chain infrastructure

1. Which storage equipment of cold chain products do you have?..
2. Do you have refrigerators for storing cold chain products?
3. When your cold chain equipment has been installed to be used…………………………....
4. Is equipment furnished with monitoring devices? a) Yes [ ] (b) No [ ]
5. Are cold chain equipment and temperature monitoring devices calibrated at least once every year?

   a) Yes [ ] (b) No [ ]
6. Do calibrated devices have stickers indicating the next due date for calibration?

   a) Yes [ ] (b) No [ ]
7. Which institution did the calibration?...
8. How do you manage temperature excursions?....................

IV. Product Distribution

9. Before acquiring cold chain products, do you check their temperature?Yes [ ] (b) No []
10. If yes to the question above, what device do you use……………………………………
11. Before distributing cold chain products, do you check their temperatures? (a)Yes [ ] (b) No [ ]
12. If yes to question 2 above, what device do you use……………………………………
13. Is the device calibrated? a) Yes [ ] (b) No [ ]
14. Which transportation methods do you usually use?

    (a) Air(b) vehicle (d) others (specify)………………………………………………...

15. Where temperature control is needed, have the transportation containers/cold vans been qualified? (a) Yes [ ] (b) No [ ]

V. Cold chain technician knowledge of cold chain storage

1= strongly disagree, 2=disagree,3 = neutral,4 =agree, 5=strongly agree

CATEGORY	1	2	3	4	5
Opinion of healthcare providers on cold chain storage					
I do agree the vaccine cold chain maintenance is the responsibility of Hospitals that stores the vaccines					
I do agree that the duration of keeping vaccines at the hospital is less than two months					
I do agree all vaccines are stored between +2^{o}C to +8^{o}C					
I do agree that Vaccine vial monitor (VVM) is used for vaccines damaged by heat					
I do agree that Vaccine vial monitor (VVM) is used to check if vaccines are damaged by freezing					
A shake test must be carried out when freeze-sensitive vaccines are visibly seen to be frozen.					
Data loggers are used to measure temperature-sensitive medicines in cold chain storage					
The duration of vaccine storage at District hospital is one month					
There are four stages of VVM identifying the state of vaccines					
Vaccines and other temperature-sensitive medications can be kept in the same refrigerator if there is a shortage of refrigerators.					
Opinion of health care workers on cold chain medicine distribution					
Vaccines are distributed at -2^{o} C and -8^{o}C					
Vaccines are transported using an ice pack in the cold box to maintain the temperature					
During outreach activities, vaccines should be stored in vaccine carriers with ice parks					
Before distributing vaccines, you should check only their expiry date					
Before distributing vaccines, you should check only their VVM					

THANK YOU FOR YOUR CONTRIBUTION

Appendix 3. Questionnaire for storage facilities at the private retail pharmacy

Survey on the Assessment of medicines cold chain storage conformity with the World Health Organization requirements in health facilities in Eastern Province- Rwanda

I. Demographic characteristics

Please tick [√] as appropriate

1. **Type of facility:** Private pharmacy [ ]
2. **Gender**

   (a) Male [ ]

   (b) Female [ ]

3. **Age of respondent**
   (d) 20 to 30 years [ ]
   (e) 31 to 40 years [ ]
   (f) 41 and above[ ]
4. **Education level**

(a) No Education [ ] (b) Primary [ ] (c) Secondary [ ] (d) University [ ]

5. **Profession/ training level**
   (a) Supply Chain specialist [ ]
   (b) Biomedical Engineer [ ]
   (c) Pharmacist [ ]
   (d) Nurse [ ]
   (e) Other...
6. **Since when have you been doing this field?**

   (b) 0 to 3yrs [ ] (b) 4 to 7yrs [ ] (c) 8 to 12yrs [ ] (d) above 12yrs [ ]

I. Management of Cold Chain Medicines

1. How do you receive and or transport cold chain products from your supplier?..................
2. Before acquiring cold chain products, do you check their temperature?

   a. Yes [ ] (b) No [ ]

2. If yes to question 2 above, what device do you use…………………………………
3. Is the device calibrated? a) Yes [ ] (b) No [ ]

4. What type of storage facility do you use? ……………………………………….....……
5. Is the storage device equipped with temperature monitoring devices? (a) Yes [ ] (b) No [ ]
6. If yes to the question above, which monitoring device is used………………………………
7. Is the device calibrated?
    i. Yes [ ] (b) No [ ]
8. Which institution did the calibration? ………………………………………………….
9. Are calibration records available for each temperature-recording device?
    i. Yes [ ] (b) No [ ]
10. 10. List the different types of cold chain products kept in your facility. ………………........
11. Is there any food stored in the storage facility? (a) Yes [ ] (b) No [ ]
12. Are there standard operations procedures (SOPs) describing storage procedures of cold chain products? Yes [ ] (b) No [ ]
13. Is temperature monitoring being recorded? (a) Yes [ ] (b) No [ ]
14. If your response is yes to question 13 above, are records available at least for three months? (a) Yes [ ] (b) No [ ]
15. Does the facility have a regular preventative maintenance plan to maintain a cold chain storage facility?
    (a)Yes [ ] (b) No [ ]
16. When do you switch on the storage facility? (a) Morning [ ] (b) Afternoon [ ] (c) Evening [ ] (d) Always switched on [ ]
17. In the event of power failure, how do you maintain storage conditions appropriately? ……
18. Do you have an automated generator to cater for power failure? (a) Yes [ ] (b) No [ ]
19. Which of the following institutions visit your facility? Tick as many
    (a) Rwanda FDA (b) RBC (c) RSB (d) Others (specify)……………………..
20. Do they specifically inspect cold chain medicines storage facilities? (a) Yes [ ] (b) No [ ]
21. Do you have insulin in your facility? (a) Yes [ ] (b) No [ ]
22. What information do you give to the patient while dispensing insulin to them?
    a) Dosage
    b) Storage conditions
    c) Side effects
    d) Administration route

23. How do you pack insulin for the patient?..

……………………………………………………………………………………………

24. What information do you give to the patient on insulin storage?..

....

....

....

THANK YOU FOR YOUR CONTRIBUTION

Appendix 4. Questionnaire for storage facilities at central medical stores

I. Demographic characteristics

Please tick [√] as appropriate

1. **Type of facility**

    a) Rwanda Medical Supply ltd (Central Medical Store) [ ]

    b) Expanded Program Form Immunization [ ]

2. **Gender**

(a) Male [ ]

(b) Female [ ]

3. **Age of respondent**

    (g) 20 to 30 years [ ]
    (h) 31 to 40 years [ ]
    (i) 41 and above[ ]

4. **Education level**

(b) No Education [ ] (b) Primary [ ] (c) Secondary [ ] (d) University [ ]

5. **Profession/ training level**

    a) Supply Chain specialist [ ]
    b) Biomedical Engineer [ ]
    c) Pharmacist [ ]
    d) Nurse [ ]
    e) Other...

6. **Since when have you been doing this field?**

    0 to 3yrs [ ] (b) 4 to 7yrs [ ] (c) 8 to 12yrs [ ] (d) above 12yrs [ ]

II. Product Distribution

1. Are there systems to monitor whether cold chain products/vaccines are transported and stored under the appropriate temperature conditions at the health facility? (a) Yes [ ] (b) No [ ]
2. If yes to the question above, which system do you have?

    Transportation____

    Reception____

Storage____

3. Before transporting cold chain products to the service delivery points, do you check their temperatures?
    a. Yes [ ] (b) No [ ]
4. If yes to question 2 above, what device do you use_______________________________
5. Do you have a system to ensure product quality transported to the last mile? Yes [ ] (b) No [ ]
6. If Yes to the question above, which system do you have?
    e) Monitoring and evaluation report [ ]
    f) Use thermometers and /or fridge tags during transportation of cold chain products [ ]
    g) Other____
    h) Not applicable
7. Which transportation methods do you usually use to transport cold chain products?
    (a) Air
    (b) Calibrated vehicle
    (c) Other vehicles
8. Where temperature control is needed, have the cold transportation vans been qualified?
    (a) Yes [ ] (b) No [ ]
9. Do vehicles have temperature monitoring devices? (a) Yes [ ] (b) No [ ]
10. Are the temperature monitoring devices on vehicles calibrated? (a)Yes [ ] (b) No [ ]
11. Are vehicles secured? (a) Yes [ ] (b) No [ ]
12. Is there a maintenance plan for vehicles transporting cold chain products? (a) Yes [ ] (b) No[ ]
13. What contingency plan do you have in place if you encounter a breakdown of vehicles

………………………………………………………………………………………......

THANK YOU FOR YOUR CONTRIBUTION

Appendix 5: Checklist for cold chain assessment

HEALTH INFRASTRUCTURE

A Cold chain equipment	**Yes**	**No**
Does the facility have a WHO prequalified Refrigerator		
Does a facility have Planned preventive maintenance for cold chain equipment		
Does the Facility have ice packs and cool-packs for product distribution)		

B. Contingency plan to protect the cold chain products in an emergency	**YES**	**No**
Does the facility have a standby generator		
Is generator automated		

C. Temperature monitoring system	**Yes**	**No**
Do all refrigerators have a working thermometer?		
Do cold chain technicians record temperature daily and completely?		
Are temperature records available at least for the last three months		

COLD CHAIN DISTRIBUTION

Transportation from CMS to health facilities	**Yes**	**No**
Does the facility have a refrigerated vehicle for cold chain transportation		
Does the facility pack cold chain product together with TMD during transportation		
Does the facility monitor transportation of cold chain products up to the end-users?		

Appendix 6: Ethical clearance

COLLEGE OF MEDICINE AND HEALTH SCIENCES

DIRECTORATE OF RESEARCH & INNOVATION

UNIVERSITY of RWANDA

CMHS INSTITUTIONAL REVIEW BOARD (IRB)

Kigali, 20th /10/2021
Ref: CMHS/IRB/**297**/2021

Nyirimanzi Joseph Desire
Master's in Health Supply Chain Management
CMHS, University of Rwanda

Dear Nyirimanzi Joseph Desire

RE: ETHICAL CLEARANCE

Reference is made to your application for ethical clearance for the study entitled ***"Assessment of the Medicines Cold Chain Storage Conformity with the World Health Organization Requirements in Health Facilities in Eastern Province-Rwanda".***

Having reviewed your application and been satisfied with your protocol, your study is hereby granted ethical clearance. The ethical clearance is valid for one year starting from the date it is issued and shall be renewed on request. You will be required to submit the progress report and any major changes made in the proposal during the implementation stage. In addition, at the end, the IRB shall need to be given the final report of your study.

We wish you success in this important study.

Dr Stefan JANSEN
Ag Chairperson Institutional Review Board,
College of Medicine and Health Sciences, UR

Cc:

- Principal, College of Medicine and Health Sciences, UR
- University Director of Research and Postgraduate studies, UR

Email: researchcenter@ur.ac.rw P.O Box 3286 Kigali, Rwanda www.ur.ac.rw

Appendix 7: Turnitin scrores

ASSESSMENT OF MEDICINES COLD CHAIN STORAGE CONFORMITY WITH THE REQUIREMENTS OF THE WORLD HEALTH ORGANIZATION IN HEALTH FACILITIES IN THE EASTERN PROVINCE- RWANDA

ORIGINALITY REPORT

13%	12%	9%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Thomas Bizimana, Pierre Claver Kayumba, Lutz Heide. "Prices, availability and affordability of medicines in Rwanda", PLOS ONE, 2020 Publication	1%
2	link.springer.com Internet Source	1%
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