

Short Communication

Optimising Vaccine Cold Chain: Essential Components of Effective Preventive and Curative Maintenance

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A B S T R A C T

The vaccine cold chain plays a crucial role in maintaining the potency and safety of vaccines during storage, transportation, and distribution. This article provides guidance to decision-makers in developing and implementing effective preventive and curative maintenance strategies for cold chain systems. The key components discussed include human resources for maintenance, training and capacity building, monitoring system performance, choosing an appropriate service model, planning, and budgeting, spare part management, standard operating procedures (SOPs), establishment of an equipment specification committee, and knowledge management. The article emphasises the importance of compliance with international guidelines and standards to ensure the highest quality of cold chain services. The implementation of these strategies will support the sustainability and functionality of the cold chain system, safeguarding public health.

Keywords: Cold Chain, Preventive and Curative Maintenance, Public Health

Introduction

Immunisation stands as one of history's most successful and cost-effective public health interventions, saving two to three million lives annually.¹ To reduce child mortality rates, it is crucial to monitor the effective delivery of potent vaccines through a well-maintained cold chain system and ensure high vaccine coverage.² The system employed to maintain vaccines in optimal condition is known as the cold chain, alternatively referred to as the vaccine supply chain or immunisation supply chain. The cold chain comprises a sequence of stages meticulously crafted to ensure that vaccines remain within the temperature ranges recommended by the World Health Organization (WHO), spanning from the manufacturing stage to the actual administration point.³ The vaccine cold chain is vital for preserving vaccine potency by maintaining proper temperature conditions during storage, transportation, and

distribution.⁴ Adhering to the WHO guidelines, vaccines should be stored in suitable refrigeration equipment with temperature monitoring, while transportation requires vaccine carriers with prepared coolant packs.⁵

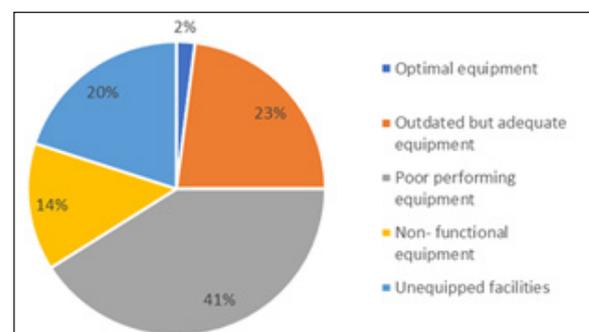


Figure 1. Cold Chain equipment status in 57 GAVI supported low- and middle-income countries (2014)

Data from 134,000 immunisation points in the 57 Gavi (the Vaccine Alliance)-supported countries reveal that 20% of the countries lack cold chain equipment, 23% are non-functional, and 40% face limitations like freezing risks or expensive fuel. Only 2% of the nations met WHO maintenance standards in 2014, with maintenance weakening from sub-national to service delivery levels.⁶ Inadequate maintenance endangers immunisation goals. Research suggests that one-third of issues need specialists, one-third result from errors, and one-third require basic repairs.⁷ Establishing a maintenance framework is crucial to empower users, ensure proper installation, and provide prompt expert support.

Addressing sub-optimal maintenance systems is essential, as functionality issues persist in many countries even for up to two years. This communication offers guidance to decision-makers on implementing preventive and curative maintenance strategies for cold chain systems to ensure efficient and effective vaccine distribution.

Essential Components of a Reliable and Effective Vaccine Cold Chain Maintenance System

1. **Human Resources for Cold Chain Repair and Maintenance System:** The success of equipment maintenance and repair systems relies on a diverse team of staff with specific roles and responsibilities. This includes:
 - **Equipment Users:** Healthcare workers, vaccine managers, custodial staff, or in-house technical staff responsible for equipment maintenance, including operating, monitoring, reporting, and basic preventive maintenance
 - **Technicians:** Staff trained in mechanics, refrigeration, or electronics, conducting repair and preventive maintenance for cold chain equipment

- **Engineers:** Qualified professionals in electrical, mechanical, or electronics engineering, skilled in complex repair procedures and managing maintenance systems
- **Managers:** Essential for effective systems, including maintenance team managers, cold chain managers, and supervisors. They plan training, update SOPs, monitor activities, and manage resources.
- **Support Staff:** Administrative personnel, data collectors, managers, and drivers facilitating maintenance and repair implementation.

2. **Training and Capacity Building:** Proper training of cold chain technicians and personnel is essential for effective maintenance and repair. Training should cover cold chain principles, equipment operation, troubleshooting techniques, and maintenance procedures.

The various types of training programmes for users and technicians may include the following:⁸

- **Basic Training:** This helps in developing fundamental knowledge and skills in operating and maintaining cold chain equipment. It covers topics such as proper equipment usage, basic maintenance procedures, temperature monitoring, and identifying common equipment issues.
- **On-the-Job Training:** It provides practical guidance and hands-on experience in healthcare settings, including record-keeping and inventory management.
- **Skill Development Training:** This enhances specialised skills and proficiency in performing specific tasks related to cold chain equipment maintenance and repair. This training programme focuses on developing specialised skills required for performing specific tasks in cold chain equipment maintenance and repair.

The following training can be considered by the countries on cold chain repair, maintenance and management:⁹

Table I. The following training can be considered by the countries on cold chain repair, maintenance and management

Type of Training	Duration of Training (Days)	Participants	Training Contents
Repair and maintenance for Ice Lined Refrigerator, deep freezer, solar equipment	5–6	Engineers, technicians	<ul style="list-style-type: none"> • Operation and maintenance of Ice Lined Refrigerator, deep freezer, and solar equipment • Troubleshooting techniques • Temperature monitoring • Identifying common equipment issues
Repair and maintenance of cold rooms	5–6	Engineers, technicians	<ul style="list-style-type: none"> • Comprehensive maintenance of cold rooms • Complex repair procedures • Management of maintenance systems • Troubleshooting techniques

Training for vaccine and cold chain handlers	2–3	Cold chain managers and handlers	<ul style="list-style-type: none"> • Handling and management of vaccines • Cold chain equipment and maintenance basics • Vaccine stock management • Inventory management
Training on vaccine and cold chain management for programme managers	5–6	National and sub-national managers	<ul style="list-style-type: none"> • Vaccine procurement and forecasting • Cold chain and temperature monitoring • Stock management and vaccine distribution • Planning and budgeting for cold chain maintenance • Infrastructure improvement strategies • Monitoring and reporting system

3. Monitoring System Performance/ Review Mechanism:

Regular monitoring of maintenance and repair systems at various levels (national, regional, and health facilities) is crucial for long-term success. Performance indicators, such as the percentage of functional cold chain equipment, repair frequency, and temperature alarms, help identify areas for improvement and justify budget allocation.

4. Choosing an Appropriate Service Model:

Different facility types, geographical locations, equipment types, and maintenance procedures may require varied service models such as the following:

- **Ministry of Health Clinical (or Biomedical) Engineers:** In-house technicians employed by the Ministry of Health to maintain and repair medical equipment, provide calibration, user training, and decommissioning
- **Parastatal Technical Organisations:** Government-owned or government-funded organisations that offer specialised cold chain equipment technicians and training programmes⁹
- **Private Technical Companies or Individuals:** Private technicians working in national, regional, or local companies or as independent contractors
- **Manufacturer or Appointed Agent:** Certain equipment may require repairs by the manufacturer

Clear institutional or contractual frameworks should be established, defining maintenance standards, intervals, and emergency response times.

5. Managing and Maintaining Cold Chain in Remote Rural Areas:

Remote rural areas pose significant challenges in managing and maintaining cold chain systems. To enhance the cold chain system's effectiveness in remote rural areas, key management and maintenance strategies include leveraging the Controlled Temperature Chain (CTC) to reduce refrigeration

dependence, expanding storage capacity with solar options, optimising equipment performance in varying temperatures, accounting for cold box weight in logistics planning, use of long-range passive containers and temporary storage for mobile teams, and ensuring adequate storage capacity for uninterrupted vaccine supply.¹⁰

6. Planning and Budgeting:

An effective cold chain equipment maintenance system requires substantial and sustained financial commitment. Budgeting should consider preventive maintenance, curative repairs, spare parts and consumables, training programmes, infrastructure improvements, and monitoring and reporting costs. Integrating repair and maintenance plans within national health and immunisation strategies ensures long-term sustainability.

7. Spare Part Management:

Spare part management is critical to overcome equipment repair obstacles. To ensure a smooth supply of spare parts and consumables, it is crucial to:

- Incorporate spare parts purchase and control into maintenance plans and budgets
- Analyse maintenance records to forecast spare part consumption and determine order requirements
- Strategically decide on the distribution of physical spare part inventories across the country
- Include a spare part indent and stock module in the Cold Chain Management Information System (MIS)

8. Standard Operating Procedures (SOPs):

Robust maintenance and repair systems rely on well-defined SOPs. These should cover installation, equipment operation, preventive maintenance, equipment disposal, and equipment inventories. Model SOPs should be developed at the national level and adapted by sub-national or facility-level managers. The SOPs

for preventive maintenance of refrigerators include ensuring proper installation by keeping them away from direct sunlight and heat sources, maintaining ventilation, and placing them on a level floor with adequate space for air circulation. The power supply should be protected with “Do Not Unplug” signs, emergency contact information, and voltage regulators. Proper storage of vaccines involves using thermometers and freeze indicators in the coldest area, storing vaccines by expiration date for easy access, and having an emergency plan in case of equipment failure or power cuts. While arranging packaged vaccines, they should be stored in uncovered containers with vertical space between stacks of cartons for air circulation and not placed directly in front of freezer fans or outlets. Scheduled preventive maintenance tasks include daily temperature checks and recording, addressing temperature discrepancies, removing water, wiping off water droplets, checking lid gaskets, and cleaning the refrigerator and grill periodically.

- 9. Equipment Specification Committee:** Constituting an equipment specification committee ensures evidence-based technical inputs on cold chain equipment. The committee can be a part of the broader National Logistics Working Group (NLWG) and can have a similar structure of governance. As per a landscape analysis of the National Logistics Working Group (NLWG), the members of the committee could be mainly representatives from Expanded Programme on Immunization, UNICEF/WHO, pharmacy and drug departments, and other technical departments at the Ministry of Health, non-governmental organisations (NGOs) and other development partners.¹¹ The committee should develop technical specifications, review guidelines, pilot new technologies, and coordinate research and development.

If a country has a national resource centre dedicated to cold chain management, it can play the role of the secretariat for the Cold Chain Equipment Specification Committee. The secretariat’s responsibilities include coordinating committee activities, gathering data, managing knowledge resources, and ensuring that equipment specifications are informed by evidence and expert input, contributing to the committee’s efficient functioning.

- 10. Establishment of a Reporting System for Cold Chain Repairs and Maintenance through a Cold Chain MIS:** Implementing a Cold Chain MIS facilitates data collection, storage, and analysis related to equipment repairs and maintenance. Digital tools and technologies

can streamline data entry, cloud-based storage ensures accessibility and security, and automated dashboard generates customised reports and dashboards.

- 11. Knowledge Management:** Facilitating knowledge sharing and collaboration among stakeholders is crucial for effective cold chain maintenance. Platforms for workshops, webinars, and online forums can disseminate best practices, case studies, and innovative solutions. Regular updates to guidance materials based on emerging best practices enhance maintenance system effectiveness.

Conclusion

To maintain vaccine potency and ensure the success of immunisation programmes, a robust cold chain maintenance system is essential. The key components discussed in this article, including human resources for maintenance, training and capacity building, monitoring system performance, choosing an appropriate service model, planning, and budgeting, spare part management, standard operating procedures (SOPs), establishment of equipment specification committee, and knowledge management, collectively contribute to the sustainability and functionality of the cold chain system. Ensuring the integrity of vaccines is of utmost importance, and while cold chain infrastructure may represent a relatively small cost, its value in safeguarding vaccines cannot be underestimated. GAVI, the Vaccine Alliance, along with its Cold Chain Equipment Optimization Platform is one such platform to support cold chain strengthening.¹²

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