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**Vaccine Vial Monitors (VVMs) induced vaccine
management policies and their impact on National
Immunization Programme outcomes (socio-economic
value of VVMs)**

A case study of Zambia

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A DISSERTATION

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Abstract

In the framework of vaccine management, this thesis provides a thorough examination of the effects of vaccine vial monitors, or VVMs, on vaccine delivery and use. The study uses a cross-sectional methodology to examine health workers' knowledge and training on vector vector magnitude meters (VVMs), their confidence in the accuracy of VVMs, the impact of VVMs on vaccine discard due to heat damage, their role in preserving vaccines following disruptions in the cold chain, modifications to vaccine management practices, and their effects on the usage of multi-dose vials. The study's conclusions show that a sizable percentage of healthcare professionals have had VVM training, however the amount and frequency of this training varied. The majority of healthcare professionals also express confidence in the accuracy of VVMs, highlighting the vital role that these indicators play in vaccination quality monitoring. By decreasing vaccine discard due to heat damage, VVMs have made vaccination management techniques more effective. Additionally, they have been essential in preserving vaccines after breaks in the cold chain, guaranteeing that vaccine quality is maintained under difficult circumstances. The study emphasizes how VVMs have impacted vaccination management practices, demonstrating the flexibility of healthcare professionals in utilizing new instruments and technology. They also affect which vials are used in immunization sessions; vials with the VVM label are chosen because they are thought to be more dependable and safer. The study emphasizes how difficult it is to make decisions about whether to reuse opened multi-dose vials, which calls for detailed guidelines that take into account more than just VVM measurements. The study recommends structured training programs, awareness campaigns, a consistent supply of vaccines labeled with VVMs, and explicit rules for the reuse of opened vials in order to maximize the potential benefits of VVMs in vaccination management. Future investigations should look more closely at the variables impacting health professionals' decisions on opened vials, as well as the effect of VVMs on vaccination coverage rates and

cost-effectiveness. This thesis advances knowledge on the function of VVMs in vaccine management and provides useful suggestions for boosting vaccination program efficacy, cutting down on vaccine waste, and eventually benefiting public health outcomes.

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Chapter 1: Introduction

1.1. Background

The escalating expenses associated with vaccines and the growing demands for cold chain storage provide notable obstacles in the realm of healthcare and immunization. This section provides an in-depth exploration of the contextual history around these difficulties, elucidating the many elements that require effective management of vaccines (Bown et al., 2022). Vaccination has been widely acknowledged as a very efficacious strategy for mitigating the spread of infectious diseases and upholding the well-being of the general population. Nevertheless, because to the progress made in the field of medical technology and the increasing variety of vaccines accessible, the expenses associated with immunization initiatives have experienced a significant increase (Piot et al. 2019). The observed rise can be attributed to a range of variables, such as advancements in vaccine research and the necessity for administering numerous doses in order to achieve sufficient immunization. Consequently, health systems on a global scale are currently facing the economic challenge of acquiring and disseminating vaccinations, particularly in settings with limited resources. In addition, the increased range of vaccines available has prompted a reassessment of the storage conditions that must be maintained along the cold chain. Vaccines are delicate biological substances that necessitate stringent temperature regulation in order to preserve their effectiveness (Kartoglu & Milstien, 2014). It is imperative to maintain vaccinations within designated temperature ranges throughout the entirety of the distribution process.

Nevertheless, this phenomenon has resulted in heightened logistical intricacies and financial burdens, alongside the imperative for more advanced cold chain infrastructure (Brandau et al., 2003). One of the primary considerations revolves around the preservation of

optimal vaccine inventory levels in order to adequately satisfy the prevailing demand. Stockouts, characterized by the unavailability of vaccines at the required time, have the potential to cause disturbances in immunization timetables and compromise the overall efficacy of vaccination initiatives. On the other hand, over stocking of vaccinations might lead to wastage due to the potential expiration of vaccines prior to their utilization. Achieving an optimal equilibrium necessitates meticulous forecasting and proficient inventory management.

Ensuring precise vaccination forecasting is crucial in order to effectively reduce instances of both stockouts and wastage. The accurate determination of vaccine requirements necessitates a comprehensive grasp of various factors, including the characteristics of the target population, epidemiological patterns, immunization rates, and the advent of novel vaccines (Iwu et al., 2020). The occurrence of inaccurate predictions in the field of forecasting can result in the wastage of vaccines, as they may reach their expiration date before being utilized, or alternatively, it can contribute to a shortage of vaccinations during critical periods, so posing a risk to public health. One additional risk pertains to equipment malfunctions that occur throughout the cold chain. The integrity of vaccinations can be compromised due to the exposure to temperature changes caused by faulty refrigeration equipment. The preservation of cold chain infrastructure is vital; nonetheless, it might provide financial and logistical difficulties in areas with limited resources (Iwu et al., 2020). Furthermore, it is of utmost importance to ensure that healthcare professionals know the requisite policy skills to effectively handle vaccines (Azadi et al., 2020). This include knowledge pertaining to the proper administration of vaccines, diligent temperature monitoring, and adherence to globally recognized standards.

The efficacy of the cold chain is dependant on the abilities and competency of the persons participating in vaccine distribution and administration. Given the aforementioned issues, it is imperative to develop comprehensive regulations and protocols that effectively

tackle the escalating expenses associated with vaccinations and the intricate nature of the cold chain (Iwu, 2019). The effective management of vaccinations not only leads to cost savings but also plays a crucial role in facilitating equitable access to immunizations for the most vulnerable populations. Inadequate administration of vaccines can result in a myriad of adverse outcomes, encompassing escalated healthcare expenditures and the occurrence of preventable diseases that can be mitigated through vaccination.

In the present scenario, the implementation of Vaccine Vial Monitors (VVMs) has had a significant impact. Vaccine vial monitors (VVMs) are adhesive labels that exhibit sensitivity to temperature and are attached to vials containing vaccines (Moila, 2013). The alteration in coloration occurs as a result of exposure to elevated temperatures, so serving as a conspicuous visual cue that signifies the possibility of vaccination impairment. Vaccine vial monitors (VVMs) have significantly transformed the management of vaccines by providing instantaneous, on-vial data regarding the vaccine's susceptibility to temperature variations (Bhattacharjee, 2016). This valuable information empowers healthcare professionals to make well-informed judgments regarding the viability of vaccines (Iwu, 2019). The implementation of effective measures has resulted in a notable decrease in the likelihood of providing vaccinations that have been compromised, thereby mitigating the issue of vaccine wastage. Moreover, the implementation of Vaccine Vial Monitors (VVMs) has resulted in enhanced safety and increased quality of vaccines, hence contributing to the overall success of immunization programs.

The introduction of Vaccine Vial Monitors (VVMs) has enabled health professionals to accurately assess the effectiveness of vaccines, a capability that was previously lacking. This method holds particular significance in settings with low resources, such as Zambia, where prioritizing the quality of vaccinations and optimizing resource utilization is of utmost importance (Bhattacharjee, 2016). Efficient vaccine management is of utmost importance in

the field of global healthcare, as it directly influences the efficacy of immunization programs, the cost-effectiveness of healthcare systems, and the overall public health outcomes. This underscores the significance of minimizing wastage and ensuring quality in vaccine administration (Drolet et al., 2018). This section explores the significance of efficient vaccination management and the many issues that arise when this critical responsibility is not adequately addressed. Efficient management of vaccines is essential for various reasons, with one of the most crucial factors being the significant financial expenses linked to the purchase and distribution of vaccines. Vaccinations represent a very cost-effective measure within the realm of public health interventions. However, their affordability has been progressively diminishing due to many variables, including the emergence of novel vaccinations, the requirement for multiple doses per individual, and the introduction of increasingly sophisticated and intricate vaccine formulations (Drolet et al., 2018). As a result, healthcare organizations are facing the imperative to dedicate a significant percentage of their financial resources towards the acquisition of vaccines. The effective management of these resources is crucial in order to optimize the returns on investment in vaccinations.

One of the primary dilemmas in the field of vaccine management revolves around striking a delicate equilibrium between ensuring sufficient vaccine supplies and minimizing unnecessary wastage (Kelso et al., 2013). Stockouts, characterized by the unavailability of vaccinations at the required time, have the potential to cause disturbances in immunization timetables, diminished coverage rates, and the potential reemergence of diseases that can be prevented through vaccination. On the contrary, excessive stocking of vaccinations might lead to the expiration of these vaccines prior to their utilization, so wasting valuable resources and compromising the long-term financial viability of immunization initiatives. The precise prediction of vaccination demand is a critical component of effective administration. In order to mitigate the occurrence of both stockouts and wastage, it is imperative for healthcare systems

to accurately forecast vaccine demands. The process of forecasting requires a comprehensive comprehension of demographic patterns, epidemiological variables, the extent of immunization, and the use of novel vaccines. The presence of inaccurate forecasting has the potential to result in substantial financial losses and profound public health ramifications.

The quality of vaccines is an essential component of effective vaccine management. Vaccines are delicate biological substances that necessitate stringent temperature regulation in order to sustain their potency and effectiveness. The efficacy of vaccinations can be compromised when exposed to temperatures over the permitted range, hence posing a possible risk to patients (Kartoglu & Milstien, 2014). The maintenance of the cold chain, a system encompassing temperature-controlled storage and transit, is of utmost importance. The integrity of vaccines might be compromised due to equipment malfunctions and inadequate maintenance, hence emphasizing the significance of effectively managing the cold chain. In addition, the management of vaccines include the requisite knowledge and competencies of healthcare professionals who are entrusted with the tasks of handling, storing, and administering vaccinations (Kartoglu & Milstien, 2014). It is imperative that the personnel has comprehensive training and knowledge pertaining to vaccine management protocols, encompassing the proper handling of vaccines that are sensitive to temperature fluctuations, as well as the vigilant monitoring of storage conditions. The efficacy of vaccination administration is inherently tied to the proficiency and conscientiousness of healthcare professionals.

The issue of vaccine wastage is a matter of great concern within the healthcare industry, since it entails not only a financial loss but also a reduction in the number of individuals who are able to obtain essential vaccines (Kartoglu & Ames, 2022). The process of waste reduction entails the meticulous control of vaccination inventories, efficient cold chain management, and the proper disposal of expired vaccines. The presence of ineffective vaccine management

practices can result in significant levels of wastage, hence placing additional burden on healthcare expenditures and impeding progress towards the overarching objective of attaining high rates of immunization coverage. The assurance of vaccine quality holds similar importance (Kartoglu & Ames, 2022). Inadequate storage conditions for vaccines can result in diminished potency, so compromising their efficacy and, in certain instances, posing potential safety risks. This not only poses a risk to the individuals who are receiving the vaccines, but also poses a risk to the wider population due to the potential decline in herd immunity. Ensuring quality assurance in the management of vaccines is crucial in order to ensure the continued effectiveness and safety of these medical interventions.

Given the aforementioned issues, it becomes evident that there is a pressing need for effective vaccine management. Through the optimization of vaccine procurement, forecasting, stock management, cold chain logistics, and healthcare worker training, it is feasible to mitigate wastage, decrease expenses, and enhance the overall efficacy of vaccinations (Dixit et al., 2019). The effective management of vaccines plays a crucial role in maximizing their efficacy in the prevention and control of infectious illnesses. Vaccine Vial Monitors (VVMs) have emerged as a noteworthy invention in the field of vaccine management. The temperature-sensitive labels that are attached to vaccine vials offer immediate and continuous data regarding the extent to which vaccines have been subjected to variations in temperature (Dixit et al., 2019). This technological advancement effectively mitigates the potential for administering contaminated vaccinations, therefore simultaneously addressing concerns related to wastage and quality assurance. Vaccine vial monitors (VVMs) have significantly transformed the management of vaccines and have also made notable contributions to the overall effectiveness of immunization programs. The significance of precise vaccine forecasting and equipment maintenance within the realm of vaccine management cannot be overemphasized (Ashok et al., 2017). These two important factors play an instrumental role in assuring the efficiency,

effectiveness, and reliability of immunization programs, which in turn impact public health outcomes and the financial sustainability of healthcare systems. The key to effective vaccination management lies in the precise prediction of vaccine supply and demand. The task at hand entails accurately forecasting the need for vaccines by leveraging a thorough comprehension of variables like population demographics, epidemiological patterns, and the implementation of novel vaccines. The importance of precise forecasting cannot be overstated as it serves as a crucial measure to mitigate two prominent challenges: stockouts and wastage.

Stockouts refer to situations where vaccines are not accessible when they are required, resulting in disturbances to immunization schedules, decreased rates of coverage, and the possibility of a comeback of diseases that can be prevented through vaccination. Precise prediction of future vaccine demand is crucial for maintaining optimal vaccine availability, distribution, and scheduling, hence mitigating the likelihood of inventory shortages and facilitating the smooth execution of immunization initiatives (Manupati et al., 2021). On the other hand, over stocking of vaccines might lead to their expiration prior to utilization, hence resulting in substantial financial losses and squandering of resources. The utilization of precise forecasting techniques in healthcare systems enables the achievement of a delicate equilibrium between maintaining adequate vaccination supplies to fulfill demand and preventing avoidable wastage resulting from the expiration of vaccines (Manupati et al., 2021). The maintenance of this equilibrium is crucial for ensuring the long-term financial viability of immunization programs and maximizing the efficient deployment of resources.

Accurate forecasting additionally reduces the necessity for emergency vaccine procurements, which can incur substantial costs and pose logistical difficulties (Okeagu et al., 2021). The ability to anticipate vaccine requirements facilitates enhanced strategic planning and financial allocation within healthcare systems, leading to enhanced cost-effectiveness and operational efficiency. On the contrary, the utilization of ineffective forecasting methods might

result in substantial financial liabilities and jeopardize public health. The ramifications for public health might be severe when there is a shortage of vaccines due to an underestimation of the demand (Okeagu et al., 2021). The act of overestimating demand results in escalated expenses as a consequence of procuring superfluous vaccines and subsequently disposing of expired doses. In addition, the maintenance of equipment within the cold chain holds significant importance in ensuring the purity and effectiveness of vaccines. Vaccines are delicate biological substances that necessitate stringent temperature regulation in order to preserve their efficacy. Exposure to temperatures over the authorized range has the potential to compromise the efficacy and safety of vaccinations, so rendering them unsuitable for administration. The cold chain refers to the whole network of storage and transit processes that are carefully regulated to ensure the maintenance of optimal temperature conditions, hence safeguarding the quality of vaccines (Okeagu et al., 2021). The integrity of vaccines and the overall cold chain might be compromised as a result of equipment breakdowns and inadequate maintenance. Significant dangers can be posed by faulty refrigeration equipment, temperature monitoring devices, and cold storage units. The implementation of routine maintenance and continuous monitoring of this equipment is crucial in guaranteeing that vaccines are stored and transported within the designated temperature range.

The maintenance of equipment is of paramount importance not only in preserving the quality of vaccines but also in mitigating potential financial losses. The replacement of damaged vaccines and equipment can incur significant costs, and the repercussions of equipment failures can have far-reaching effects on the overall immunization program, impacting public health results and requiring supplementary expenditures. The efficacy of equipment maintenance is intricately linked to the proficiency and conscientiousness of healthcare personnel engaged in vaccine management (Bown & Bollyky, 2022). It is imperative for healthcare staff to possess comprehensive training in the appropriate utilization, upkeep,

and surveillance of cold chain equipment. This include the identification of indicators that signal equipment faults, the implementation of regular inspections, and the timely execution of repair measures when deemed required.

The repercussions of equipment maintenance failure might be severe. Temperature excursions, which may arise from equipment problems, have the potential to lead to vaccine wastage and reduced vaccine quality, hence posing risks to patient safety. In addition, the occurrence of equipment malfunctions has the potential to disrupt the established immunization schedules and undermine the confidence of the general public in healthcare systems (Bown & Bollyky, 2022). Within the given setting, technology has assumed a pivotal role in facilitating significant advancements in the domains of vaccine forecasting and equipment maintenance. The integration of big data and artificial intelligence has significantly improved the precision of vaccine demand projections, resulting in the development of advanced forecasting models. These models possess the capability to assess extensive quantities of historical and real-time data, hence equipping healthcare systems with enhanced and dependable forecasting capabilities. In a similar vein, advancements in technology have facilitated the implementation of remote monitoring systems and instantaneous alerts for cold chain equipment (Bown & Bollyky, 2022). Currently, there are temperature monitoring systems that are equipped with digital interfaces, enabling them to offer uninterrupted data on the status of equipment and temperature conditions. This enables healthcare professionals to swiftly attend to concerns and uphold the efficacy of immunizations.

The function of supply chain management is of utmost importance in the distribution of vaccines, as it serves as the fundamental framework for ensuring the efficiency and effectiveness of immunization programs. The vaccine supply chain is comprised of a multifaceted network of procedures and individuals accountable for the acquisition, storage, transportation, and distribution of vaccinations to their designated beneficiaries. The complex

nature of this system plays a crucial role in guaranteeing the preservation of vaccines' purity and effectiveness, hence playing a significant part in the achievement of immunization initiatives and the safeguarding of public health (Bown & Bollyky, 2022). The purchase of vaccinations is a key role within the realm of supply chain management. This process encompasses the evaluation, procurement, and obtaining of vaccinations from diverse producers or suppliers. Efficient procurement processes play a crucial role in ensuring a cost-effective vaccine supply, particularly in light of the escalating costs of vaccines and the increasing variety of vaccines available. The important components in vaccine procurement encompass the use of efficient negotiation techniques with suppliers, the adoption of transparent pricing tactics, and the incorporation of bulk purchase considerations. During the procurement phase, it is crucial to evaluate the quality and validity of vaccinations to verify their compliance with the necessary criteria.

After the acquisition of vaccinations, it is important to store them under specific temperature settings in order to preserve their efficacy. The maintenance of the vaccine cold chain is an essential element within the supply chain, encompassing the proper storage and delivery of vaccinations under controlled temperature conditions. Cold storage units and refrigeration equipment, such as cold rooms and cold boxes, play a crucial role in maintaining the integrity of the cold chain. Continuous temperature monitoring and warning systems offer real-time data regarding temperature conditions, thereby ensuring the maintenance of vaccinations within the prescribed range. The lack of adequate temperature management can result in the deterioration of vaccines, leaving them useless and potentially hazardous for administration. Efficient distribution of vaccines is an additional fundamental aspect of supply chain management. The transportation of vaccines is a crucial process that involves the movement of these medical supplies from central storage facilities to different immunization places, such as health clinics, hospitals, and outreach locations. This necessitates meticulous

strategizing of transportation pathways, encompassing the evaluation of variables such as geographical distance, existing infrastructure, and climatic conditions. Ensuring the integrity of the cold chain during the shipping process is crucial in order to preserve the quality of vaccines. The implementation of insulated containers, cold boxes, and temperature monitoring equipment serves to guarantee the maintenance of vaccinations within the designated temperature range throughout their transportation.

Inventory management plays a crucial role in the realm of supply chain management by effectively maintaining the availability of vaccines as required, while simultaneously reducing any unnecessary wastage. Effectively managing vaccine inventories, accurately predicting demand, and closely monitoring expiration dates are crucial factors in achieving optimal equilibrium. Automated inventory systems, in conjunction with periodic audits, play a crucial role in mitigating stockouts and minimizing vaccine wastage, hence enhancing the overall efficacy of immunization programs. The effective functioning of the vaccination supply chain heavily relies on the utilization of communication and information technology. The availability of up-to-date information regarding vaccine inventory, temperature conditions, and transportation schedules is crucial for making well-informed judgments and implementing prompt remedial measures. The progress in information technology has facilitated the creation of digital platforms and tracking systems that furnish stakeholders with current information and promote decision-making based on facts.

The success of supply chain management in vaccine distribution relies heavily on the fundamental aspects of collaboration and coordination among the various players involved. Governments, international organizations, non-governmental organizations, healthcare practitioners, and manufacturers all fulfill vital functions. The establishment of robust alliances and collaborative efforts plays a pivotal role in optimizing the distribution of vaccines and mitigating operational inefficiencies within the supply chain. Furthermore, it is imperative to

provide training and enhance the ability of healthcare professionals and supply chain staff in order to equip them with the requisite competencies to successfully handle vaccines and uphold the integrity of the cold chain. The importance of worldwide vaccine distribution has been underscored in recent years due to the implementation of COVID-19 vaccination campaigns (Iwu, 2019). The effective dissemination of these vaccinations has been largely contingent upon the robustness and adaptability of supply chain management. Significant logistical complexities have emerged, specifically in the endeavor to achieve fair and impartial distribution on a worldwide level. Effective management of the supply chain and attainment of extensive vaccination coverage have relied upon the crucial collaboration of nations, international entities, and vaccine producers. In addition, the integration of cutting-edge technology and methodologies, such as unmanned aerial vehicle deliveries, portable immunization facilities, and electronic monitoring systems, has significantly contributed to the optimization and accountability of vaccine dissemination. The aforementioned technological advancements have shown to be particularly advantageous in facilitating access to immunization services for geographically isolated or marginalized populations, hence promoting the fair allocation of vaccines.

1.2. Problem Statement

The issue of effectively managing vaccine quality and minimizing wastage in a cost-efficient manner is a critical concern in the field of vaccine management. This difficulty carries significant consequences for public health, healthcare systems, and the global health economy. Vaccines play a crucial role in the prevention of infectious diseases, and their effectiveness is closely correlated with their quality and potency (Zepp, 2010). Ensuring the integrity of vaccines throughout the entirety of the supply chain is of paramount importance, since even slight deviations from the prescribed storage temperatures can result in the deterioration of vaccine efficacy. The failure to adequately maintain appropriate storage conditions poses a

substantial public health hazard, since it may lead to the administration of vaccinations that are either ineffective or harmful to persons. Hence, ensuring the quality of vaccines is of utmost importance in safeguarding both individuals and communities against avoidable illnesses.

Simultaneously, the minimization of vaccine wastage is vital to guarantee effective deployment of resources and maintain financial sustainability. Wastage is observed when vaccines reach their expiration date prior to being utilized, resulting in their ineffectiveness. Additionally, vaccine degradation or disposal might occur as a consequence of inadequate handling, shipping, and distribution procedures. Vaccine waste poses a significant economic burden on healthcare systems due to the loss of valuable resources and the acquisition of vaccinations that are not completely utilized. The aforementioned factor exerts influence on healthcare budgets and the cost-effectiveness of immunization programs. Achieving an optimal equilibrium between preserving the quality of vaccines and eliminating unnecessary wastage presents a complex and complicated dilemma. The effective management of vaccine inventory, precise forecasting of vaccine needs, streamlined procurement processes, strict adherence to cold chain protocols for storage and shipping, and comprehensive training of healthcare personnel in vaccine management are essential components in this regard. Insufficient management of any of these factors can result in either compromised vaccination quality or avoidable wastage, both of which can have detrimental effects on public health and the optimal allocation of resources.

The accurate prediction of vaccination demand is essential in effectively addressing this challenge. The accurate prediction of future demands necessitates a thorough comprehension of various factors, including population demographics, epidemiological patterns, and the implementation of novel vaccinations. The task at hand is not a singular event, but rather an ongoing endeavor that necessitates consistent modifications in order to accommodate evolving circumstances. The potential consequences of inaccurate forecasting include the occurrence of

vaccine shortages, which in turn can lead to a decline in vaccine coverage and the reemergence of diseases that could have been prevented through vaccination. The potential consequences of overestimating vaccination demand include excessive stockpiling and subsequent increased waste of vaccines. Therefore, the efficient management of vaccinations relies on accurate forecasting in order to ensure that the quantities of vaccines are in line with the real demand. Furthermore, it is imperative to acknowledge that the cold chain plays a crucial role in upholding the quality of vaccines. Vaccines are delicate biological substances that necessitate stringent temperature regulation. The efficacy and efficiency of vaccines can be compromised when they are exposed to temperatures that fall beyond the approved range. The cold chain encompasses a number of essential components, such as refrigeration equipment, temperature monitoring devices, and transportation systems, which collectively ensure the preservation of vaccines within the designated temperature range. Within the supply chain, there is a potential for equipment breakdowns or temperature excursions to transpire, hence posing a risk to the quality of vaccines. The preservation of vaccine quality relies heavily on maintaining the integrity of the cold chain and swiftly addressing concerns related to equipment maintenance and temperature monitoring.

Another facet of the difficulty pertains to the effective management of vaccination inventory. The practice of inventory control involves the systematic monitoring and management of vaccine stock levels, accurate forecasting of demand, and diligent monitoring of expiration dates. Inadequate inventory management practices can result in stockouts, which occur when vaccinations are not available when required, or overstocking, resulting in unnecessary loss. Automated inventory systems, regular audits, and meticulous record-keeping are essential components in maintaining optimal equilibrium, guaranteeing the availability of vaccinations as needed, while simultaneously eliminating unnecessary loss. The significance of training and capacity building for healthcare professionals engaged in vaccination management

should not be overlooked. These folks are actively engaged in the forefront of vaccination administration and are responsible for making crucial determinations regarding their utilization. It is imperative that individuals possess comprehensive training and knowledge on appropriate vaccine handling, cold chain management, and temperature monitoring. Insufficient training can give rise to errors in the handling of vaccines, perhaps leading to degraded vaccine quality or wasteful wastage.

The issue of ensuring vaccination quality and minimizing wastage in a cost-effective manner is not solely a technical one, but also a significant aspect of achieving global health parity. The effective management of vaccines is crucial in order to facilitate the distribution of vaccinations to populations that have limited access to healthcare services, reside in distant locations, or face resource constraints. This is vital for promoting equal and fair availability of immunization opportunities. Furthermore, within the framework of the worldwide dissemination of COVID-19 vaccines, ensuring fair and inclusive availability as well as effective administration play pivotal roles in bringing an end to the pandemic and mitigating the emergence of novel variations. In the past few years, advancements in technology and innovation have presented significant resolutions to these aforementioned issues. Temperature monitoring systems, such as Vaccine Vial Monitors (VVMs), provide instantaneous data regarding the exposure of vaccines to temperature variations, hence mitigating the potential for providing vaccines that may have been compromised (Whetham, 2023). The integration of big data and artificial intelligence in advanced forecasting models has resulted in enhanced precision in predicting vaccine demand. The advent of digital platforms and tracking systems has facilitated the instantaneous sharing of information and enhanced data-driven decision-making, hence bolstering the efficacy of vaccine management methods. The establishment of rigorous standards in the storage, distribution, and management of vaccines plays a crucial role in ensuring the efficacy and safety of immunization programs. The implementation of these

criteria is crucial in guaranteeing the preservation of vaccine quality, the safe administration of vaccinations, and the successful attainment of their intended public health objectives. Ensuring stringent protocols for the storage, distribution, and management of vaccines is crucial in order to retain the integrity and effectiveness of these biologically derived products. Vaccines exhibit a pronounced susceptibility to fluctuations in temperature and necessitate storage under designated temperature thresholds in order to uphold their efficacy.

Even slight deviations from these established parameters can result in the decline of vaccination potency, so compromising their effectiveness and perhaps posing safety risks during delivery. Hence, strict compliance with accurate storage conditions is of utmost importance in mitigating potential public health hazards. Furthermore, the maintenance of stringent standards in the storage, distribution, and management of vaccines is vital in order to prevent unnecessary wastage and mitigate any financial setbacks. Inadequate management strategies have the potential to result in the expiration of vaccinations prior to their utilization, so rendering them devoid of value and imposing a financial strain on healthcare systems. The occurrence of vaccine waste not only incurs financial losses but also diminishes the number of individuals who receive essential immunizations, hence increasing the risk of prospective outbreaks of diseases that can be prevented through vaccination. Ensuring the preservation of good standards necessitates a thorough focus on all facets of vaccine management. The cold chain, a system of temperature-controlled storage and transportation, assumes a pivotal role in the management of vaccines. The inclusion of cold storage units, refrigeration equipment, and temperature monitoring devices is of utmost importance within this system. The implementation of routine maintenance and vigilant monitoring of this equipment is necessary in order to guarantee that vaccines are stored and transported in accordance with the prescribed temperature range.

In addition, it is imperative that the distribution of vaccinations, which entails the transportation of vaccines from centralized storage facilities to diverse immunization sites, strictly adheres to rigorous criteria. The process entails meticulous strategizing of transportation pathways, taking into account variables such as geographical span, infrastructure availability, and climatic conditions. Ensuring the integrity of the cold chain during the transportation of vaccines is imperative in order to sustain the quality of the vaccines. The use of insulated containers, cold boxes, and temperature monitoring devices serves to guarantee that vaccines maintain their prescribed temperature range throughout their transportation process. Accurate prediction of vaccine supply is an additional factor that contributes to maintaining high levels of efficiency in vaccine management. The accurate prediction of demand requires a comprehensive comprehension of population demographics, epidemiological patterns, and the use of novel vaccinations. The method is characterized by its dynamic nature, necessitating frequent modifications in order to effectively respond to evolving situations. Precise prediction plays a crucial role in mitigating stockouts and overstocking, so guaranteeing the timely availability of vaccines and reducing unnecessary waste.

Inventory management is a crucial element of maintaining high standards in vaccine management. The process entails the monitoring of vaccine inventory levels, the prediction of demand, and the surveillance of expiration dates. Effective inventory management is crucial for ensuring the timely availability of vaccines, thereby mitigating the risk of stockouts and minimizing wastage. Automated inventory systems and periodic audits play a crucial role in ensuring optimal resource allocation and maintaining appropriate inventory levels. Ensuring adequate training and capacity building for healthcare workers and supply chain personnel is crucial in maintaining optimal standards in vaccination management. These professionals are tasked with the responsibility of managing, storing, and disseminating vaccinations, while also

monitoring and ensuring appropriate temperature conditions. It is vital to guarantee that individuals receive comprehensive training in the appropriate protocols and possess a clear comprehension of the significance of upholding elevated benchmarks, since this is fundamental to ensuring the safety and efficacy of vaccines. The maintenance of high standards in vaccination management is of utmost importance, especially in settings with limited resources and countries that face logistical challenges. In the aforementioned situations, the task of upholding quality standards can pose significant challenges, primarily attributable to constraints in resources and infrastructure. Nevertheless, it is in these particular contexts that the demand for vaccines is typically the greatest, and it is imperative to maintain stringent criteria to guarantee the effective distribution of vaccines to marginalized communities.

Furthermore, within the framework of global vaccine distribution, the establishment of rigorous criteria is essential in order to attain fair and impartial availability of vaccinations. The meticulous storage and distribution of vaccines play a crucial role in promoting the fair allocation of vaccines, thereby enabling disadvantaged communities and geographically isolated regions to access the same degree of immunization against vaccine-preventable illnesses as more easily reachable places. In recent years, the integration of technology and innovation has emerged as a crucial factor in maintaining and enhancing the quality of vaccine management. Temperature monitoring systems, such as Vaccine Vial Monitors (VVMs), offer immediate data regarding vaccine exposure to temperature variations, hence mitigating the potential for giving compromised vaccines. The integration of big data and artificial intelligence in advanced forecasting models has resulted in enhanced precision in predicting vaccine demand. The advancement of digital platforms and tracking systems has facilitated the instantaneous flow of information and supported data-driven decision-making processes, hence improving the adherence to elevated standards.

Temperature monitoring systems have become essential instruments in the domain of vaccine management, assuming a crucial function in tackling the difficulties related to preserving vaccine integrity and reducing unnecessary loss (Yaquub, 2017). These devices deliver real-time temperature information, addressing a crucial challenge in vaccine management, which is the maintenance of vaccine potency. One of the primary obstacles encountered in the field of vaccine management is to the preservation of vaccine quality across the entirety of the supply chain. Vaccines are delicate biological substances that necessitate stringent temperature regulation in order to maintain their effectiveness. The efficacy and safety of vaccinations may be compromised when exposed to temperatures that deviate from the approved range, rendering them ineffective or even hazardous for administration. This difficulty is exacerbated in areas with limited resources, where ensuring continuous temperature control can pose significant difficulties. Temperature monitoring technologies, such as Vaccine Vial Monitors (VVMs), have significantly transformed the sector by offering a resolution to this particular predicament (Yaquub, 2017). Vaccine Vial Monitors (VVMs) are adhesive labels of reduced dimensions that undergo a chromatic transformation during exposure to elevated temperatures, so serving as a conspicuous visual cue of potential impairment to vaccines. The provision of real-time information about vaccine vials enables healthcare professionals to make well-informed judgments regarding the suitability of vaccines, hence reducing the likelihood of administering compromised vaccines.

Voting Verification Machines (VVMs) are straightforward yet remarkably efficient instruments that provide numerous significant benefits. Primarily, these technologies provide healthcare professionals with the capacity to evaluate the quality of vaccines directly at the location where healthcare services are provided (Chan, 2006). Prior to delivering a vaccination, healthcare professionals have the ability to assess the vaccination Vial Monitor (VVM) on the vaccine vial in order to ascertain if it has been subjected to elevated temperatures (Whetham,

2023). The safety of a vaccination can be determined by assessing the color displayed on the vaccination Vial Monitor (VVM). If the VVM shows an acceptable color, it signifies that the vaccine is deemed safe for administration. Conversely, if the VVM exhibits any signs of damage, it is recommended to discard the vaccine. The provision of prompt feedback guarantees that only vaccines that adhere to the most stringent quality criteria are delivered to individuals. The utilization of Vaccine Vial Monitors (VVMs) has been found to have a substantial impact on mitigating vaccine waste, which is recognized as a prominent obstacle in the realm of vaccine management. Prior to the introduction of Vaccine Vial Monitors (VVMs), healthcare professionals frequently depended on visual inspections or temperature logs as means of evaluating vaccine quality. These methods were found to be less precise and dependable. Consequently, a substantial quantity of vaccine doses was squandered due to healthcare staff frequently opting to trash vaccines as a precautionary measure, rather than administering doses that might have been damaged. Vaccine vial monitors (VVMs) offer a heightened level of objectivity and real-time evaluation, hence reducing the necessity for unwarranted vaccine waste.

Vaccine vial monitors (VVMs) contribute to the overall improvement in vaccine management efficiency by mitigating the risk of stockouts. Stockouts refer to the situation where vaccinations are not available at the required time, hence causing disruptions in immunization schedules and resulting in diminished coverage rates (Chan, 2006). Before the implementation of Vaccine Vial Monitors (VVMs), healthcare professionals exhibited caution when administering vaccinations that had seen minor temperature variations, as there was concern regarding their potential efficacy. This cautious approach occasionally resulted in the unnecessary depletion of vaccine resources, leading to shortages in the availability of vaccines. Vaccine vial monitors (VVMs) alleviate this concern by empowering healthcare professionals to administer vaccines with confidence, provided that the VVMs show their safety.

Additionally, Vaccine Vial Monitors (VVMs) play a significant role in enhancing the financial viability of immunization programs. By implementing strategies to prevent vaccine wastage, healthcare organizations can optimize resource use and mitigate financial losses incurred by the disposal of unused vaccines. This, consequently, enhances the cost-effectiveness of vaccination programs by conserving vital resources that can be allocated to other crucial healthcare requirements.

The implementation of Vaccine Vial Monitors (VVMs) has played a crucial role in effectively tackling the issue of fair vaccine allocation. In situations with limited resources and inadequate access to services, where the preservation of optimal temperature conditions for vaccines is especially difficult, Vaccine Vial Monitors (VVMs) offer a straightforward and dependable method for evaluating the quality of vaccines. This practice guarantees that vaccines are administered with equivalent levels of quality assurance in both remote and easily accessible areas. Vaccine vial monitors (VVMs) play a significant role in promoting fair and equal access to immunization services, so ensuring that individuals residing in distant and underserved regions can avail themselves of an equivalent degree of safeguard against vaccine-preventable illnesses. In recent times, there have been notable advancements in technology that have significantly enhanced the functionalities of temperature monitoring systems. Digital temperature monitoring devices that have been equipped with advanced data storage capabilities and real-time alarm systems offer a higher level of accuracy and specificity in terms of temperature condition information. These devices has the capability to transfer data to centralized systems, so enabling remote monitoring and facilitating prompt responses to temperature excursions.

1.3. Significance of the Study

The study's importance rests in the potential economic value associated with the effective management of vaccines, which is a crucial component of healthcare systems and

public health that extends beyond national boundaries and has wide-ranging benefits for society worldwide. The effective management of vaccines extends beyond the realm of healthcare and serves as a significant catalyst for economic growth, offering a multitude of advantages that eventually enhance the welfare of individuals, communities, and nations. Primarily, the efficient management of vaccines directly influences healthcare spending and the allocation of resources. Vaccines play a vital role in the realm of preventative healthcare, since they provide a cost-efficient method for mitigating diseases that would otherwise impose significant financial burdens on healthcare systems. Efficient vaccine management enables healthcare systems to optimize resource allocation by decreasing vaccine wastage and maintaining the preservation of vaccine quality. Consequently, this phenomenon results in significant financial benefits that can be reallocated to address other pressing healthcare priorities, including illness management and the enhancement of healthcare facilities.

In addition, the efficient management of vaccines plays a crucial role in mitigating the financial impact of disease outbreaks. Preventable diseases not only incur direct healthcare expenditures but also give rise to indirect economic ramifications. The negative consequences encompass diminished productivity, heightened rates of absenteeism in both professional and educational settings, and the burden placed on healthcare systems, potentially leading to the reallocation of resources from other critical health services. Efficient management of vaccines plays a crucial role in mitigating the risk of disease outbreaks by guaranteeing timely availability and protecting the integrity of vaccines. The implementation of a preventative approach serves to limit the economic consequences of epidemics and effectively prevents the allocation of resources away from other healthcare priorities. In addition, the implementation of efficient vaccine management systems plays a crucial role in promoting economic stability through its positive impact on the well-being and productivity of the population. Vaccinations provide patients with protection against diseases that have the potential to cause disability,

long-term health complications, and untimely mortality. A workforce that is in good health exhibits higher levels of productivity, hence resulting in a rise in economic production. Additionally, vaccine-preventable diseases frequently impose a substantial cost on caretakers, thereby diminishing their capacity to engage in the labor market. The promotion of a productive and healthy population through efficient vaccine management can have an indirect positive impact on economic growth.

The economic advantage of efficient vaccine management is very significant, particularly in the setting of pandemics. The COVID-19 pandemic has brought to the forefront the worldwide economic ramifications associated with the rapid transmission of an infectious disease. The implementation of efficient vaccination management strategies, encompassing the allocation and dissemination of COVID-19 vaccines, plays a pivotal role in mitigating the transmission of the virus and its associated socioeconomic impacts. The implementation of widespread vaccination not only serves as a means of preserving human lives, but also facilitates the revival of economic activity by enabling the reopening of enterprises, the reintegration of employees into the workforce, and the restoration of a state of normalcy within communities. In addition, the effective management of vaccines plays a crucial role in upholding global health security. The prevention of the global dissemination of infectious illnesses is a topic of paramount importance, given that outbreaks occurring in a particular geographical area can result in significant economic and social ramifications on a global scale. The implementation of efficient vaccine management practices, which encompass the fair allocation of vaccinations, plays a crucial role in attaining worldwide health security. This is primarily accomplished by mitigating the potential for infectious illnesses to spread over international boundaries and precipitate global emergencies. The accomplishment of the Sustainable Development Goals (SDGs) is inherently dependent on effective vaccination management. The Sustainable Development Goals (SDGs) contain a wide range of economic,

social, and environmental objectives, which notably include the promotion of health and well-being as outlined in SDG 3. The provision of vaccinations and the efficient administration of vaccine distribution play a crucial role in the attainment of Sustainable Development Goal 3. These efforts are vital in diminishing death rates, averting the spread of diseases, and realizing universal health coverage. The economic advantages associated with effective vaccination management are in line with the larger Sustainable Development Goals (SDGs), including the eradication of poverty (SDG 1), the provision of quality education (SDG 4), the promotion of gender equality (SDG 5), and the reduction of disparities (SDG 10). These goals are fundamental to fostering economic and social development in numerous dimensions.

The significance and multifaceted nature of Vaccine Vial Monitors (VVMs) in enhancing vaccine management are noteworthy, as their influence extends to national vaccination programs and worldwide public health. Vaccine Vial Monitors (VVMs) represent a significant advancement in the field, as they effectively tackle key obstacles related to the preservation of vaccine integrity, minimizing unnecessary loss, and guaranteeing the efficacy of immunization endeavors. Vaccine vial monitors (VVMs) are diminutive labels that are sensitive to temperature and are placed to vials containing vaccines. These visual indicators provide a means to assess the possible harm to vaccines caused by variations in temperature that occur during their storage and shipment. The technology underlying Vaccine Vial Monitors (VVMs) is characterized by its exquisite simplicity. It involves the utilization of a color-changing square, typically attached to a vaccine vial or container, which undergoes a progressive alteration in color when subjected to heat. The transition from light to dark serves as a visual representation of the progressive accumulation of temperature excursions, so signifying the potential jeopardy to the effectiveness of vaccines.

The principal function of Vaccine Vial Monitors (VVMs) within the context of vaccine management is to furnish healthcare professionals with up-to-date data regarding the quality of

vaccines at the location where they are administered. This enables healthcare professionals to make well-informed decisions regarding the usability of vaccines, so substantially mitigating the likelihood of giving compromised vaccines. Vaccine Vial Monitors (VVMs) provide healthcare professionals with a prompt visual indicator, facilitating the assessment of a vaccine's safety for administration or the need for its disposal. This practice enhances the efficacy of vaccination management by guaranteeing that only vaccines that adhere to the most stringent quality criteria are provided to individuals. One of the primary advantages associated with the use of VVMs is their ability to effectively mitigate vaccine waste. Prior to the use of Vaccine Vial Monitors (VVMs), healthcare professionals frequently had to depend on less accurate techniques to evaluate the quality of vaccines, such as ocular examinations or temperature records. Frequently, these methodologies resulted in a notable quantity of vaccine doses being squandered, as healthcare professionals exercised prudence and disposed of vaccines exhibiting even slight temperature variances. Vaccine Vial Monitors (VVMs) offer a heightened level of objectivity and real-time evaluation in assessing the quality of vaccines, hence substantially reducing the need for unwarranted vaccine waste.

The utilization of Vaccine Vial Monitors (VVMs) has significant economic ramifications due to the reduction in vaccine wastage. The disposal of unused vaccinations imposes a financial burden on healthcare systems, as valuable resources are allocated towards the procurement and administration of vaccines that are ultimately not utilized. This outcome leads to financial savings that can be reallocated towards other crucial healthcare requirements, hence enhancing the overall effectiveness and long-term viability of healthcare initiatives. Moreover, through the reduction of wastage, VVMs enhance the resource efficiency and cost-effectiveness of healthcare systems, thereby ensuring the optimal utilization of valuable healthcare resources. The substantial influence of policies caused by Vaccine Vial Monitors (VVM) on national immunization programs is evident. The integration of VVMs into

vaccination management procedures has resulted in the formulation of comprehensive rules and guidelines. Vaccine quality assessment and the improvement of vaccine management have been significantly enhanced by the widespread adoption of Vaccine Vial Monitors (VVMs) in national vaccination programs. The implementation of these rules has resulted in the establishment of uniform methods and practices in the management of vaccines, surpassing geographical boundaries at both regional and national levels.

The implementation of VVM-induced policies has also been crucial in facilitating the fair allocation of vaccines, which is a pivotal component of both domestic and international immunization endeavors. Vaccine Vial Monitors (VVMs) play a crucial role in promoting equity in vaccine distribution by offering a uniform and reliable approach to evaluating vaccine quality. This ensures that populations residing in underserved and geographically isolated locations receive immunizations that adhere to the same rigorous quality standards as those in more accessible places. The aforementioned factor plays a crucial role in augmenting the scope and efficacy of national immunization initiatives, hence guaranteeing the safeguarding of individuals residing in marginalized communities against diseases that can be prevented by vaccination. The regulations implemented through the use of Vaccine Vial Monitors (VVM) have far-reaching implications for global health security. The prevention of the global transmission of infectious illnesses holds significant significance in an increasingly interconnected global landscape. Vaccine-preventable diseases and the corresponding policies they have engendered play a significant role in bolstering global health security by mitigating the potential for infectious diseases to traverse national boundaries and engender international catastrophes. The equitable distribution of vaccines and the confirmation of their quality are crucial factors in mitigating the transmission of the COVID-19 virus and revitalizing economic activity, particularly within the framework of global health emergencies.

1.4. Objectives of the Study

The objectives of the study are as follows:

- Review and analyze vaccine management policies applied in Zambia from VVM perspective
- Analyze vaccine management practices and processes from VVM perspective
- Evaluate health staff knowledge, attitude and practices on VVM use
- Calculate the socio-economic value of VVM implementation based on the established assumptions
- Recommend policy and programmatic improvements in order to use VVM to its utmost potential.

1.5. Specific Objectives

Specifically, the study will focus on the following policies and practices/processes for in-depth analyses:

- Controlled temperature chain
- In-country vaccine transport (cool water-packs)
- Multi-dose vial policy documents
- Local or International vaccine arrival (acceptance/rejection)
- Stock management (organizing storage area with the help of VVM, rotation of stocks with the help of VVM, earliest-expiry-first-out and VVM, VVMs role in dispatches, VVMs role in temperature excursions/alarms, vaccine wastage)
- Campaigns and VVMs
- Routine immunization sessions (fixed sessions, outreach sessions)

1.6. Scope And Limitation

The comprehensive understanding of the implementation, impact, and potential issues connected with Vaccine Vial Monitors (VVMs) and national vaccination programs in Zambia

necessitates a thorough examination of the scope and limitations of this study. This study aims to conduct a comprehensive examination of Vaccine Vial Monitors (VVMs) and their incorporation into the vaccine management policies and procedures in Zambia. The method entails conducting a thorough examination and assessment of current policies and their implementation, with a specific emphasis on the integration and adherence of Vaccine Vial Monitors (VVMs) across all stages of the vaccine distribution cycle, including storage, transportation, and administration. The scope of this study encompasses an investigation on the knowledge, attitudes, and practices of healthcare professionals with regards to the utilization of Vaccine Vial Monitors (VVMs). The objective of this study is to assess the extent of healthcare personnel's comprehension of Vaccine Vial Monitors (VVMs) and their ability to effectively apply this knowledge in the routine administration of vaccinations. Additionally, this study aims to quantitatively assess the socio-economic implications of implementing VVMs in Zambia, utilizing established assumptions. Its objective is to furnish empirical proof of the economic benefits associated with VVMs in the context of vaccination management.

Furthermore, the research will provide detailed examinations of crucial policies and practices/processes that are pertinent to the management of vaccines utilizing VVMs. The areas of focus will encompass an examination of the controlled temperature chain, the utilization of cooling mechanisms for in-country vaccine transport, policy documents pertaining to multi-dose vials, protocols for the arrival of vaccines at local or international destinations, strategies for stock management involving Vaccine Vial Monitors (VVMs), and the significance of VVMs in vaccination campaigns and routine immunization sessions. The present study aims to provide a comprehensive review of the integration of VVMs (vaccine vial monitors) into several aspects of vaccine management in Zambia. Nevertheless, it is important to acknowledge that this study does possess several limitations. One constraint that arises pertains to the intricate nature and interconnectedness of multiple components that exert influence on

the management of vaccines. The comprehensive examination of the subject matter may be limited in scope, as the multitude of factors influencing the effective utilization of VVMs presents a challenge to encompassing every intricate aspect. Furthermore, it is important to acknowledge potential limitations in terms of the accessibility and comprehensiveness of the data and statistical information utilized in this study. Obtaining comprehensive, current, and accurate data pertaining to many aspects of vaccination management, particularly in relation to financial assessments and socio-economic ramifications, might present difficulties.

Additionally, another constraint that should be considered is the possibility of biases arising during the process of data gathering. The findings and conclusions of a study may be unwittingly influenced by biases, depending on the sources and methods employed for data collecting. Additionally, it is important to consider that the study's duration and available resources could impose limitations on the comprehensive nature of the research, which in turn may constrain the scope of the recommendations offered for enhancing policies and programs. The presence of temporal constraints may potentially hinder the comprehensive evaluation of the enduring effects of VVMs on immunization initiatives. Furthermore, it is important to note that the applicability of the findings may be constrained to the particular circumstances of Zambia, and may not have direct relevance to diverse socio-economic or healthcare environments. When extending the conclusions or recommendations to different countries or locations, it is crucial to thoroughly analyze and account for the unique healthcare infrastructures, policies, and socio-economic contexts present in those specific areas.

Chapter 2: Literature Review

2.1. Introduction

The literature review plays a crucial part in this study by enabling a thorough investigation of the significant function that vaccination Vial Monitors (VVMs) play in vaccination management. The purpose of this introduction is to provide an overview of the literature review, including its purpose, context, and objectives. This will help to establish a clear understanding of the importance and relevance of the forthcoming talks. The primary objective of the literature review is to synthesize and evaluate the current body of information, research, and perspectives pertaining to VVMs and their incorporation into vaccine management strategies. This review aims to integrate the combined knowledge of scholars, practitioners, and organizations engaged in the fields of public health, immunization programs, and vaccine management. Through the examination and integration of previous research, established protocols, and specific instances, this study aims to provide a valuable contribution towards a more comprehensive comprehension of the effects and potential advancements that Vaccine Vial Monitors (VVMs) have had on the management of vaccines.

The literature evaluation is situated within the broader framework of global public health, specifically emphasizing immunization efforts. The administration of vaccinations is a crucial component of the public health system, and it has a significant impact on maintaining the effectiveness of vaccines, reducing waste, and protecting the health of the population. The careful management and allocation of vaccines have a crucial role in the effectiveness of vaccination initiatives, particularly in settings with limited resources. In such contexts, it is of utmost importance to ensure the maintenance of vaccine quality and the reduction of unnecessary loss. Furthermore, this literature evaluation is also relevant to the wider context of enhancing global immunization endeavors. Vaccination programs have made significant advancements in effectively mitigating a wide range of potentially fatal illnesses. Nevertheless,

the efficacy of these interventions is contingent upon the implementation of robust vaccine management techniques. Vaccine vial monitors (VVMs), which are specifically intended to monitor and assess the extent of temperature-induced damage to vaccines, play a crucial role as indispensable tools within these tactics. Gaining a comprehensive understanding of the efficacy of vaccinations and the rules governing their utilization is crucial in the pursuit of universal vaccine coverage and the assurance of global vaccine safety and effectiveness.

Based on the aforementioned, the literature review has a number of interconnected aims. The primary objective of this study is to offer a complete examination of vaccination management policies and practices, encompassing both the global and national contexts. This entails comprehending the standards and guidelines established by prominent organizations such as the World Health Organization (WHO) and their subsequent application in diverse nations. Through an in-depth analysis of these policies, this review will provide a fundamental basis for comprehending the indispensability of instruments such as VVMs in the effective management of vaccine supply chains. Furthermore, the purpose of this review is to clarify the significance of Vaccine Vial Monitors (VVMs) in the management of vaccines. This paper aims to provide a comprehensive analysis of various types and categories of Vaccine Vial Monitors (VVMs), elucidating their role in monitoring vaccine stability and their potential to enhance overall vaccine management practices. Another aspect of this purpose involves emphasizing the economic and public health advantages associated with VVMs. Through a comprehensive analysis of these factors, this review aims to demonstrate the crucial role that Vaccine Vial Monitors (VVMs) play in safeguarding the authenticity and accessibility of vaccines.

Additionally, the literature study will explore the correlation between Vaccine Vial Monitors (VVMs) and the Multi-Dose Vial Policy (MDVP). The MDVP, first referred to as the open-vial policy, plays a crucial role in vaccine management methods, specifically in the reduction of vaccine wastage. Gaining insight into the impact of Vaccine Vial Monitors

(VVMs) on Mean Dose Vial Percentage (MDVP) and their role in reducing vaccine wastage is a vital aspect of this investigation. The fourth objective pertains to evaluating the effects of VVMs by means of previous research studies and case analyses. This review seeks to offer evidence-based insights into the contributions of Vaccine Vial Monitors (VVMs) to the decrease of vaccine wastage and the improvement of vaccination management practices. It achieves this by evaluating impact studies undertaken in several countries, including Turkey, Nepal, and Bhutan. The primary purpose of this literature review is to enhance the existing knowledge base on vaccine management. Specifically, it seeks to emphasize the crucial significance of Vaccine Vial Monitors (VVMs) in guaranteeing the safety, effectiveness, and accessibility of vaccines in vaccination initiatives. This review aims to provide a comprehensive understanding of the impact and potential of VVMs in the context of public health and global vaccination campaigns. By examining their role in vaccine management, this study contributes to the greater goal of protecting public health worldwide.

2.2. Vaccine Management Policies and Practices

Approximately 40.5% of the participants exhibited a degree of reluctance or hesitation in relation to the COVID-19 vaccine. Remarkably, a significant majority of participants, amounting to 81%, shown an awareness of the significance associated with the administration of COVID-19 vaccinations. Furthermore, an impressive 77% of respondents conveyed their inclination to endorse the vaccine to their acquaintances and loved ones. The aforementioned findings are consistent with research undertaken in other sub-Saharan African nations such as Cameroon and the Democratic Republic of Congo, where different levels of reluctance towards vaccination were seen. There are multiple variables that contribute to vaccine reluctance in Zambia, which align with global patterns observed in vaccine hesitancy. The presence of skepticism towards pharmaceutical corporations, insufficiency of information regarding vaccines, and apprehensions regarding financial implications are prominent factors

contributing to the phenomenon of vaccine hesitancy in countries characterized by elevated rates of hesitancy. Within the given framework, it was observed that 30% of the participants held the perception that vaccines originating from Western countries possessed superior quality. Additionally, a majority of 65% expressed the belief that COVID-19 vaccines had undergone expedited development and approval processes. Comparable patterns were observed in Egypt, where 28.5% of respondents indicated a predilection for vaccines originating from the United States. These preferences underscore a lack of confidence in indigenous healthcare systems and the dissemination of inaccurate information regarding the efficacy and safety of vaccines specifically designed for use in Africa.

	Strongly Agree/Agree	Neutral	Strongly Disagree/Disagree
It is important to get a vaccine to protect people from COVID-19. (n = 3966)	3212 (81.0%)	513 (12.9%)	241 (6.1%)
Pharmaceutical companies are going to develop safe and effective COVID-19 vaccines? (n = 3891)	2395 (61.6%)	1111 (28.6%)	385 (9.9%)
COVID-19 vaccines made in Europe or America are safer than those made in other countries. (n = 3853)	1155 (30.0%)	1318 (34.2%)	1380 (35.8%)
I would take a vaccine to protect against COVID-19. (n = 3953)	3159 (79.9%)	425 (10.8%)	369 (9.3%)
I am hesitant to take the vaccine due to side effects from the vaccine. (n = 3905)	1580 (40.5%)	581 (14.9%)	1744 (44.7%)
I will recommend my family and friends to get vaccinated against the COVID-19 vaccine? (n = 3954)	3070 (77.6%)	521 (13.2%)	363 (9.2%)
I will get my children vaccinated against COVID-19? (n = 3704)	2421 (65.4%)	658 (17.8%)	625 (16.9%)
COVID-19 vaccine maybe faulty or fake. (n = 3942)	1005 (25.5%)	1304 (32.6%)	1633 (41.4%)
COVID-19 vaccine was rapidly developed and approved. (n = 3917)	2550 (65.1%)	912 (23.3%)	455 (11.6%)
COVID-19 vaccine might cause some medical complications in the future. (n = 3921)	1474 (37.6%)	1551 (39.6%)	896 (22.9%)
COVID-19 vaccine is being promoted for commercial gain. (n = 3906)	1046 (26.8%)	1318 (33.7%)	1542 (39.5%)
The government should make the vaccine available for all citizens for free. (n = 3931)	3408 (86.7%)	342 (8.7%)	181 (4.6%)

Table 1: Attitudes and perceptions towards COVID-19 vaccine.

One noteworthy issue highlighted in the present study pertains to the belief, as reported by 25% of participants, that COVID-19 vaccines are either defective or counterfeit. The aforementioned findings exhibit similarities to problems documented in previous research conducted in Zambia and the United Kingdom, hence highlighting significant implications about the safety and efficacy of vaccines. The proliferation of conspiracy theories, such as the notion that Africans are utilized as trial subjects for Western vaccines, has the potential to exert

a substantial influence on public attitudes regarding the safety and effectiveness of vaccines. Additionally, this study demonstrates a correlation between vaccine acceptance and the perception of danger. The findings of this study indicate that individuals with better educational attainment and older age exhibited a greater propensity to embrace COVID-19 immunization. These results align with prior investigations undertaken in the United States, the Middle East, and several African countries. A study conducted by the Africa CDC revealed a notable variation in trends, indicating that those with lesser levels of education demonstrated a higher propensity to express belief in the significance and safety of vaccines. The observed discrepancy can potentially be ascribed to factors such as the size of the sample, the geographical context of the study, and so necessitates additional inquiry.

The study additionally conducted a comparative analysis of vaccine hesitancy among various healthcare institutions in Kenya, providing insights into the divergent attitudes and beliefs regarding COVID-19 vaccines. The study findings indicate that those receiving care in faith-based hospitals exhibited a greater degree of reluctance towards vaccination, as seen by 42% of participants considering the vaccine as counterfeit or defective. In contrast, the corresponding figures for government hospitals and commercial hospitals were 29% and 17% respectively. In a similar vein, individuals affiliated with faith-based hospitals exhibited a higher perception of the vaccine being produced and licensed at a faster pace. Approximately 82% of these participants held this perspective, in comparison to 53% in government hospitals and 64% in private hospitals.

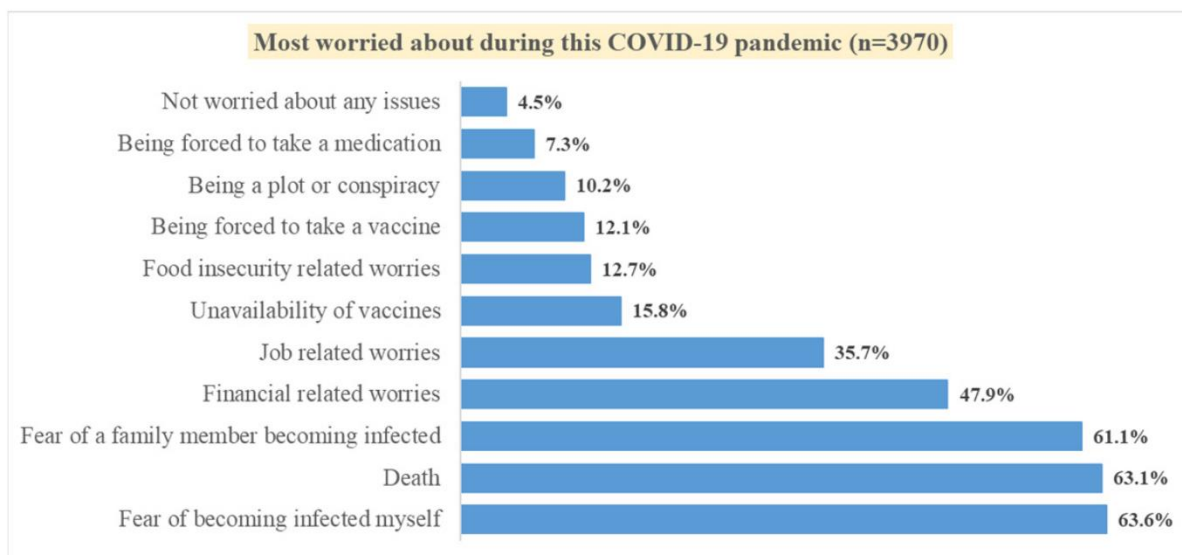


Table 2: Proportions of the issues respondents worried about most during the COVID-19 pandemic

The sources of vaccine information exhibited variability among diverse healthcare organizations. Private institutions predominantly relied on healthcare professionals and scientific papers, while government institutions exhibited a similar reliance on healthcare providers but demonstrated a preference for media sources. Faith-based facilities, on the other hand, strongly relied on both healthcare providers and media sources. The observed variations can be ascribed to the geographic dispersion of the sampled population, which indicates the impact of regional media and local healthcare professionals on the dissemination of vaccine-related information. Education had a substantial role in the present study, as seen by the varying educational backgrounds of the participants across different types of hospitals. Specifically, participants from government hospitals exhibited the lowest levels of education, while those from private hospitals predominantly held undergraduate or postgraduate degrees. In contrast, individuals affiliated with faith-based hospitals were commonly found to possess diplomas. It is worth noting that there were variations in vaccination rates across different types of hospitals. Private hospitals exhibited a higher vaccination rate of 82%, but government hospitals and faith-based hospitals reported lower rates of 52% and 55% respectively. The observed

geographical distribution of vaccine acceptance corresponds with the official reports provided by the Government of Kenya, which indicate greater rates of immunization in Nairobi and comparatively lower rates in Mombasa.

The investigation also took into account the participants' economic situation, uncovering that individuals affiliated with government and faith-based hospitals were more commonly found in low-income households characterized by greater rates of unemployment. The aforementioned finding exhibited a continuous pattern of individuals displaying a hesitancy about accepting the vaccine. In addition, it was found that a higher proportion of participants from government hospitals (11%) and faith-based hospitals (7%) expressed a lack of importance regarding vaccination for the purpose of protecting others, in comparison to participants from private hospitals (3%). The prevalence of concerns over vaccine side effects was significantly greater among participants in faith-based hospitals, as seen by 71% of respondents expressing such concerns. In comparison, 40% of participants in government hospitals and 29% of those in commercial hospitals had similar issues. The observed gap may be plausibly ascribed to variations in individuals' educational backgrounds and their primary sources of vaccine-related knowledge.

According to Pickering et al. (2009), vaccines are essential instruments in the field of public health as they help prevent and control infectious diseases. Nonetheless, strict supply chain management is just as important to the effectiveness and safety of vaccines as the composition of the shots themselves. The handling, storage, distribution, and administration of vaccines within vaccination programs are governed by a set of rules, laws, and protocols known as vaccine management policies that are implemented at the local, national, and international levels (Pickering et al., 2009). In order to maximize coverage, reduce waste, and guarantee the efficacy and safety of vaccinations, these regulations are essential. Strong vaccine management practices are essential for a number of reasons and form the foundation of immunization

programs (World Health Organization, 2021). First of all, they offer a uniform framework that controls every step of the vaccine supply chain, including production, shipping, storage, and delivery. In today's globalized world, where vaccinations are produced in one nation, shipped to all countries, and given locally, standardization is very important. The likelihood of mistakes, poor administration, and lowered vaccine quality dramatically rises in the absence of cogent policies.

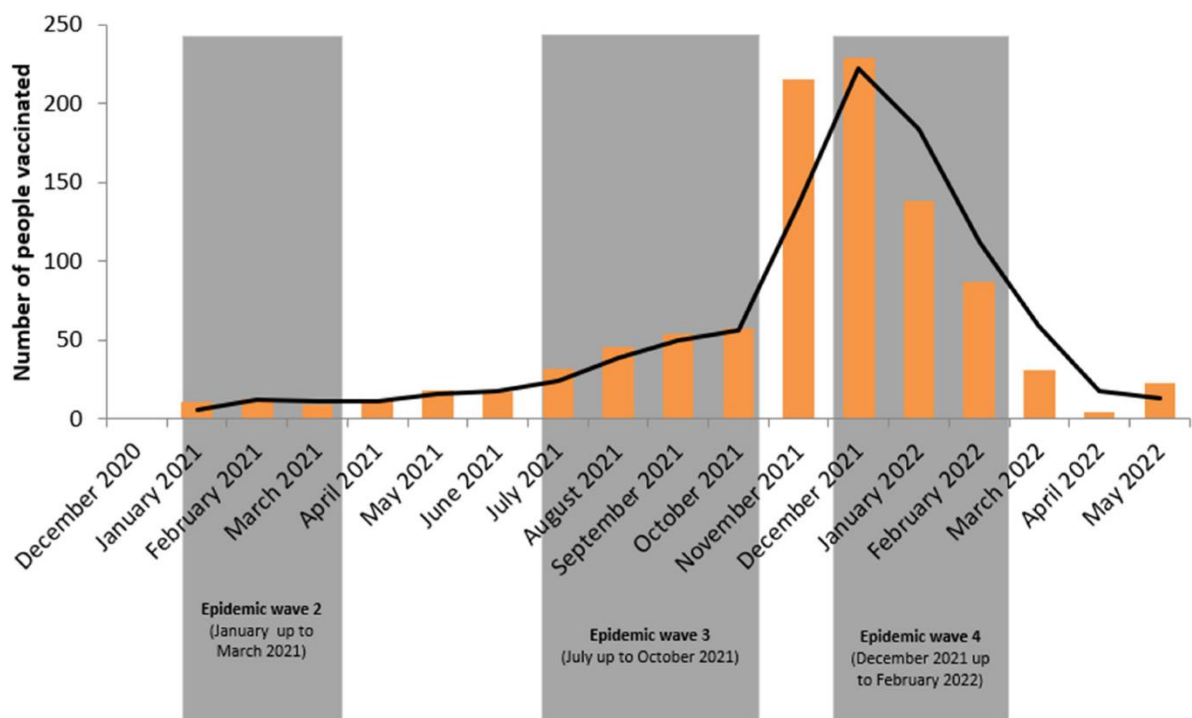


Figure 1: COVID-19 vaccine demand trend

According to World Health Organization, (2021), the purpose of vaccine management policies is to maintain the effectiveness of vaccines by controlling the storage and transportation environments. Because vaccines are extremely sensitive biological products, exposure to severe temperatures can reduce their effectiveness or possibly cause injury. Strict temperature controls and monitoring procedures are mandated by effective regulations to avoid temperature excursions that can compromise the effectiveness of vaccines (World Health Organization, 2021). Furthermore, the important problem of vaccination waste is addressed by

these policies. A significant amount of vaccinations expire, break, or are exposed to the wrong temperatures, all of which result in their waste every year. By recommending best practices including the use of multi-dose vial policies and vaccine vial monitors, proper vaccine management policies seek to minimize such waste. These tactics help medical professionals use vaccinations more effectively, reducing needless disposals. All phases of vaccine handling are covered by effective vaccination management policies. These policies offer comprehensive guidance on how vaccinations should be managed from the time they are produced until they arrive in recipient nations and are finally administered. They outline the storage requirements, the length of vaccine viability, the suggested handling techniques, and the credentials needed for staff members engaged in vaccination administration (Assefa & Abunna, 2018). These rules also emphasize how crucial it is to have trustworthy data management and information systems in order to monitor vaccination distribution, coverage rates, and adverse occurrences. Strong data management is essential to vaccination management because it makes it possible to quickly identify program gaps, problems, and areas for improvement.

2.2.1. Global Vaccine Management Standards

According to Assefa & Abunna, (2018), the proficient administration of vaccinations is a crucial component of public health systems on a global scale, and the development of universal benchmarks and recommendations is vital to guarantee the excellence, security, and effectiveness of vaccines. International organizations, such as the World Health Organization (WHO), have a significant impact on the establishment and distribution of these standards. This section will examine the international standards and recommendations pertaining to vaccination management, as well as the principal organizations responsible for its development and implementation. According to World Health Organization (2021), the World Health Organization (WHO) is widely recognized as the primary international body responsible for establishing and maintaining standards pertaining to the management of vaccines. The

document offers extensive guidance and suggestions that are crucial for nations to develop, execute, and assess their domestic policies regarding vaccine management (World Health Organization, 2021). The aforementioned standards encompass all aspects of vaccine management, spanning from the production process to the dispensation of vaccines within healthcare facilities.

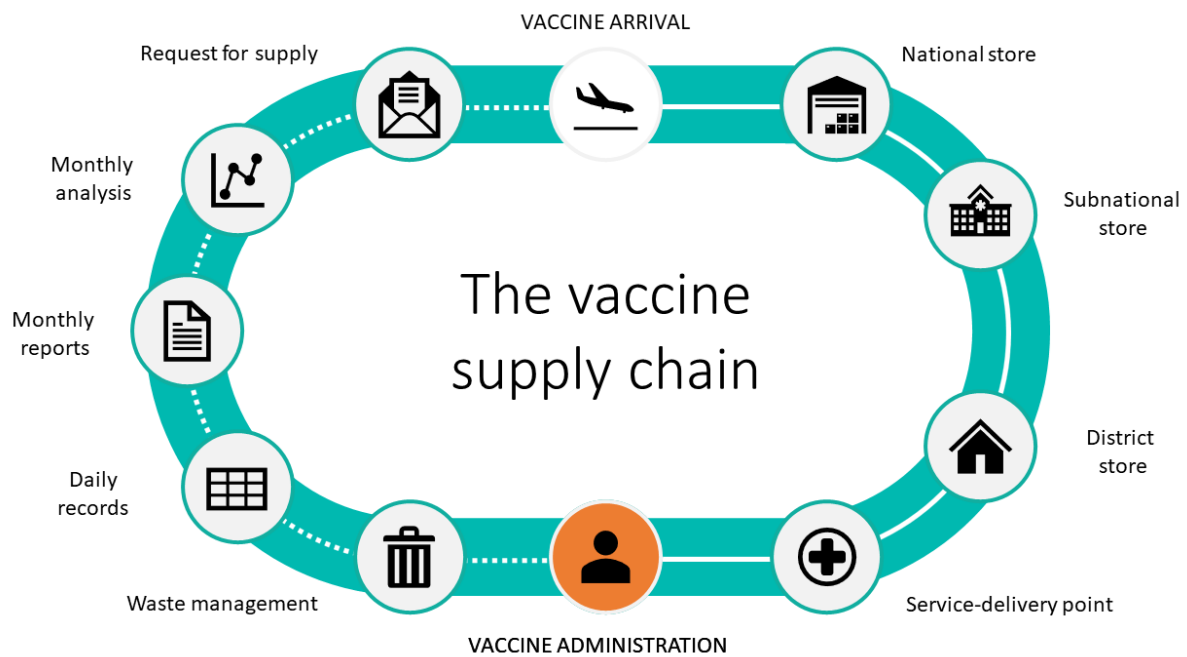


Figure 2: Vaccine management trend

According to World Health Organization (2014) report, the "Effective Vaccine Management (EVM) Assessment Tool" is a fundamental document offered by the World Health Organization (WHO). The EVM framework plays a vital role in the World Health Organization's strategy for vaccination management. The purpose of this assessment is to evaluate and enhance the implementation of vaccine management practices at the national level, utilizing a set of nine overarching global criteria. The aforementioned criteria encompass several aspects like pre-shipment and arrival protocols, temperature regulation, capacity for cold storage and transportation, infrastructure and equipment upkeep, stock administration, distribution practices, regulations pertaining to vaccination management, and information

systems (World Health Organization, 2014). Countries can enhance their vaccine management procedures and uphold the quality of vaccines by following the rules established by the EVM framework, thereby aligning with international standards. One of the foremost difficulties encountered in vaccine management pertains to the maintenance of appropriate temperature settings, a critical factor for ensuring the potency and safety of vaccines. The World Health Organization (WHO) provides comprehensive guidelines on cold chain management, which includes the essential temperature ranges for the storage and transportation of vaccines (World Health Organization, 2018). The temperature recommendations provided are tailored to the various vaccines, taking into consideration the unique storage requirements of each vaccine. Maintaining vaccines within the designated temperature range is of utmost importance in order to mitigate the risks of vaccine degradation, waste, and diminished efficacy.

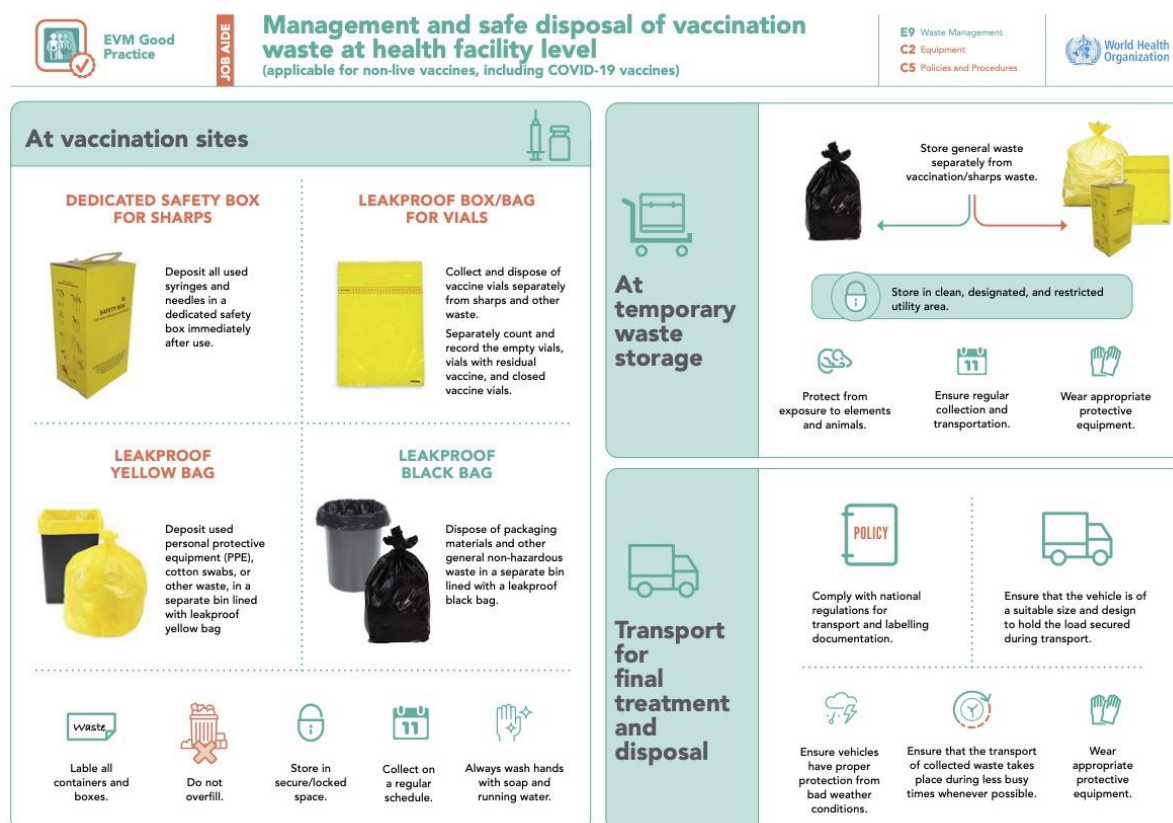


Figure 3: Essential Programme in immunization

Furthermore, according to World Health Organization (2018), the World Health Organization (WHO) supports the utilization of specialized instruments in the context of vaccination management, such as vaccination Vial Monitors (VVMs). Vaccine vial monitors (VVMs) play a crucial role in the surveillance of vaccine safety and effectiveness throughout the processes of storage and transportation. Vaccines are incorporated into international standards in order to safeguard them from extreme heat, a circumstance that has the potential to compromise their efficacy and safety (World Health Organization (2018)). Vaccine vial monitors (VVMs) serve as a visual indicator for vaccine workers, signaling whether a vaccine has been subjected to temperatures that exceed its permissible range. Furthermore, the World Health Organization (WHO) underscores the significance of data management and information systems in the context of vaccine management. Maintaining accurate documentation, which encompasses the surveillance of vaccine inventory levels and the utilization of vaccine return forms, is crucial for effectively monitoring the movement of vaccines along the supply chain (World Health Organization (2018)). The process involves the aggregation, processing, and analysis of data in order to generate feedback reports that facilitate the identification of issues and potential remedies across various tiers of the vaccine supply chain.

According to World Health Organization (2016), another crucial element of global vaccination management guidelines is the management of multi-dose vials. The World Health Organization (WHO) offers guidelines on regulations regarding multi-dose vials (MDVP) in order to mitigate vaccine waste. The Multi-Dose Vial Policy (MDVP) establishes the guidelines for the appropriate utilization of opened multi-dose vials in subsequent immunization sessions, resulting in a reduction in the wastage of vaccine doses (Nkandu, nd). In order to enhance adherence to the multi-dose vial policy, the World Health Organization (WHO) implemented the use of visual verification monitors (VVMs) as visual indicators to assist in determining the appropriateness of an open multi-dose vial for future utilization

(World Health Organization, 2016). In addition, the World Health Organization (WHO) plays a crucial role in lobbying for the acquisition of vaccines that are equipped with Vaccine Vial Monitors (VVMs). The organization urges Member States to incorporate Vaccine Vial Monitors (VVMs) as part of the essential criteria for vaccine procurement agreements. This measure guarantees that all acquired vaccines conform to international norms for temperature monitoring (Basu & Rustagi, 2022). It is crucial to acknowledge that global standards are subject to constant evolution in light of scientific progress, changes in vaccine technologies, and enhancements in best practices. Consequently, the World Health Organization (WHO) consistently revises its guidelines in order to incorporate the latest advancements in vaccine management. The dedication to flexibility and advancement guarantees the continued relevance and efficacy of vaccine management guidelines.

In addition, according to Jolly (2014), the World Health Organization (WHO) engages in collaborative efforts with other international organizations and partners within the realm of vaccination. The primary objective of these collaborations is to advance and distribute standards pertaining to vaccine management (Jolly, 2014). UNICEF, the United Nations International Children's Emergency Fund, plays a crucial role as a significant collaborator in numerous nations, namely in the areas of vaccine procurement and distribution (Basu & Rustagi, 2022). The collaboration between UNICEF and WHO is aimed at ensuring the effective distribution, storage, and management of vaccinations, hence facilitating their delivery to the designated recipients. Ensuring the safety, potency, and efficacy of vaccines is crucial for effective vaccination management, as it plays a pivotal role in protecting public health. Leading international organizations, with the World Health Organization (WHO) at the vanguard, have produced a set of important recommendations and criteria for successful vaccine management in order to attain this objective (Jolly, 2014). This section examines the essential suggestions and criteria that serve as the foundation for effective vaccine management

policies and practices. One of the initial stages in the management of vaccinations involves the crucial task of ensuring that vaccines are received in a good state and accompanied by accurate documentation. The primary suggestion in this context is to implement comprehensive pre-shipment and arrival protocols.

This is the process of validating the adherence to approved temperature conditions throughout the storage and transportation of vaccines, as well as testing the functionality of Vaccine Vial Monitors (VVMs) to detect any potential heat-related deterioration (Beigbeder, 2001). To ensure a comprehensive assessment of the shipment's condition upon arrival, it is imperative to complete and document a thorough Vaccine Arrival Report (VAR). Ensuring appropriate temperature management is of utmost importance in preserving the efficacy of vaccines. The World Health Organization (WHO) establishes certain temperature ranges for the storage and transportation of vaccinations, taking into consideration the unique temperature requirements of different vaccine types (World Health Organization, 2018). The temperature ranges typically observed, ranging from +2°C to +8°C, serve to maintain the efficacy of vaccines. The guideline is unequivocal: vaccinations must be stored and delivered within specified temperature limits in order to mitigate the risk of impairment and diminished efficacy.

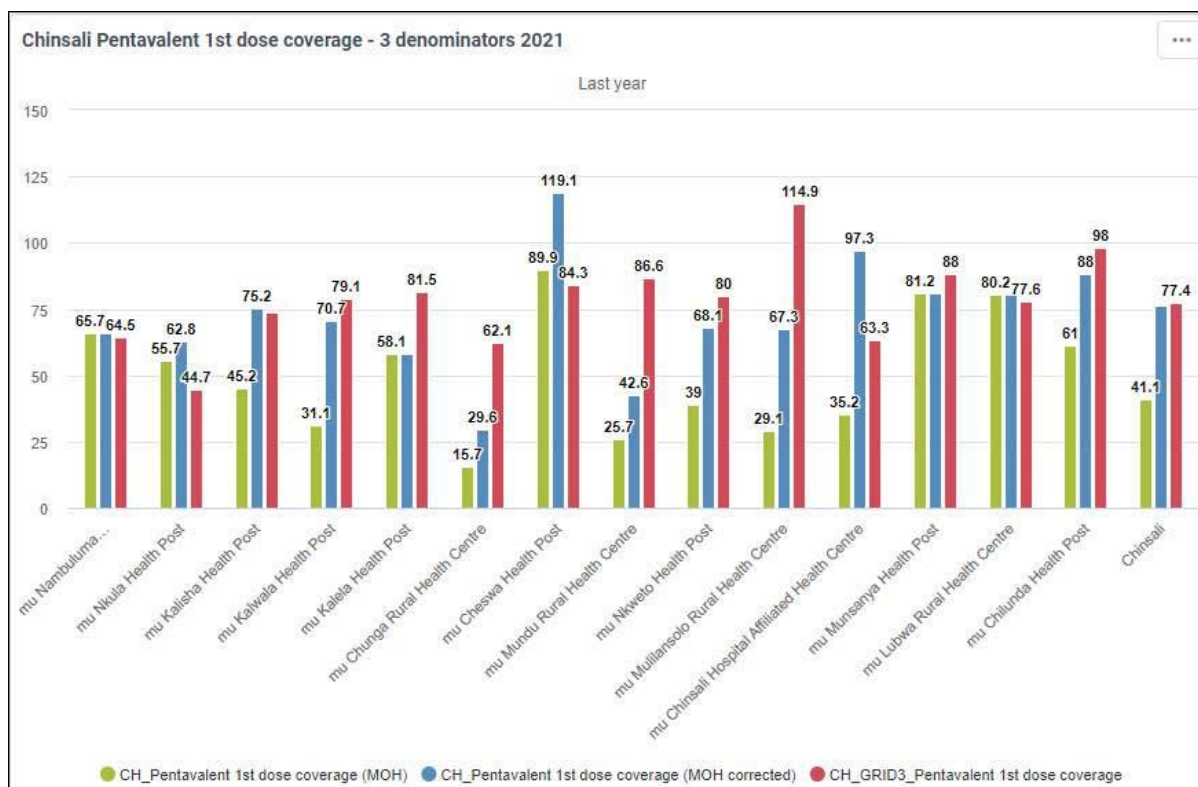


Figure 4: A chart showing facility-level immunization coverage rates compared across MoH and Grid3 population denominators

According to World Health Organization (2023), regional Vaccine Implementation Plan 2022–2026, WHO South-East Asia Region. Adequate cold storage, dry storage, and transportation capacity are essential elements of efficient vaccination management. In order to adhere to the requirements, set by the World Health Organization (WHO), vaccines necessitate storage in cold storage units that satisfy the organization's criteria (World Health Organization, 2023). These criteria encompass the utilization of well-maintained refrigerators and freezers. The infrastructure in place guarantees the preservation of quality and safety of vaccinations along the whole supply chain, while also ensuring an adequate supply to satisfy the demands of the program. The regular maintenance of infrastructure and cold chain equipment is of utmost importance. This encompasses the refrigeration units and freezing apparatus employed for the purpose of preserving vaccines, as well as the transportation mechanisms responsible for their conveyance. The implementation of regular maintenance practices plays a pivotal role

in mitigating equipment failures, hence guaranteeing the uninterrupted storage and transportation of vaccines under optimal temperature conditions.

Vaccine management relies heavily on the implementation of efficient stock management systems. The objective is to limit the amount of unused vaccines while also ensuring that the supply of vaccines consistently aligns with the demand. This entails the meticulous monitoring of inventory levels and the adoption of effective stock rotation strategies. Effective record-keeping and management play a crucial role in facilitating this process (World Health Organization, 2023). Another crucial factor is the efficient dissemination of vaccines throughout each level of the supply chain. Ensuring the effective delivery of vaccines and associated supplies to end-users while preserving the integrity of the cold chain is of paramount importance. This process encompasses both push and pull strategies, incorporating routine delivery and adaptive ordering processes. It is imperative to establish comprehensive vaccine management policies at both national and local levels, adhering to internationally recognized standards (Wilson et al., 2008). These policies provide guidance for the management, preservation, dissemination, and minimization of vaccine waste. It is imperative to ensure that vaccine quality and safety are upheld by adhering to the recommendations set forth by the World Health Organization (WHO) and other internationally recognized standards. The utilization of information technology is crucial for the monitoring and management of vaccine supplies (Wilson et al., 2008). Efficient systems for record-keeping and reporting play a crucial role in monitoring the distribution, consumption, and wastage of vaccines, hence facilitating well-informed decision-making. It is imperative to establish feedback loops that can effectively detect and address difficulties in a prompt way.

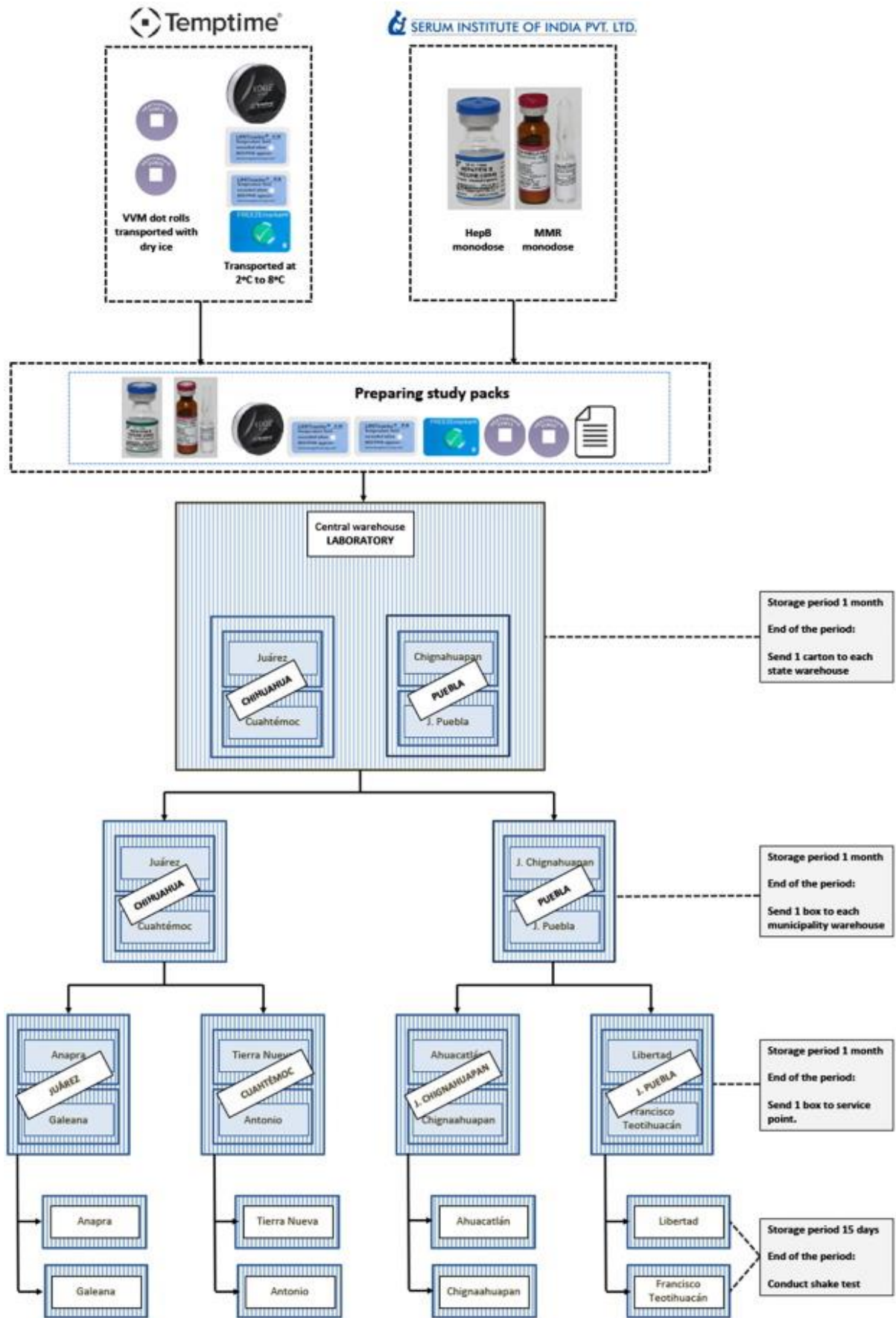


Figure 5: A vaccine cold chain temperature monitoring

The primary suggestions and criteria for efficient vaccine management underscore the importance of upholding the cold chain, closely monitoring temperatures, limiting vaccine wastage, and establishing suitable rules and procedures (Dubé et al., 2018). It is imperative to acknowledge that these criteria are interconnected and function cohesively to uphold the quality and safety of vaccinations. The aforementioned standards are derived from a comprehensive understanding of world knowledge and encompass the distinct specifications of various vaccinations. National and local vaccine management policies are established based on these foundations. Adherence to these criteria is of utmost importance in order to mitigate vaccine-related harm, minimize wastage, and mitigate the possible hazards associated with vaccinations that are inefficient or dangerous (Dubé et al., 2018). The significance of vaccination Vial Monitors (VVMs) in ensuring efficient vaccination management should also be emphasized. Vaccine vial monitors (VVMs) are adhesive labels that incorporate heat-sensitive polymers (Conway et al., 2012). These labels are affixed to vaccine vials with the purpose of monitoring and indicating the cumulative heat exposure experienced by the vaccines. Visual indicators are utilized to detect possible heat damage, hence preventing the administration of vaccinations that have been subjected to temperature circumstances that are deemed unsuitable. Vaccine vial monitors (VVMs) are considered essential instruments for individuals responsible for vaccine handling, as they significantly contribute to the standards and requirements of efficient vaccine management.

2.2.2. Vaccine Management Practices In Zambia

According to Ekhaguere et al., (2020), the Health Management Information System (HMIS) in Zambia functions as the principal means of data gathering for public health initiatives and disease surveillance. It gathers data on symptoms and service provision at the health facility level on a monthly basis. This approach is dependent on the officially anticipated population numbers from the 2010 census, as published by ZamStats. However, it encounters

some problems. The demographic data is antiquated and does not accurately represent the substantial increase in urban population since the previous census. In addition, it should be noted that the population multipliers employed in demographic computations have remained unchanged since 1992. The availability of disaggregated population data at the level of health facility catchment areas is lacking, thereby necessitating the use of facility headcount data as a substitute (Ekhaguere et al., 2020). The discrepancy between the data on the number of individuals and the data on the population of a given area leads to the production of false indicators at the national level. Furthermore, the lack of a universally accepted approach for determining catchment populations based on headcount at the facility level results in variations in the accuracy and reliability of population denominators. The activities related to the Homeless Management Information System (HMIS) primarily rely on paper-based methods at the facility level, which poses a challenge in effectively utilizing data in a timely manner (Ekhaguere et al., 2020). The difficulties at hand can potentially be addressed through the utilization of cutting-edge geospatial data and mapping technology. The partnership with the Grid3 initiative has permitted the development of population estimates at health facility and district levels through the utilization of geospatial data, hence enhancing the accuracy of such data. The incorporation of Grid3 population maps into HISP South Africa's collaboration with the Expanded Program on Immunization (EPI) in Chinsali district has resulted in improved micro-planning, assessment of geographic accessibility, and planning of outreach sites. The aforementioned endeavors have already resulted in enhanced understanding of the extent of vaccination coverage in Zambia.

	Population revised 0-11 months	GRID3 Population 0-11 months	GRID3 Population 0-11 months 0-30 mins	GRID3 Population 0-11 months 0-60 mins
Cheswa HP	283	400	240	266
Chilunda HP	167	150	78	133
Chinsali Hospital Affiliated HC	1,311	2,015	1,683	1,941
Chunga Rural HC	520	248	96	200
Kalela HP	454	324	242	299
Kalisha HP	113	115	101	112
Kalwala H	492	440	254	368
Lubwa Rural HC	435	450	321	346
Mulilansolo Rural HC	939	550	429	529
Mundu Rural HC	561	276	214	263
Munsanya HP	324	299	191	273
Mwalule HP		201	156	179
Nambuluma Police Rural HC	318	324	228	283
Nkula HP	188	264	146	177
Nkweto HP	135	115	93	114
Chinsali	6,240	6,171	4,472	5,483

Figure 6: Facility-level catchment population data from Chinsali district in Zambia, comparing revised MoH estimates with Grid3 calculations that are further disaggregated by travel time from the facility

According to Yadav & Kumar, (2023), the successful administration of vaccinations necessitates the intricate coordination of operational and administrative tasks to safeguard the quality, safety, and efficacy of vaccines throughout the whole supply chain, spanning from production to the final recipient. The provision of comprehensive guidelines and recommendations by the World Health Organization (WHO) serves to encourage the implementation of these practices, with the ultimate goal of establishing a global framework for the management of vaccines (Yadav & Kumar, 2023). One of the primary elements of vaccination management techniques involves the process of receiving and inspecting vaccines. Ensuring the integrity and temperature of the shipment is of utmost importance. The procedures suggested by the World Health Organization (WHO) place emphasis on the inspection of vaccine shipments upon arrival. This inspection aims to verify whether the vaccinations have been kept and transported in accordance with the acceptable temperature range, which normally ranges from +2°C to +8°C. In order to accomplish this, vaccines are outfitted with Vaccine Vial Monitors (VVMs) - labels containing heat-sensitive substances that undergo color changes

upon exposure to inappropriate environmental conditions. It is imperative to conduct inspections on the Vaccine Vial Monitors (VVMs) in order to verify their indication of the continued viability of the vaccines.

According to Manupati et al., (2021), after the receipt and inspection process, it is crucial to prioritize the maintenance of appropriate storage conditions. According to the rules set forth by the World Health Organization (WHO), it is stipulated that vaccines must be stored in refrigeration units that adhere to international standards for maintaining optimal temperature control (World Health Organization, 2021). It is imperative for these refrigerators to possess uninterrupted power supply as well as contingency systems in order to sustain the necessary temperature range. The regular monitoring and recording of temperatures are of utmost importance. It is recommended that refrigerators be equipped with temperature alarms, and regular monitoring of temperatures should be conducted to ensure the maintenance of appropriate conditions for vaccines. When faced with temperature fluctuations, it is crucial to implement suitable remedial actions in order to ensure the preservation of vaccination potency. In addition, it is important to note that vaccination management standards encompass the transportation of vaccines. Ensuring the preservation of the cold chain is crucial throughout the entirety of the shipping procedure. The World Health Organization (WHO) underscores the importance of employing temperature-controlled transportation methods, such as vaccine carriers equipped with ice packs, cold boxes, or refrigerated trucks, based on the unique demands of the vaccine being delivered (World Health Organization, 2021). It is imperative to maintain the efficacy of vaccines by preventing exposure to temperature variations during transportation.

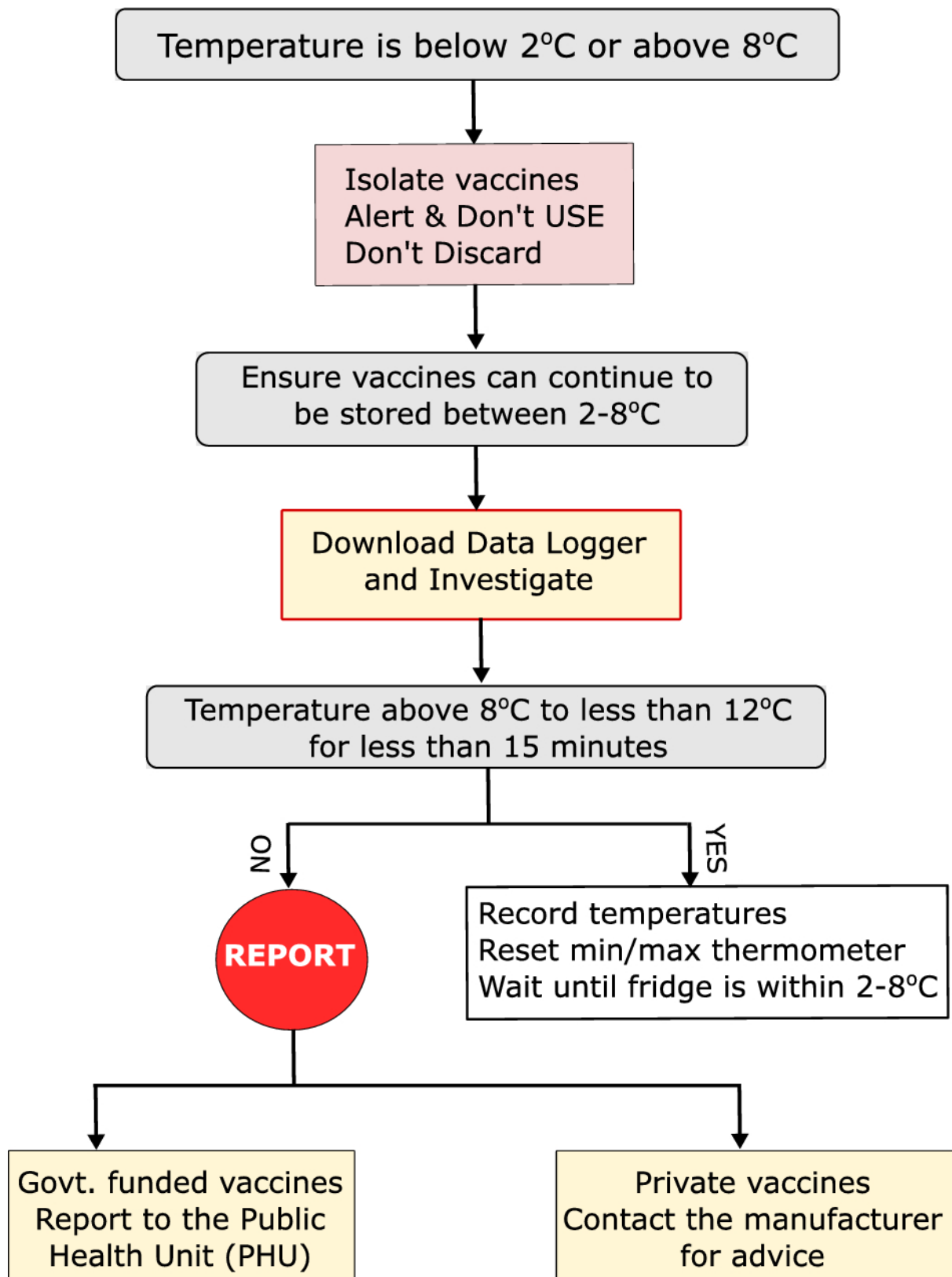


Figure 7: A reliable vaccine tracking and monitoring system for health clinics using blockchain

According to Kisaka & Tumwebaze, (2023), the concept of "First Expired, First Out" (FEFO) constitutes a substantial component of vaccine management strategies. The aforementioned principle stipulates that vaccinations have to be administered in the sequence they are obtained, with the aim of reducing wastage and preserving the effectiveness of the vaccines (Kisaka & Tumwebaze, 2023). The attainment of efficient stock management entails the meticulous monitoring of stock levels, adherence to appropriate stock rotation protocols, and the prevention of stockouts. The utilization of stock cards and ledgers for the purpose of monitoring stock movement and guaranteeing sufficient supply is a basic aspect of the First Expired, First Out (FEFO) principles. The implementation of a minimum-maximum stock system is an integral aspect of achieving efficient inventory management (Kisaka & Tumwebaze, 2023). This strategy guarantees the maintenance of a minimum stock of vaccinations to fulfill immediate demand, while also preventing excessive inventory and reducing the likelihood of vaccine wastage resulting from expiration. Accurate prediction, grounded in analysis of consumption patterns and vaccine demands, is crucial for the successful implementation of this strategy. The notion of "zero tolerance" regarding vaccine wastage represents a significant element within vaccination management methods. The World Health Organization (WHO) emphasizes the importance of minimizing vaccine waste to the greatest extent possible (Kisaka & Tumwebaze, 2023). There are other factors that can contribute to its occurrence, including exposure to inappropriate temperatures, administrative errors, or vaccine expiration. In order to attain a state of zero tolerance, it is imperative to adopt a holistic strategy that encompasses meticulous vaccine storage, effective stock management, and prompt utilization. The implementation of staff training is crucial in mitigating wastage by ensuring appropriate handling and administrative practices.

The concept of quality assurance is a prevalent and recurring topic within the realm of vaccination management procedures. The standards established by the World Health

Organizations emphasize the significance of upholding the quality, safety, and efficacy of vaccines (World Health Organization, 2008). This pertains to the protection of vaccinations against light, sunlight, and other unfavorable environmental factors. In addition, it necessitates rigorous compliance with the manufacturer's rules and recommendations pertaining to the management of vaccines. Documentation and record-keeping are essential components of vaccination management protocols (World Health Organization, 2008). Accurate and comprehensive documentation is of utmost importance in order to facilitate efficient monitoring, assessment, and accountability processes. The aforementioned documents encompass Vaccine Arrival Reports (VARs), temperature monitoring logs, stock ledgers, and immunization records. It is imperative to have a complete information system that effectively facilitates the collection, management, and accurate reporting of data.

According to Maurice & Davey, (2009), furthermore, the implementation of appropriate documentation plays a crucial role in guaranteeing the traceability of the vaccine. In the event of complications arising from a particular batch of vaccines, the utilization of records becomes crucial in tracking the dissemination and application of these vaccines. This facilitates the implementation of focused interventions and recalls, if deemed required. In addition to the operational components, managerial functions assume a pivotal role in the management of vaccines (Maurice & Davey, 2009). It is imperative to assign certain individuals who will have the responsibility of managing and directing the management of vaccines. These designated professionals will be tasked with ensuring that all operational duties related to vaccine management are executed accurately and with optimal efficiency. Potential positions within this context could encompass Vaccine Store Managers, Cold Chain Supervisors, and Immunization Program Managers. Training and capacity building are integral components of managerial activities. It is imperative that personnel receive comprehensive training in vaccine management, adhering to training programs endorsed by the World Health Organization

(WHO). The onus lies with management to ensure that personnel are sufficiently trained and equipped to effectively and securely handle vaccines.

The management of vaccines also includes the evaluation of performance and the ongoing pursuit of improvement. It is imperative to conduct regular assessments in order to evaluate the performance of vaccine management, identify areas that necessitate improvement, and subsequently adopt appropriate corrective measures (Maurice & Davey, 2009). This entails the implementation of routine internal audits and the pursuit of external assistance or validation when deemed appropriate. The significance of information systems and data management in the context of vaccine management techniques cannot be overstated. Efficient data collection, monitoring, and reporting should be facilitated by these technologies (Maurice & Davey, 2009). The analysis of data is essential for the evaluation of several factors related to vaccine consumption, stock levels, temperature management, and waste. Based on the findings of this investigation, it is possible to make well-informed judgments aimed at enhancing vaccine management.

The initial and pivotal task in vaccination management involves the reception and examination of vaccines. The establishment of a robust framework is crucial in guaranteeing the integrity of vaccines, by safeguarding them from potential detrimental circumstances during their transportation and verifying their suitability for administration. This stage involves the verification of the shipment's integrity and the evaluation of the temperature of vaccines upon their arrival. Vaccine Vial Monitors (VVMs), which consist of labels containing heat-sensitive material, assume a crucial function in this context. The Vaccine Vial Monitors (VVMs) undergo a color shift when vaccines have been subjected to inappropriate environmental conditions (Eriksson et al., 2017). Thorough examination guarantees the viability of vaccinations, thereby enabling the timely identification and reporting of compromised shipments.

After the receipt and inspection of vaccines, the subsequent crucial step is ensuring appropriate storage conditions. According to World Health Organization, (2006), vaccines exhibit a high degree of sensitivity to variations in temperature, and even little variances have the potential to compromise their efficacy. The guidelines issued by the World Health Organization (WHO) place significant emphasis on the storage of vaccines in refrigeration units that adhere to international norms for temperature regulation, often falling within the range of +2°C to +8°C. It is imperative for these freezers to possess an uninterrupted power supply, accompanied by contingency measures to ensure the maintenance of the necessary temperature range (World Health Organization, 2006). Regular temperature monitoring is essential, and refrigerators ought to be equipped with temperature alarms. The preservation of the vaccine's potency is contingent upon the implementation of appropriate storage conditions.

Equipment	Temperature	Storage Capacity	Holdover time
Electrical			
Deep Freezer (Large)	-15°C to -25°C	Ice packs or OPV stock for 3 months (275 to 300 Litres)	At 43°C for 2 hrs 30 mins (minimum)
ILR (Large)	+2°C to +8°C	BCG, OPV, IPV, RVV, DPT, TT, Measles/MR, Hep-B, Penta, IPV, Vaccine stock for 3 months (135 to 160 litres)	At 43°C for 20 hrs (minimum)
Deep Freezer (Small)	-15°C to -25°C	Ice packs (105 to 125 litres)	At 43°C for 2 hrs 30 mins (minimum)
ILR (Small)	+2°C to +8°C	BCG, OPV, IPV, RVV, DPT, TT, Measles/MR, Hep-B vaccine stocks for one month (90-105 litres)	At 43°C for 20 hrs (minimum)
Non-electrical			
Cold Box (Large)	+2°C to +8°C	All vaccines stored for transport or in case of power failure (20 to 25 litres)	At 43°C for 96 hrs (minimum)
Cold Box (Small)	+2°C to +8°C	All vaccines stored for transport or in case of power failure. (5 to 8 litres)	At 43°C for 48 hrs (minimum)
Vaccine carrier (1.7 litres)	+2°C to +8°C	All vaccines carried for 12 hours (4 conditioned Ice packs & 16-20 vials)	At 43°C for 36 Hrs (minimum)

Figure 8: Technical specifications of cold chain equipment

Vaccine management methods encompass the logistical aspects associated with the transportation of vaccines. The maintenance of the cold chain, which is responsible for preserving the necessary temperature conditions for vaccines, is of utmost importance during the transit process. The role involves the utilization of temperature-controlled transportation methods, such as vaccine carriers equipped with ice packs, cold boxes, or refrigerated vehicles, depending on the unique demands of the vaccine being transported. It is imperative to note that maintaining a stable temperature throughout the transportation of vaccinations is of utmost importance, since any variations in temperature can potentially compromise their effectiveness (World Health Organization, 2006). Efficient stock management plays a crucial role in the implementation of vaccination management techniques, and it is led by the principle known as "First Expired, First Out" (FEFO). The aforementioned principle stipulates that vaccines ought to be administered in the sequence they are acquired, with the intention of reducing unnecessary loss and preserving the efficacy of the vaccines. A crucial aspect of this role is meticulous monitoring of stock levels, adherence to appropriate stock rotation protocols, and prevention of stockouts (Magina, 2013). The utilization of stock cards and ledgers for the purpose of monitoring stock movement and guaranteeing a sufficient inventory is of paramount importance in facilitating the optimal functioning of the First Expired, First Out (FEFO) principle. Efficient vaccination distribution and administration rely heavily on the implementation of effective stock management practices.

Inventory management is a crucial operational aspect that is closely associated with the First Expired, First Out (FEFO) principle (Magina, 2013). The function incorporates the implementation of a minimum-maximum stock system, which guarantees the maintenance of a minimum stock level to fulfill immediate demand and a maximum stock level to prevent excessive inventory and the potential loss of vaccines due to expiration. Accurate prediction, grounded in analysis of consumption patterns and vaccination needs, is crucial for the

successful implementation of this strategy. An essential aspect of inventory management involves the diligent monitoring of stock levels, making appropriate adjustments to orders as required, and effectively mitigating the occurrence of stockouts or overstocking. Enforcing a "zero tolerance" approach towards vaccine waste is an additional essential responsibility. Vaccine wastage may arise from a range of factors, including inadequate temperature control, administrative oversights, or expiration of vaccine doses (Ghaemmaghmanian et al., 2022). The reduction of wastage necessitates the implementation of a complete strategy that encompasses meticulous vaccine storage, effective stock management, and timely utilization. This integral function is in line with the purpose of conserving expensive vaccination supplies and ensuring broader accessibility to the protection they provide.

The maintenance of vaccine quality, safety, and potency is a crucial aspect of vaccination management protocols (Ghaemmaghmanian et al., 2022). The important purpose of this process involves implementing measures to protect vaccines from potential degradation caused by exposure to light, sunlight, and other unfavorable environmental factors that may undermine their overall quality. Additionally, it necessitates rigorous compliance with the manufacturer's rules and recommendations pertaining to the management of vaccines. Adhering to these criteria is crucial in order to maintain the efficacy and safety of vaccines. The establishment and maintenance of comprehensive documentation and record-keeping systems are integral components of vaccine management protocols. A fundamental aspect of this duty involves the diligent upkeep of precise and all-encompassing records, which play a vital role in facilitating efficient monitoring, evaluation, and responsibility. The aforementioned documents encompass Vaccine Arrival Reports (VARs), temperature monitoring logs, stock ledgers, and immunization records (Gedi, 2022). It is imperative to have a complete information system to guarantee the accurate collection, management, and reporting of data. The implementation of appropriate documentation facilitates the capacity to trace

vaccinations, hence playing a critical role in addressing potential concerns associated with a particular batch of vaccines. In addition to the operational aspects, the inclusion of managerial duties is crucial for the successful implementation of vaccine management techniques.

These measures encompass the appointment of accountable individuals, such as Vaccine Store Managers, Cold Chain Supervisors, and Immunization Program Managers, who are responsible for overseeing and organizing vaccine management (Gedi, 2022). The primary responsibility of these individuals is to ensure the accurate and efficient execution of all operational duties. Staff training is a crucial component of managerial functions, as it guarantees that individuals receive sufficient training and possess the necessary skills to handle vaccinations in a safe and efficient manner. Adequate training plays a crucial role in minimizing errors and ensuring accurate administration of vaccines. Periodic evaluations constitute a fundamental component of vaccination management protocols. These assessments provide the evaluation of vaccine management performance, the identification of areas necessitating improvement, and the implementation of corrective measures (Lloyd & Cheyne, 2017). This entails the performance of routine internal audits and the pursuit of external assistance or validation when deemed essential. Data analysis is a crucial component of performance assessment as it offers valuable insights into several aspects such as vaccine consumption, stock levels, temperature control, and wastage. Based on the aforementioned study, it is possible to make educated judgments in order to consistently enhance vaccine management procedures (Lloyd & Cheyne, 2017). The proper management of vaccines relies heavily on the utilization of information technology and data management techniques. These systems ought to facilitate the effective gathering, monitoring, and reporting of data. The analysis of data is a crucial component of this role, as it provides valuable insights for decision-making and contributes to the maintenance of efficient and effective vaccine management (Lloyd & Cheyne, 2017). The utilization, stock levels, temperature management, and wastage of vaccines can be effectively

evaluated through the analysis of data. Information systems that are robust in nature play a crucial role in providing real-time data, which is of utmost importance in facilitating prompt adjustments to the processes involved in vaccination management.

2.3. Vaccine Vial Monitors (VVMs)

According to Kartoglu et al., (2020), vaccine Vial Monitors (VVMs) are indispensable instruments in the field of vaccine management, providing a crucial function in maintaining the integrity, safety, and effectiveness of vaccines from their production stage until their delivery to individuals. The aforementioned labels demonstrate the progress made in ensuring the quality of vaccines and play a crucial role in the worldwide immunization plan. This section will explore the importance of VVMs and their crucial function in safeguarding the desired effectiveness and dependability of vaccinations (Kartoglu et al., 2020). Vaccinations represent a very efficacious measure in the realm of public health, effectively mitigating the occurrence of numerous fatalities each year through safeguarding persons from a range of infectious ailments. Nevertheless, these vital biological products exhibit a high degree of sensitivity to environmental variables, including fluctuations in temperature. In order to preserve their integrity and optimize their efficacy, vaccines necessitate meticulous storage and handling procedures, wherein temperature assumes a pivotal role. Any deviations from these specified circumstances have the potential to undermine the efficacy and safety of the vaccination, resulting in its ineffectiveness or potential injury (Kartoglu et al., 2020). This matter is particularly relevant in areas characterized by low availability of reliable refrigeration or unstable electricity, where the cold chain, which guarantees the appropriate temperature maintenance of vaccinations, may be susceptible.

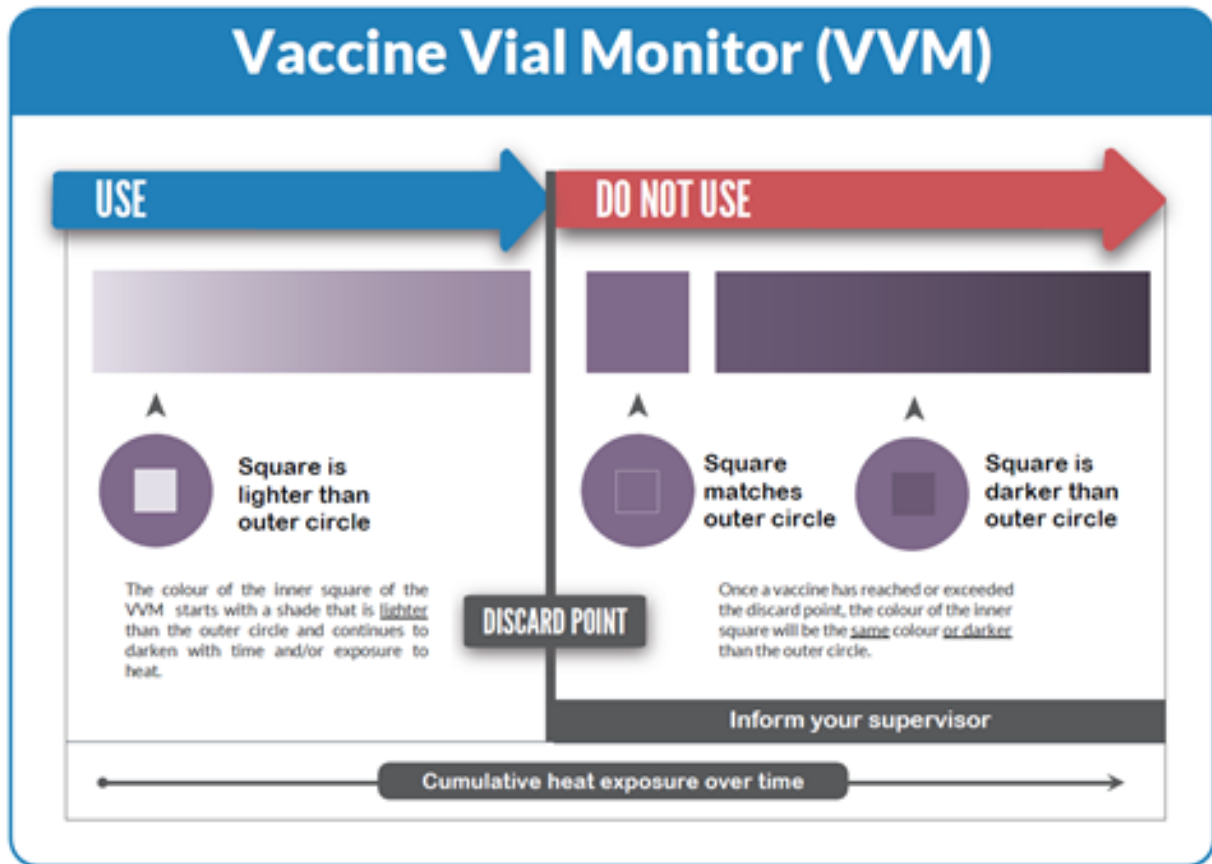


Figure 9: Vaccine vial monitor (VVM)

Vaccine Vial Monitors (VVMs) are utilized in this context. Vaccine Vial Monitors (VVMs) are adhesive labels that are applied to vaccine vials. Their principal purpose is to visually indicate the cumulative heat exposure that a vaccine has undergone. The vaccines are specifically engineered to undergo a color change in response to elevated temperatures, so functioning as a conspicuous and readily understandable indicator that the vaccine's safety and efficacy may have been compromised (Kartoglu & Ames, 2022). The concept is characterized by its remarkable simplicity, which is accompanied with a profound level of effectiveness. Virtual Voting Machines (VVMs) represent a remarkable technological advancement due to their ability to operate without the need for external power sources, intricate machinery, or specific expertise for interpretation (Kartoglu & Ames, 2022). These devices have the potential to be utilized in various contexts, encompassing remote and resource-constrained regions

where the availability of advanced monitoring apparatus may be limited. The inherent simplicity of VVMs confers a significant advantage, since it enables healthcare professionals, who frequently operate in demanding environments, to readily ascertain the safety of a vaccination prior to administration. When a healthcare professional observes a change in color of the vaccination Vial Monitor (VVM) affixed to a vaccination vial, they are aware that it is necessary to dispose of the vial and refrain from administering its contents to patients.

According to Kartoglu & Ames, (2022), the unambiguous and non-verbal communication of risk is a key factor contributing to the efficacy of VVMs. This aspect holds significant importance in areas characterized by linguistic diversity and varying levels of literacy. Voting Verification Machines (VVMs) have the ability to overcome language and educational obstacles by effectively communicating a message through the use of color alteration. As an illustration, a vaccine vial that possesses an undamaged Vaccine Vial Monitor (VVM) may have a green coloration, so signifying the vaccine's suitability for administration (Kartoglu & Ames, 2022). On the contrary, when the VVM exhibits an alternative hue, such as red, it functions as a definitive cautionary signal indicating that the vaccine has encountered elevated temperatures and must not be utilized. The inherent simplicity and widespread use of VVMs render them an indispensable instrument in the context of immunization procedures. The provision of essential information to healthcare professionals enables them to make crucial determinations regarding the safety of vaccines, especially in contexts where resources are scarce and conditions are demanding. The implications of this discovery are extensive, especially in areas where ensuring a stable cold chain for vaccinations might present significant challenges. Moreover, the incorporation of VVMs is in accordance with the ideals of justice and accessibility within the healthcare domain (Kartoglu & Ames, 2022). This measure guarantees that individuals who are most susceptible and marginalized, typically dwelling in geographically isolated regions with little healthcare facilities, are able to obtain safe and

efficacious vaccines. In this particular context, the VVM technology serves as a safeguard for public health by extending its reach to populations that may face exclusion from crucial immunization initiatives due to logistical obstacles or inadequate storage conditions.



Vaccine	Exposure to heat/light	Exposure to cold
Heat and light sensitive vaccines		
OPV	Sensitive to heat	Not damaged by freezing
Measles/MR	Sensitive to heat and light	Not damaged by freezing
BCG, RVV and JE	Relatively heat stable, but sensitive to light	Not damaged by freezing.
Freeze sensitive vaccines		
HepB/Penta/PCV	Relatively heat stable	Freezes at -0.5°C (Should not be frozen)
IPV, DPT and TT	Relatively heat stable	Freezes at -3°C (Should not be frozen)
At the PHC level, all vaccines are kept in the ILR for a period of one month at temperature of +2°C to +8°C		
Vaccines sensitive to heat		Vaccines sensitive to freezing
<ul style="list-style-type: none"> ■ BCG (after reconstitution) ■ OPV, Rota ■ IPV ■ MR ■ Rotavirus ■ JE ■ DPT ■ BCG (before reconstitution) ■ TT, ■ Penta, HepB, PCV 	<p>Most sensitive</p>  <p>Least sensitive</p>	<ul style="list-style-type: none"> ■ HepB ■ PCV ■ Penta ■ IPV ■ DPT ■ TT <p>Most sensitive</p>  <p>Least sensitive</p>

Figure 10: Sensitivity of vaccines to heat, light and freezing

It is worth mentioning that VVMs have received endorsement and recommendation from the World Health Organization (WHO), an authoritative body responsible for establishing global standards and guidelines pertaining to vaccine management and vaccination protocols. The World Health Organization (WHO) acknowledges the importance of Vaccine Vial Monitors (VVMs) in the management of vaccinations, emphasizing their role in safeguarding

the quality of vaccines and reducing the likelihood of giving vaccines that may be ineffective or pose possible danger. Vaccine Vial Monitors (VVMs) have played a crucial role in addressing the issue of vaccine wastage, which is a prominent concern within the field of vaccine management. Through the provision of a distinct visual manifestation of heat exposure, the utilization of such indicators serves to diminish the probability of employing vaccine vials that have surpassed their safety threshold. Consequently, this practice effectively mitigates the necessity of discarding vaccine doses that possess significant value. This phenomenon, in turn, enhances the cost-effectiveness of immunization programs and guarantees broader vaccine coverage, particularly in settings with limited resources. An additional salient factor pertaining to Vaccine Vial Monitors (VVMs) is their contribution towards fostering confidence in vaccines and the overall immunization procedure. The issue of vaccine hesitancy is an increasingly prevalent global concern, with apprehensions regarding vaccine safety being a prominent factor influencing individuals' reluctance to receive vaccinations. The presence and conspicuous utilization of Vaccine Vial Monitors (VVMs) can function as a visual confirmation for communities that vaccinations are being handled with great caution and are delivered exclusively when they satisfy rigorous safety and quality criteria. This measure has the potential to enhance public trust in vaccination initiatives and thus lead to increased rates of vaccine coverage.

In order to have a comprehensive understanding of the essential operation of Vaccine Vial Monitors (VVMs) in the monitoring of cumulative heat exposure, it is imperative to delve into the scientific principles that underlie their functionality. Vaccine Vial Monitors (VVMs) are intelligently crafted indicators affixed to vaccine vials, for the purpose of visually signaling whether a vaccine has been subjected to high heat, thereby potentially jeopardizing its quality, safety, and effectiveness. The color-changing technology utilized in this context is founded upon several fundamental principles, rendering it a dependable and easily accessible instrument

within the realm of vaccine management. The fundamental principle that forms the basis of VVMs is the reaction of a thermally sensitive substance to the accumulation of thermal energy (Ashok et al., 2017). The monitors are fitted with an ink or dye that has been particularly developed to exhibit a color shift in response to variations in both time and temperature. This response is directly associated with the total amount of heat exposure encountered by the vaccine vial.

The core component of VVM technology is a heat-responsive element, consisting mostly of a thermosensitive chemical or pigment. The selection and engineering of this element are performed in such a manner that its response aligns with the degradation process experienced by vaccines when subjected to prolonged durations of hot temperatures. The degradation of the vaccine might arise from various factors, such as the deterioration of its structural integrity, alterations in its chemical composition, or the denaturation of proteins (World Health Organization. (2006). Vaccine vial monitors (VVMs) are intricately crafted to accurately reflect the degradation process, so guaranteeing that any detrimental heat exposure to a vaccine vial will be shown by a corresponding change in color of the VVM. The operational mechanism of VVMs is intricately linked to Arrhenius' equation, a widely recognized notion in the field of chemical kinetics (Ashok et al., 2017). The aforementioned equation elucidates the correlation between temperature and the kinetics of chemical reactions. According to the provided information, it is indicated that the rate of a chemical reaction exhibits an exponential increase in response to changes in temperature. Within the realm of vaccines, it may be inferred that an increase in the temperature of a vaccine vial can expedite any degradation processes it may undergo. Volumetric vapor-mediated materials (VVMs) utilize this fundamental principle to offer a distinct visual representation of thermal exposure.

The heat-sensitive component present in Vaccine Vial Monitors (VVMs) is meticulously adjusted to maintain its stability when exposed to temperatures falling within the

specified storage range for the vaccine (World Health Organization, 2006). The temperature range in question generally aligns with the conditions necessary for the vaccination to maintain its stability and efficacy. Nevertheless, in instances where the temperature of the vial surpasses this designated range, the heat-sensitive component experiences heightened instability, resulting in a commencement of chemical reactions and subsequently manifesting as a discernible alteration in hue. In practical terms, this is the operational mechanism of VVMs: When a vaccine vial is subjected to temperatures that fall outside the prescribed storage range, the heat-reactive component within the Vaccine Vial Monitor (VVM) initiates a response. The rate at which the color changes is intentionally calibrated to correspond with the level of accumulated heat exposure, so ensuring that the modification in color serves as a dependable indicator of potential compromise in the vaccine.



Figure 11: Storing vaccines in ILR

According to Ghaemmaghamian et al., (2021), as an illustration, a visual vaccination monitor (VVM) has the potential to provide a green coloration when the vaccine remains within the designated temperature range for safe storage. As the ambient temperature rises, the Visual Temperature Monitoring (VVM) system undergoes a chromatic transition, often progressing from a green hue to a yellowish shade, and ultimately to a red coloration. This sequence of events can be likened to a cautionary mechanism, indicating that the vaccine has been subjected to temperatures that may cause harm, so rendering it unsuitable for further use (Ghaemmaghamian et al., 2021). The VVMs exhibit a notable strength in their visual simplicity. Healthcare professionals do not necessitate any specialized training for the interpretation of color changes; their knowledge should be limited to recognizing that the color green signifies a safe vaccine, whilst any other color denotes a potential risk. This universally applicable and easily comprehensible methodology empowers healthcare professionals to promptly assess the efficacy of vaccines, without relying on intricate apparatus or substantial scientific expertise.

According to Yaqub, (2017), moreover, VVMs are purposefully engineered to consider the accumulation of heat exposure rather than solely focusing on momentary temperature swings. This implies that the Vaccine Vial Monitor (VVM) will accurately indicate the overall effect of multiple instances of increased temperature, even if they are of short duration. The observed phenomenon of the gradual change in color in the Vaccine Vial Monitor (VVM) can be attributed to the duration of exposure of the vaccine to higher temperatures, as well as the extent to which this exposure deviates from the specified storage conditions (Ghaemmaghamian et al., 2021). The degree of color alteration exhibits a direct correlation with the potential impact on the efficacy of the vaccine. The consideration of cumulative heat exposure is a crucial element in the context of Vaccine Vial Monitors (VVMs), as it corresponds to the practical difficulties encountered in the storage and transportation of vaccines. In

numerous geographical areas, the lack of reliable access to refrigeration, occurrences of power outages, and logistical challenges might give rise to circumstances wherein vaccines are susceptible to temperature changes. Vaccine vial monitors (VVMs) offer a more precise evaluation of risk by measuring the cumulative heat exposure, thereby considering the dynamic conditions under which vaccines are managed.

2.3.1.VVM Types and Vaccine Stability

Vaccine Vial Monitors (VVMs) are available in several configurations, each designed to cater to distinct vaccines and their respective stability prerequisites (Creati et al., 2007). The various varieties of Vaccine Vial Monitors (VVMs) play a crucial role in ensuring the effectiveness and safety of vaccinations. In order to comprehend their relevance, it is imperative to examine the divergences in Vaccine Vial Monitors (VVMs) and their congruence with the stability prerequisites of different vaccines.

Type 1 Vaccine Vial Monitors

Type 1 Vaccine Vial Monitors (VVMs) are specifically engineered for vaccines that possess a high degree of stability, even when subjected to suboptimal storage conditions (Creati et al., 2007). These vaccinations have the ability to endure a specific degree of heat exposure without experiencing substantial deterioration. An example of this would be vaccinations that necessitate storage within the temperature range of 2°C to 8°C, a commonly adopted guideline for numerous routine immunization initiatives. The Type 1 Vaccine Vial Monitors (VVMs) are designed to exhibit this stability, typically maintaining a green color for a longer duration. They shift to a more responsive stage, such as yellow, only after being exposed to elevated temperatures for a protracted period.

Type 2 Vaccine Vial Monitors

Vaccines exhibiting heightened sensitivity to heat and necessitating more stringent temperature regulation are commonly linked to Type 2 Vaccine Vial Monitors (VVMs). The

VVMs have been designed with enhanced sensitivity to temperature fluctuations, enabling them to detect signs of heat damage at an earlier stage (Creati et al., 2007). Under identical conditions as Type 1 VVMs, it is possible for them to undergo an earlier transition to a warning color, such as yellow. The purpose of this communication is to notify healthcare professionals that these vaccines carry an elevated risk of degradation as a result of heat exposure, potentially rendering them unsuitable for administration.

Types 3 Vaccine Vial Monitors

According to Kartoglu & Milstien, (2014), type 3 vaccine vial monitors (VVMs) are linked to vaccines that exhibit high sensitivity to heat and necessitate stringent storage and handling protocols. The efficacy of these vaccines can be compromised by brief exposures to temperatures that deviate from their recommended range. Type 3 Vaccine Vial Monitors (VVMs) are designed with a high degree of sensitivity to fluctuations in temperature. They exhibit rapid color changes, promptly shifting to an alerting hue whenever there is a departure from the prescribed storage settings (Kartoglu & Milstien, 2014). The swift transition to a color indicative of caution, typically red, functions as a potent advisory against the use of vaccines that have been subjected to elevated temperatures, so signifying a noteworthy likelihood of diminished effectiveness.

The careful choice of the suitable Vaccine Vial Monitor (VVM) type is of utmost importance as it corresponds to the precise temperature stability attributes of the vaccine (Kartoglu & Milstien, 2014). This guarantees that the vaccination Vial Monitor (VVM) offers a precise depiction of the risk linked to the vaccination when subjected to higher temperatures. Furthermore, it is crucial to acknowledge that the utilization of Vaccine Vial Monitors (VVMs) extends beyond the mere process of vaccine selection. The vaccine's trajectory encompasses various stages, spanning from its production by the producer to its subsequent administration at healthcare facilities (Kartoglu & Milstien, 2014). This holds special significance for vaccines

that exhibit sensitivity to temperature fluctuations, since their efficacy can be compromised by exposure to elevated temperatures at any stage of the transportation process. Therefore, Vaccine Vial Monitors (VVMs) have emerged as a crucial instrument in preserving the integrity of the cold chain for vaccines.

Vaccine Vial Monitors (VVMs) provide the capability to be customized and integrated onto vaccine vial labels or packaging materials in order to align with the preferences of vaccine manufacturers and program administrators. The readability of these texts remains consistent, even when subjected to different lighting conditions, so ensuring their accessibility to healthcare professionals across diverse locations. Vaccine vial monitors (VVMs) can be utilized in tandem with additional temperature-monitoring instruments, including data loggers and temperature indicators, to offer a comprehensive understanding of the environmental conditions to which vaccines have been exposed. The advantages of matching Vaccine Vial Monitor (VVM) types with vaccine stability become apparent when considering the wide range of immunization programs that are implemented globally. Certain vaccines, such as those targeting tetanus or diphtheria, exhibit remarkable stability, rendering Type 1 Vaccine Vial Monitors (VVMs) appropriate for their storage and monitoring. The visual vaccination monitors (VVMs) have the ability to sustain their green coloration for prolonged durations, thereby corresponding to the extended shelf life of the vaccines they accompany.

In contrast, vaccinations such as the oral polio vaccine, which are susceptible to heat, necessitate the use of Type 3 Vaccine Vial Monitors (VVMs) that rapidly transition to the red warning stage, indicating their sensitivity to temperature variations. The selection of an appropriate Vaccine Vial Monitor (VVM) type is not solely a matter of convenience, but rather a crucial element in guaranteeing the effectiveness of the vaccine and the triumph of vaccination endeavors. The appropriate utilization of Vaccine Vial Monitors (VVMs) reduces the likelihood of giving vaccinations that have been compromised, hence protecting public

health and upholding the confidence of healthcare professionals and the populations they serve. The potential ramifications of an erroneous assessment of vaccine stability, as evidenced by the Vaccine Vial Monitor (VVM), can be significant. The administration of a vaccine that has been subjected to elevated temperatures may lead to a misleading perception of immunity, pose a risk to public health, and undermine trust in immunization initiatives. The selection of Vaccine Vial Monitor (VVM) type has significant implications for vaccine makers and distributors within a wider framework. It exerts an impact on the logistics of the supply chain, necessitates certain storage needs, and determines the techniques employed for distribution. Selecting the appropriate Vaccine Vial Management (VVM) type is crucial in promoting effective vaccine management protocols, hence minimizing unnecessary wastage and expediting the prompt distribution of vaccines to their designated users. Furthermore, the utilization of Vaccine Vial Monitors (VVMs) aids in the mitigation of expenses related to the distribution of vaccines. This is due to the fact that vaccines can be transported under less strict temperature control measures provided the VVMs are in accordance with the vaccine's inherent stability properties.

2.3.1.1. Vaccine Vial Monitors (VVMs) and Their Role in Identifying Vaccine Stability and Suitability for Use

According to Eriksson et al., (2017), vaccine Vial Monitors (VVMs) play a crucial role in the domain of vaccine management by facilitating the evaluation of vaccine stability and ascertaining their appropriateness for utilization. The primary objective of Vaccine Vial Monitors (VVMs) is to function as visual indicators, furnishing healthcare professionals with significant data pertaining to the safety and effectiveness of vaccines. These straightforward yet efficient gadgets provide valuable information regarding the total heat exposure encountered by vaccines, so enabling healthcare professionals to make well-informed judgments regarding their viability (Eriksson et al., 2017). Vaccine vial monitors (VVMs) play

a crucial role in assessing vaccine durability by monitoring the temperature conditions to which a vaccine has been subjected.

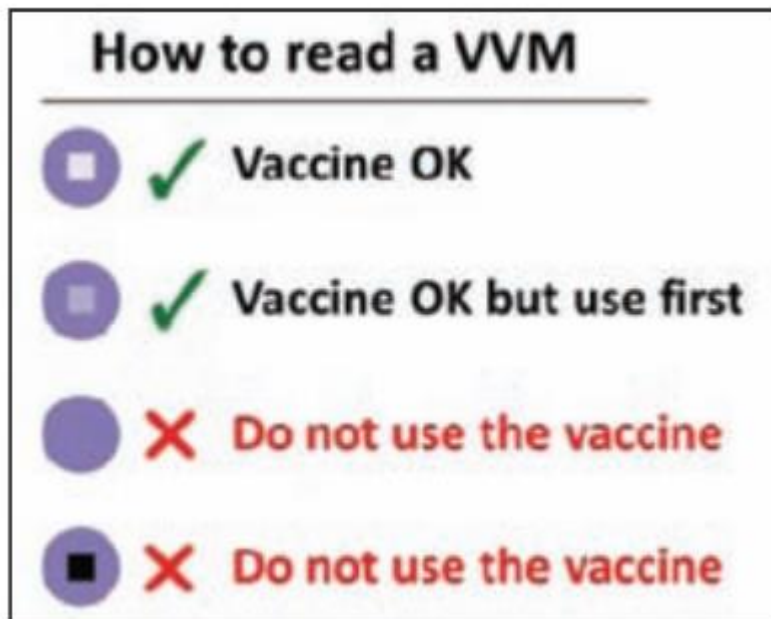


Figure 12: Different stages of vaccine vial monitor

The preservation of potency for numerous vaccinations necessitates the maintenance of a specified temperature range. The exposure of vaccines to high temperatures might result in denaturation, so compromising their efficacy. Vending machine monitors (VVMs) mitigate this issue by undergoing a color change when subjected to extended periods of inadequate temperatures (Eriksson et al., 2017). In this manner, they function as indicators akin to traffic lights for vaccines, wherein varying color transitions are employed to denote the extent of heat-induced impairment and the stability of the vaccine.

According to Zweig, (2006), the presence of the green stage on a Vaccine Vial Monitor (VVM) serves as a reliable indicator of the stability of a vaccine. The color in question is commonly observed when the vaccine has been stored within the prescribed temperature range, so providing healthcare professionals with the assurance that the vaccine retains its potency and is appropriate for administration. The administration of the vaccine instills trust in the attainment of its targeted protective efficacy among patients (Zweig, 2006). The significance

of this matter cannot be overstated, as the administration of vaccinations plays a crucial role in the prevention and management of several diseases. Any compromise in the stability of vaccines can have a profound influence on the overall well-being of the general population. Nevertheless, the efficacy of VVMs extends beyond the preliminary phase of environmental sustainability. Vaccine vial monitors (VVMs) exhibit corresponding responses as they are exposed to increasingly elevated temperatures or varying temperature conditions. When the vaccine is subjected to temperatures that deviate significantly from the permitted range, the Vaccine Vial Monitor (VVM) undergoes a transition to a yellow stage, indicating that the vaccine is usable but requires careful handling and administration (Zweig, 2006). The presence of a yellow stage serves as a crucial indicator for healthcare professionals, signifying that the stability of the vaccination is compromised. In such cases, it is advisable for healthcare workers to explore alternate options that offer greater suitability. The transitional period plays a critical role in safeguarding the efficacy of the vaccinations that are being delivered.

According to Kartoglu & Ames, (2022), in situations characterized by prolonged exposure to high temperatures, resulting in significant degradation of the vaccine's integrity, the Vaccine Vial Monitor (VVM) progresses to a red stage. This observation suggests that the utilization of the vaccination may be contraindicated due to its potential diminished efficacy in conferring the anticipated level of protection. The red stage serves as a forceful disincentive for healthcare staff, effectively notifying them of the potential shortcomings of the vaccine since a result, Vaccine Vial Monitors (VVMs) serve the purpose of preventing the unintentional administration of vaccines that may not only lack efficacy but also have negative effects on the health of patients, since they have the potential to provide a misleading perception of protection.

The progressive color change mechanism exhibited by Vaccine Vial Monitors (VVMs) is closely correlated with the stability characteristics of various vaccines. The diverse

sensitivity of Vaccine Vial Monitors (VVMs) enables them to adjust according to the precise temperature needs of the vaccines they are paired with (Kartoglu & Ames, 2022). Type 1 Vaccine Vial Monitors (VVMs) are employed for vaccines that possess enhanced heat tolerance. These VVMs exhibit a prolonged transition period from green to yellow, indicating the vaccine's capacity to endure suboptimal environmental conditions to some extent. On the other hand, vaccinations that have poorer resistance to heat, such as specific live attenuated vaccines, utilize Type 2 or Type 3 Vaccine Vial Monitors (VVMs). The VVMs exhibit a higher rate of transition to the yellow and red stages, respectively, which suggests that the vaccine is susceptible to temperature variations.

In addition to the surveillance of overall heat exposure, Vaccine Vial Monitors (VVMs) also function as an instructional resource for healthcare professionals (Kartoglu & Ames, 2022). The provision of a concise and visually illustrative depiction of a vaccine's condition allows healthcare practitioners to comprehend the potential consequences of temperature deviations on the stability of the vaccination. This enables individuals to make well-informed judgments on the usability of vaccines and to take appropriate measures, such as maintaining the cold chain or opting for alternative vaccines when required. The accessibility of VVMs in diverse healthcare settings, especially those with little resources, is attributed to their simplicity and universality. These gadgets possess an intuitive interface and necessitate only a small amount of training (Kartoglu & Ames, 2022). Consequently, healthcare practitioners in rural or underserved regions can proficiently employ these tools to evaluate the stability of vaccines. The enhanced accessibility of vaccines plays a crucial role in promoting equitable distribution and mitigating the potential risks associated with compromised immunization programs.

Moreover, it should be noted that Vaccine Vending Machines (VVMs) are not exclusively restricted to the dispensation of vaccines within healthcare institutions. These initiatives expand their utility to encompass immunization campaigns, outreach activities, and

mobile clinics (Kartoglu & Ames, 2022). In situations of this nature, vaccines may encounter a broader spectrum of environmental circumstances, hence amplifying the significance of Vaccine Vial Monitors (VVMs). The capacity to promptly assess the suitability of vaccines is crucial for guaranteeing the safe and efficient administration of immunizations in such contexts. Furthermore, Vaccine Vial Monitors (VVMs) contribute to the mitigation of vaccine wastage. Healthcare professionals can effectively manage vaccine inventory by promptly identifying the status of vaccinations and taking appropriate actions to replace or dispose of those that are no longer viable for administration (White & Lal, 2019). By adopting this approach, not only are valuable vaccine supplies conserved, but also the potential risk of administering ineffective vaccines to patients is minimized.

2.4. Economic and Public Health Benefits of VVMs

The complex and significant benefits of Vaccine Vial Monitors (VVMs) encompass both economic and public health aspects. These modest yet influential indicators play a crucial role in the domain of vaccine management, making substantial contributions to the operational efficiency and overall success of vaccination programs on a global scale. The capacity to minimize vaccine wastage and uphold vaccine quality not only promotes the economic sustainability of immunization programs but also defends public health at a worldwide level (White & Lal, 2019). One of the key economic advantages associated with the utilization of VVMs is to their ability to effectively mitigate vaccine waste. The issue of vaccine wastage poses a notable concern within immunization programs, as it has the potential to incur considerable financial losses. The production and distribution of vaccines incur significant costs, and any doses that become worthless owing to heat exposure or other environmental variables result in a direct financial detriment. Vaccine vial monitors (VVMs) effectively mitigate this concern by offering a visually perceptible and unambiguous indication of a vaccine's condition, so enabling healthcare professionals to make well-informed judgments

regarding its suitability for use (Zweig, 2006). This implies that the likelihood of vaccines being unintentionally discarded is reduced. Immunization programs effectively conserve resources, minimize expenses, and optimize the return on expenditures in vaccine procurement by employing strategies that prevent premature disposal of vaccines.

Moreover, the utilization of Virtual Vending Machines (VVMs) leads to a decrease in operational expenditures. The ability of healthcare professionals to accurately evaluate the quality of a vaccine without the need for expensive temperature monitoring equipment or laboratory testing facilitates the efficiency of the immunization procedure (Zweig, 2006). The achieved efficiency leads to cost savings, as a reduced amount of resources is required for the management and quality control of vaccines. In resource-limited settings, where financial resources are generally limited, the cost reductions resulting from immunization programs can have a significant impact on their capacity to effectively target and serve vulnerable groups. Vaccination vial monitors (VVMs) additionally contribute to the prolongation of vaccination efficacy. The provision of a visual signal pertaining to the status of a vaccination serves to empower healthcare professionals in making informed decisions and undertaking suitable measures in instances when a vaccine may have been subjected to conditions that are less than optimal (Zweig, 2006). This process may entail the relocation of vaccinations to a refrigeration apparatus that maintains the appropriate temperature conditions, or the substitution of vaccines with suitable alternatives. In both scenarios, the vaccines retain their viability for an extended duration, so ensuring their utilization prior to expiration. This practice not only mitigates the potential for vaccine wastage but also enhances vaccine coverage, thereby safeguarding a larger population from vaccine-preventable illnesses.

According to Kartoglu et al., (2020), the economic advantages of VVMs have a worldwide reach. These metrics optimize the utilization of vaccines produced and delivered globally by minimizing vaccine wastage. Consequently, this guarantees the equitable

distribution of vaccines to the most vulnerable groups. In nations with limited resources, where the availability of vaccines is a crucial public health issue, each preserved dosage presents a possibility to save lives (Kartoglu et al., 2020). Vaccine vial monitors (VVMs) play a crucial role in promoting fair and just distribution of vaccines by effectively managing resources and enhancing accessibility to vaccination services in marginalized regions. In addition to their economic benefits, Vending Machine Vendors (VVMs) play a crucial role in ensuring the protection of public health. The interdependence between public health benefits and economic factors is evident, since the prevention of vaccine wastage and the assurance of vaccine quality have direct implications on the efficacy of immunization initiatives. When vaccines are subjected to elevated temperatures and experience a decline in their efficacy, they cease to offer the intended immunological safeguard against certain diseases. In instances of this nature, the administration of these compromised vaccinations has the potential to instill a misguided perception of safety within the vaccinated populace, so posing a risk to the overall well-being of the public.

Voter-verified paper audit trails (VVPATs) serve as a protective measure against the aforementioned risk. By employing color transitions to clearly indicate the condition of a vaccine, healthcare professionals are provided with the necessary information to make informed and responsible decisions regarding the usability of the vaccine (Kartoglu et al., 2020). This practice guarantees that only vaccines exhibiting complete efficacy are provided to individuals. The scope of this safeguard include newborns, children, and persons who are susceptible and rely on immunization as a means to maintain their physical health and overall welfare. Vaccine vial monitors (VVMs) play a critical role in safeguarding the potency of live attenuated vaccines, which are susceptible to diminished efficacy even under mild exposure to increased temperatures. Additionally, the public health advantages of VVMs are in line with the wider global health agenda. The contribution made by these entities is crucial in the

attainment of universal health care, a pivotal objective outlined in the Sustainable Development Goals (SDGs) (Kartoglu et al., 2020). The provision of high-quality healthcare, which encompasses immunization services, is a crucial component in attaining universal health coverage. The efficacy of immunization programs is intricately tied to the caliber of vaccines utilized. Vaccine vial monitors (VVMs) play a pivotal role in facilitating the achievement of this essential objective by safeguarding the potency and viability of vaccines.

The public health implications of Vaccine Vial Monitors (VVMs) also encompass the prevention of disease outbreaks. The insufficient temperature control of vaccinations poses a potential threat to the resurgence of vaccine-preventable diseases. Vaccine vial monitors (VVMs) serve to limit this risk by enabling healthcare professionals to identify vaccines that have exceeded their recommended storage conditions, thereby preventing the administration of vaccines that may have lost their efficacy. This holds special significance in areas where there is a high prevalence of infectious diseases or where there is a possibility for outbreaks to occur. Vaccine vial monitors (VVMs) contribute to the prevention and control of diseases by ensuring the preservation of vaccine quality. This, in turn, leads to the preservation of human lives and a decrease in the strain on healthcare systems. Furthermore, VVMs play a crucial role in fostering vaccine trust and promoting public adoption. The absence of discernible indicators regarding the quality of vaccine administration may potentially give rise to vaccine hesitancy, since individuals may harbor apprehensions regarding the safety and efficacy of immunization. Vaccine vial monitors (VVMs) play a crucial role in fostering trust in vaccination programs through their ability to enhance transparency and provide assurance regarding the quality of vaccines. Trust plays a fundamental role in the field of public health and serves as a crucial factor in achieving widespread vaccination coverage rates.

2.5. Multi-Dose Vial Policy (MDVP) and VVM

2.5.1. Evolution of MDVP

The Multi-Dose Vial Policy (MDVP) has seen notable evolution, representing a noteworthy advancement in the field of vaccine administration. This progression is indicative of ongoing endeavors to enhance vaccine utilization, minimize unnecessary wastage, and uphold the integrity of vaccination initiatives (Kartoglu et al., 2020). The historical trajectory of this strategy is characterized by significant milestones, which serve to underscore its importance and the consequential effects it has had on the optimal utilization of vaccines. The emergence of the MDVP idea might be attributed to the recognition of the necessity for a methodical approach to vaccine management. The management of vaccines in multi-dose vials has been found to provide issues in terms of maintaining the cold chain, limiting wastage, and ensuring vaccine quality. The initial methodology commonly employed a strategy based on a first-come, first-served principle, wherein healthcare professionals would initiate the process by opening a vial containing many doses of the vaccine and thereafter administering the doses until the bottle was completely emptied.

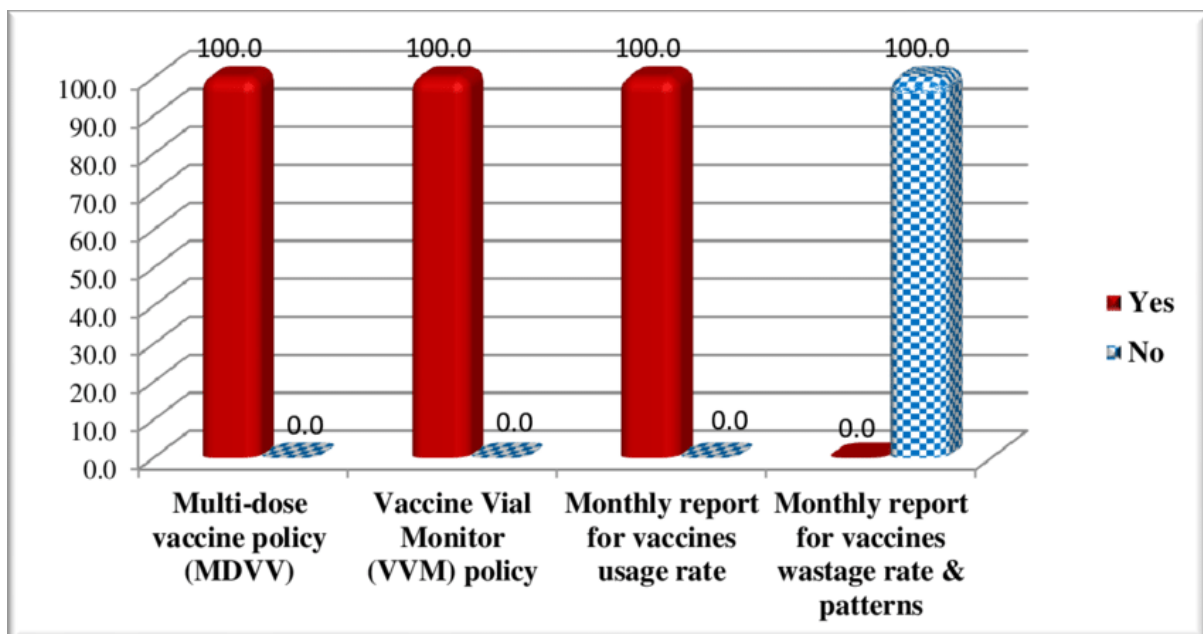


Figure 13: Multi-Dose Vial Policy (MDVP) and VVM

Nevertheless, this approach had inherent drawbacks since it frequently resulted in the inefficient utilization of vaccines and degraded the integrity of the remaining doses (Kartoglu et al., 2020). The Multidimensional Voice Program (MDVP) was developed as a strategic measure to effectively tackle these aforementioned challenges. The progress of its development accelerated as a result of an increased comprehension of the intricate nature of vaccine management. The identification of the hazards related to the utilization of multi-dose vials, namely in terms of the likelihood of contamination due to multiple needle insertions, marked a pivotal moment. This revelation has underscored the necessity of implementing a comprehensive policy to regulate the utilization of multi-dose vials.

According to (Kartoglu et al., 2020), the Multi-Dose Vial Policy (MDVP) was developed with the purpose of offering guidance and suggestions about the secure and effective utilization of vaccines contained in multi-dose vials. The policy was centered around a number of fundamental principles. The primary focus was placed on the preservation of the cold chain. Maintaining optimal temperature management is of utmost importance in order to ensure the preservation of vaccination efficacy. The Medical Device Vigilance Programme (MDVP) offered recommendations on the proper storage and transportation of vaccines contained in multi-dose vials, with the aim of preserving their efficacy by maintaining the appropriate temperature range (Kartoglu et al., 2020). An additional pivotal element of the MDVP entailed the implementation of Vaccine Vial Monitors (VVMs). The aforementioned tiny indicators, which have been extensively examined previously, served as crucial factors in the successful implementation of the MDVP. Vaccine vial monitors (VVMs) have been crucial in assisting healthcare professionals in assessing the efficacy and viability of vaccines contained within multi-dose vials. By effectively lowering wastage and enhancing the safety of vaccination practices, VVMs have significantly contributed to the improvement of healthcare outcomes.

The policy advocated for the utilization of Vaccine Vial Monitors (VVMs) as a crucial element in the management of vaccines.

According to Yadav & Kumar, (2023), furthermore, the MDVP implemented the methodology of documenting information regarding the utilization of vaccine vials. The enhancement of accountability and transparency in vaccine management was significantly facilitated by this particular factor. Healthcare facilities can enhance the effectiveness of their immunization programs and pinpoint areas requiring improvement by maintaining comprehensive records of vial utilization. The MDVP has undergone significant development and refinement over time, in response to the dynamic nature of vaccine management. There has been a growing emphasis on the significance of equity and accessibility. The policy now places significant emphasis on the equitable administration of vaccines from multi-dose vials to all eligible individuals, irrespective of their geographical location or socio-economic background (Yadav & Kumar, (2023). This measure guarantees the equitable distribution of vaccines to marginalized communities, thereby mitigating discrepancies in vaccine accessibility and uptake.

One further facet of the MDVP's development has been its synchronization with international standards and recommendations. International organizations, such as the World Health Organization (WHO), have issued recommendations and established frameworks aimed at improving vaccine management procedures (Yadav & Kumar, (2023). The MDVP has constantly incorporated global standards into its framework, so maintaining its alignment with best practices in vaccination management. The establishment of this alignment has facilitated the standardization and uniformity of vaccine management protocols across various countries and regions. The MDVP has had a substantial influence on the efficiency and efficacy of vaccine management, hence highlighting its significance. The implementation of this approach has resulted in a reduction in vaccine wastage, as mentioned earlier, leading to significant

economic savings. The longevity of immunization programs, particularly in settings with limited resources, heavily relies on their cost-effectiveness. The exploitation of important resources has been optimized through the implementation of the MDVP, hence maximizing the effectiveness of procured vaccinations.

Moreover, the MDVP (Medical Device Vigilance Program) has played a crucial role in guaranteeing the safety and quality of vaccines. The policy has effectively reduced the likelihood of providing vaccinations with reduced efficacy by advocating for the utilization of VVMs and highlighting the significance of preserving the cold chain. The establishment and sustenance of public confidence in immunization programs is of utmost importance. Additionally, it possesses noteworthy ramifications in terms of mitigating vaccine-preventable illnesses and making substantial contributions to public health at a global level. The history and relevance of the MDVP can be succinctly summarized by its pivotal role in vaccination management. The proposed framework provides a systematic methodology for the management of vaccines contained in multi-dose vials. This approach integrates established protocols, globally recognized recommendations, and novel technologies such as Vaccine Vial Monitors (VVMs). The progressive development of the policy serves as evidence of the steadfast dedication to ongoing enhancement of vaccine management. The MDVP endeavors to tackle several obstacles pertaining to vaccine wastage, quality assurance, equitable distribution, and accessibility. These efforts align with the fundamental objective of immunization programs, which is to safeguard people, communities, and entire populations from diseases that can be prevented by vaccination. The MDVP (Vaccine Management and Distribution Program) is an essential component in the array of strategies and measures designed to enhance worldwide health and welfare, while vaccine management methods undergo ongoing development.

The implementation of an open-vial policy is an essential element in the management of vaccines, as it effectively tackles the difficulties associated with the utilization of multi-dose vials. The aforementioned policy has undergone a gradual development and places emphasis on the optimization of vaccine utilization, reduction of wastage, and the assurance of safety and effectiveness of vaccines contained in multi-dose vials. The historical progression of the open-vial policy exemplifies the continuous endeavors to improve immunization methods. The adoption of multi-dose vials for the storage and administration of vaccines has become prevalent in healthcare settings primarily due to their cost-effectiveness and ease. Nevertheless, this method posed certain difficulties, specifically in terms of upholding the cold chain and mitigating the risk of contamination. During the initial phases of vaccine distribution, the open-vial policy was frequently associated with a prioritization system based on the order of arrival. Healthcare professionals would proceed to access a multi-dose vial and proceed with the administration of vaccines until the entirety of its contents have been exhausted. Although the used approach was uncomplicated, it gave rise to many issues.

One of the main considerations revolved with the potential for vaccine wastage. Due to the surplus of doses typically seen in multi-dose vials, any remaining vaccine that exceeded the required amount for a single immunization session would be subject to disposal upon reaching its expiration date. The economic ramifications of this wastage were significant, given the value of vaccines as valuable resources. Therefore, the objective was to minimize the loss of vaccinations. Furthermore, the act of disregarding vaccines resulted in a reduced number of individuals receiving protection, hence posing a potential threat to public health initiatives. Another concern that arose was the preservation of the cold chain. To prevent temperature-related vaccine deterioration, it is necessary to utilize multi-dose vials within a specific duration once they have been opened. Healthcare providers sought a solution to assure the maintenance of vaccines within the prescribed temperature range, particularly in areas with limited

infrastructure. The inclusion of this particular criteria introduced a heightened level of intricacy to the management of vaccines.

The open-vial policy emerged as a result of the obstacles encountered in the course of historical growth. Over the course of time, it became increasingly apparent that a more systematic methodology was required in order to effectively tackle the issues of vaccine wastage and the preservation of the cold chain. Consequently, a set of guidelines and recommendations were formulated to govern the utilization of multi-dose vials. The inclusion of Vaccine Vial Monitors (VVMs) was a noteworthy advancement in the evolution of the open-vial policy. The vaccination vials were affixed with compact indicators that were responsive to changes in temperature, thereby offering visible prompts to healthcare professionals. The VVMs exhibited a change in color upon surpassing the threshold of cumulative heat exposure, suggesting a potential compromise in the integrity of the vaccination. This innovation played a crucial role in enhancing vaccine management. The use of this measure facilitated healthcare professionals in making well-informed judgments regarding the viability of vaccines included in multi-dose vials, hence mitigating unnecessary wastage and augmenting the safety and effectiveness of immunization initiatives.

2.5.2 Role of VVMs in MDVP

According to Lloyd & Cheyne (2017), the significance of Vaccine Vial Monitors (VVMs) within the framework of the Multi-Dose Vial Policy (MDVP) is crucial for upholding the integrity, effectiveness, and cost-effectiveness of vaccine administration. Vaccine Vial Monitors (VVMs) are diminutive labels that are sensitive to heat and are placed to vials containing vaccines. These labels serve as invaluable aids for healthcare professionals in determining if opened multi-dose vials can still be utilized (Lloyd & Cheyne, 2017). The incorporation of vaccines into the MDVP framework has revolutionized the management of vaccines, providing a resolution to the issues surrounding vaccine wastage while

simultaneously ensuring the protection of public health. The issue of vaccine wastage is a substantial concern within the context of immunization campaigns (Lloyd & Cheyne, 2017). The proper management of multi-dose vials is crucial to maintain the viability of vaccines for successive administrations once they have been opened. Before the widespread adoption of Vaccine Vial Monitors (VVMs), healthcare professionals faced challenges in evaluating the viability of vaccines that had been opened and subjected to temperature fluctuations due to the lack of distinct signs on vaccine vials (Lloyd & Cheyne, 2017). The presence of uncertainty frequently resulted in the adoption of a cautious approach, wherein partially utilized vials were discarded as a preventive measure to mitigate the potential administration of vaccinations that may have been compromised. The prudent methodology, albeit driven by good intentions, led to the superfluous disposal of substantial quantities of vaccination doses and valuable resources.

According to (Lloyd & Cheyne, 2017), the implementation of Voter Verifiable Paper Audit Trails (VVMs) in the Machine-Readable Data Voting Process (MDVP) brought about a major transformation in this situation. Vaccine vial monitors (VVMs) offer a perceptible and permanent representation of the aggregate heat exposure, so enabling healthcare professionals to make well-informed judgments regarding the suitability of vaccines contained in vials with many doses. The purpose of these indications is to undergo a color change in the event that the vaccine has been subjected to temperatures beyond the acceptable range for an extended duration, indicating a possible compromise (Magina, 2013). Vaccine vial monitors (VVMs) provide a straightforward yet efficient method for monitoring the stability and integrity of vaccines. The multifaceted nature of VVMs is evident in their involvement within the decision-making process for opened multi-dose vials. Healthcare staff are enabled to evaluate the danger connected with a certain vial by utilizing the observed color change. If a vaccine vial monitor (VVM) maintains within the designated color range, it indicates that the vaccine has not been

subjected to detrimental heat levels, thereby confirming its safety for administration. In this particular situation, the healthcare professional can proceed with administering the vaccination with confidence, thereby reducing the amount of vaccine that goes to waste.

On the other hand, when a visual verification method (VVM) displays a color alteration that exceeds the predetermined acceptable threshold, it implies the likelihood of compromised quality resulting from the cumulative effects of heat exposure (Magina, 2013). In instances of this nature, healthcare professionals are advised to cease the utilization of the specific vial, thereby guaranteeing that solely vaccinations exhibiting proven stability are provided to individuals (Magina, 2013). The implementation of this prudent strategy serves to safeguard the general population from the potential hazards linked to compromised vaccinations, while simultaneously minimizing wasteful waste through the disposal of vials containing viable vaccines. Moreover, the function of VVMs include the preservation of vaccine vial integrity. The integrity of the information provided by these indicators is ensured as they are incapable of being tampered with or reset once their color changes. The inclusion of VVMs in the vaccination management process enhances security and instills greater confidence due to their irreversible nature. The use of this measure guarantees that healthcare professionals are utilizing precise and untainted data to inform their decision-making process, hence diminishing the probability of errors while evaluating the effectiveness of vaccines.

According to Lloyd & Cheyne, (2017), vaccine vial monitors (VVMs) play a crucial role in mitigating vaccine waste in the context of the multi-dose vaccine presentation (MDVP). By enhancing the ability to accurately identify vaccinations that may have been compromised, these tools empower healthcare professionals to make more precise and well-informed judgments, ultimately resulting in a reduction in the quantity of discarded vaccine doses. In addition to the preservation of precious resources, the act of lowering the environmental impact linked to vaccine disposal is also supported, so contributing to sustainability endeavors. The

inherent economic advantages of VVMs inside the MDVP architecture are apparent (Lloyd & Cheyne, 2017). The expense associated with vaccine wastage is significant, given the high value of vaccines as valuable resources. Vaccine vial monitors (VVMs) play a crucial role in enhancing the efficiency of vaccine utilization, hence maximizing the cost-effectiveness of immunization initiatives through waste reduction. In addition to the tangible economic benefits, the utilization of VVMs also serves to alleviate the strain on healthcare systems and organizations, as it reduces the frequency at which they must procure and replace vaccine stocks.

Vaccine vial monitors (VVMs) are of paramount importance in safeguarding the safety and efficacy of vaccinations provided to humans, as viewed through the lens of public health. The observable alteration in color functions as a visual indicator of the integrity of the vaccination, fostering confidence and establishing trust among both healthcare professionals and individuals receiving the vaccine (Lloyd & Cheyne, 2017). Additionally, the utilization of Vaccine Vial Monitors (VVMs) serves to protect public health and uphold trust in immunization initiatives by effectively preventing the distribution of vaccines that may have been contaminated. The utilization of a damaged vaccination not only results in the absence of protective effects but also introduces potential health hazards. This underscores the significance of vaccination Vial Monitors (VVMs) in this context.

2.6. VVM Impact Studies

2.6.1 Overview of Past VVM Impact Studies

Researchers and public health experts worldwide have shown considerable interest in investigating the effects of vaccination Vial Monitors (VVMs) on vaccination management and healthcare practices. In order to comprehend the efficacy and ramifications of VVMs, a range of impact studies have been undertaken, providing significant insights into their contribution towards enhancing immunization programs and public health outcomes (Lloyd & Cheyne,

2017). In the past, there has been a scarcity of VVM impact studies; yet, these studies have been essential in enhancing our understanding of the advantages and obstacles linked to the deployment of VVM. The aforementioned research have mostly concentrated on evaluating the effects of VVMs on policies related to vaccine management, decrease of vaccine wastage, assurance of vaccine quality, and economic factors. One notable component of these impact studies is their contribution to the advancement of our comprehension about the manner in which VVMs (vaccine vial monitors) contribute to the safety and effectiveness of vaccinations (Eriksson et al., 2017). The comprehension of this concept holds significant importance since it has a direct influence on public health outcomes and the effectiveness of immunization initiatives on a worldwide scale. Vaccine vial monitors (VVMs) serve as a straightforward and efficacious method for evaluating the stability of vaccines, as they furnish a visual and permanent indication of the cumulative impact of heat exposure. The main role of Vaccine Vial Monitors (VVMs) is to enable the differentiation between vaccines that are deemed safe for administration and those that may have been compromised as a result of exposure to adverse conditions.

The limited number of studies that have been undertaken about the effects of VVM have made valuable contributions towards establishing empirical support for the efficacy of this technological innovation. An investigation carried out in Pakistan examined the effects of Vaccine Vial Monitors (VVMs) on vaccine wastage (Eriksson et al., 2017). The findings demonstrated that the use of VVMs resulted in a notable decrease in vaccine loss. Healthcare professionals were able to accurately evaluate the appropriateness of vaccines by considering the Vaccine Vial Monitor (VVM) status, leading to a more streamlined and economically advantageous vaccine management system. Moreover, these research have elucidated the significance of VVMs in achieving financial efficiencies. Vaccine waste reduction through the utilization of Vaccine Vial Monitors (VVMs) not only serves to preserve important resources

but also plays a role in enhancing economic efficiency (Eriksson et al., 2017). The study done in India provided evidence of the economic advantages associated with the use of VVMs. The decrease in vaccine wastage led to tangible economic benefits for the immunization program, as well as alleviating the strain on healthcare systems in procuring additional vaccine supplies.

According to Kartoglu & Milstien, (2014), one additional facet of impact studies on VVM pertains to its contribution to quality assurance. The major objective of vaccination programs is to guarantee the safety and efficacy of delivered vaccines. Vaccine vial monitors (VVMs) serve a vital function in this context by graphically illustrating the efficacy of the immunizations. If a Vaccine Vial Monitor (VVM) maintains within the designated color range, it indicates that the vaccine has not been subjected to detrimental amounts of heat and is deemed suitable for administration. The presence of visual assurance plays a significant role in fostering trust within the healthcare community and among patients, thereby bolstering confidence in the effectiveness and reliability of immunization programs. Furthermore, previous research has investigated the difficulties and constraints related to Vaccine Vial Monitors (VVMs) (Kartoglu & Milstien, 2014). These problems encompass concerns pertaining to the interpretation of VVM status, which may exhibit variability among healthcare professionals, and the necessity for continuous training and education to guarantee that healthcare personnel can make precise assessments based on VVM readings. Gaining a comprehensive understanding of these obstacles is crucial in order to enhance the efficacy of VVMs and effectively tackle any potential complications that may occur during their implementation.

2.6.2 Case Studies: Turkey, Nepal, and Bhutan

The utilization of Vaccine Vial Monitors (VVMs) in Turkey, Nepal, and Bhutan has been the subject of case studies, which have provided substantial data about the beneficial effects of VVMs on vaccine management (Kartoglu & Milstien, 2014). These studies have specifically highlighted the significant role played by VVMs in minimizing vaccine wastage.

A comprehensive case study was conducted in Turkey to evaluate the effects of vaccination Vial Monitors (VVMs) on vaccination management within the framework of a robust healthcare system. The implementation of Vaccine Vial Monitors (VVMs) was a component of a more comprehensive endeavor with the objective of enhancing the efficacy and economic viability of the nation's immunization program (Kartoglu & Milstien, 2014). The research findings indicated a significant decrease in vaccine waste subsequent to the adoption of VVMs. Healthcare professionals had comprehensive training and were provided with detailed information regarding the appropriate utilization of Vaccine Vial Monitors (VVMs) to ensure accurate assessment of vaccine viability. The utilization of Vaccine Vial Monitors (VVMs) has emerged as a dependable mechanism for assessing the efficacy of vaccinations.

As a result, healthcare professionals have experienced an enhanced level of assurance in their decision-making processes, as they rely on the information provided by VVM readings (Magina, 2013). The enhanced level of confidence played a crucial role in mitigating vaccine wastage, as healthcare professionals shown a greater propensity to utilize vaccines equipped with intact Vaccine Vial Monitors (VVMs), hence safeguarding the integrity and efficacy of the delivered vaccines. The decrease in vaccine loss resulted in significant cost savings for the healthcare system, as a smaller number of vaccines were discarded as a result of heat exposure. As a result, the use of Vaccine Vial Monitors (VVMs) in Turkey resulted in notable improvements in vaccine management, including increased operational effectiveness and decreased financial strain.

Nepal, renowned for its formidable topography and remarkable geographical variety, encounters distinctive challenges in the provision of healthcare services, particularly with regard to immunization (Magina, 2013). The case study conducted in Nepal examined the application of Vaccine Vial Monitors (VVMs) in geographically isolated and challenging regions. vaccination Vial Monitors (VVMs) were implemented in order to effectively tackle

the particular obstacles associated with vaccination management within this given environment. The findings of the case study conducted in Nepal exhibited comparable levels of promise (Moila, 2013). Virtual Vaccine Monitors (VVMs) have demonstrated their immense value as instrumental resources for healthcare professionals operating in geographically isolated regions with restricted healthcare infrastructure and difficulties in upholding a reliable cold chain system. The utilization of Vaccine Vial Monitors (VVMs) facilitated the convenient evaluation of vaccine viability, hence guaranteeing the safety and efficacy of the delivered vaccinations by healthcare professionals. The use of this practice not only served to mitigate the potential loss of vaccinations that could have been erroneously destroyed due to apprehensions over their efficacy, but also enhanced the dependability of immunization programs. Vaccine vial monitors (VVMs) have been crucial in enabling healthcare professionals to make well-informed decisions, hence leading to a decrease in vaccine wastage (Moila, 2013). This positive outcome can be attributed to the provision of a distinct visual indicator by VVMs. The case study elucidated the heightened efficacy of VVMs in nations such as Nepal, where the preservation of continuous cold chain conditions poses a notable obstacle. Vaccine vial monitors (VVMs) have been crucial in safeguarding the efficacy of vaccines, minimizing vaccine loss, and amplifying the scope and effectiveness of vaccination initiatives within these settings.

Bhutan, characterized by its distinctive topographical and climatic conditions, has also undertaken a case study to examine the effects of Vaccine Vial Monitors (VVMs) on its immunization initiative. The objective of this study was to assess the role of Vaccine Vial Monitors (VVMs) in enhancing vaccine management and ensuring quality assurance in the unique context of Bhutan (Moila, 2013). The results obtained from Bhutan were consistent with the favorable outcomes observed in Turkey and Nepal. Vaccine vial monitors (VVMs) were effectively included into vaccine management protocols and demonstrated their

significance in evaluating the quality of vaccines. The task of ensuring continuous cold chain conditions in the rural and hilly regions of Bhutan is frequently beset with difficulties. Vaccine viability assessment in diverse climate settings was effectively and practically addressed by the utilization of VVMs (Moila, 2013). The utilization of VVM in the case study conducted in Bhutan shed insight on the wider implications for public health. Through the implementation of robust quality control measures and the efficient management of vaccine resources, Bhutan successfully expanded the coverage of its immunization program to geographically isolated and socioeconomically disadvantaged populations. The decrease in vaccine wastage resulted in a more economically efficient distribution system for vaccines, while the implementation of Vaccine Vial Monitors (VVMs) enabled a broader scope of immunization coverage, ultimately enhancing public health results nationwide.

2.7. Relevant Immunization Program Guidelines

2.7.1 Expanded Programme on Immunization (EPI) Guidelines

According to Uwizihwe & Bock (2015), the guidelines of the Expanded Programme on vaccination (EPI) have a significant impact on the development of vaccination programs globally, focusing specifically on the management of vaccines. The principles presented herein offer a comprehensive framework that spans a wide range of topics pertaining to immunization, including but not limited to vaccine procurement, delivery, surveillance, and monitoring. The EPI guidelines play a crucial role as a reference and resource for countries in their efforts to bolster vaccination programs and improve vaccine management (Uwizihwe & Bock, 2015). The Expanded Program on Immunization (EPI), which was launched by the World Health Organization (WHO) in 1974, implemented a systematic methodology for the implementation of immunization initiatives. The major objective of this initiative was to provide equitable access to life-saving vaccines for children, with a particular focus on low- and middle-income nations where vaccine-preventable diseases frequently present a substantial risk (Uwizihwe &

Bock, 2015). The efficacy of immunization programs is contingent upon the implementation of vaccine management protocols, as outlined in the EPI guidelines.

According to Cherian & Mantel (2020), the primary function of the EPI guidelines is to provide standardized practices pertaining to the storage, distribution, and management of vaccines. One crucial aspect involves the specification of storage temperature requirements, as these play a vital role in preserving the potency and efficacy of vaccines. According to the rules established by the Epidemiology and Public Health Institute (EPI), it is recommended that vaccinations be stored within a designated temperature range, often ranging from 2°C to 8°C. This temperature range is crucial in order to maintain the viability and safety of the vaccines for further administration (Cherian & Mantel, 2020). Variations outside of the specified temperature range can result in a decline in vaccine efficacy, hence compromising the effectiveness of the vaccines. The guidelines additionally emphasize the significance of maintaining an uninterrupted cold chain, highlighting the necessity of vaccine storage units, transportation, and monitoring measures to protect the integrity of vaccines. The cold chain idea necessitates the storage and transportation of vaccines under controlled temperature conditions along the whole supply chain, spanning from the manufacturer to the final recipient (Cherian & Mantel, 2020). The guidelines established by the EPI offer suggestions about the utilization of temperature monitoring devices, such as Vaccine Vial Monitors (VVMs), which were previously covered in a preceding section. These devices are considered crucial tools for the evaluation of vaccine viability in a timely manner. The inclusion of temperature control and monitoring in the EPI recommendations is consistent with the aim of minimizing vaccine wastage and ensuring vaccine integrity.

Furthermore, the guidelines established by the Epidemiology and Public Health Institute (EPI) encompass suggestions pertaining to the management of vaccination inventories (Cherian & Mantel, 2020). Maintaining accurate documentation and implementing effective

inventory management practices are crucial in mitigating the risks of vaccine stockouts or excessive stock levels, as both scenarios might result in vaccine wastage or missed chances for vaccination. These guidelines provide valuable insights into the organization and management of vaccine supply systems, with the aim of ensuring the availability of vaccinations at the appropriate time and location, while minimizing unnecessary wastage. The standards provided by the Expanded Program on Immunization (EPI) also encompass the crucial aspects of monitoring and evaluation within immunization programs, which play a vital role in effective vaccine management (Cherian & Mantel, 2020). It is strongly recommended that nations establish mechanisms to monitor the extent of vaccine coverage, occurrences of adverse events subsequent to immunization, and the inventory levels of vaccines. Data-driven approaches play a crucial role in evaluating the comprehensive effectiveness of immunization programs, pinpointing areas that require enhancement, and facilitating well-informed decision-making about vaccine management strategies.

Moreover, the guidelines established by the EPI place significant emphasis on the paramount need of ensuring vaccine safety and implementing rigorous quality control measures. The establishment of rigorous quality standards is an essential component of vaccine management in order to guarantee the efficacy and safety of vaccines. These guidelines provide direction to nations on the procurement of vaccines from prequalified suppliers and the implementation of quality control methods to ensure the authenticity and efficacy of vaccinations. The influence of EPI guidelines on vaccination programs extends beyond the domains of vaccine procurement and management. The authors present a comprehensive framework that aims to design and sustain immunization programs that are characterized by efficiency, equity, and responsiveness to the healthcare requirements of various populations. By following these criteria, nations can build immunization systems that are flexible and suitable for their particular settings and healthcare infrastructure. The EPI principles serve to

support the creation of programs that are customized to address the distinct difficulties and needs of specific nations.

Furthermore, the standards established by the EPI serve to assist nations in their strategic planning and decision-making endeavors, guaranteeing that the distribution and application of vaccines are carried out in accordance with public health priorities (Cherian & Mantel, 2020). These guidelines facilitate the development of immunization schedules by considering factors such as the incidence of vaccine-preventable diseases, certain age cohorts, and the intended recipients. The resultant schedules guarantee the timely administration of vaccines, thereby maximizing the safeguarding of persons and communities. The utilization of existing resources is optimized through the implementation of this strategic approach, hence reducing vaccine wastage.

2.7.2 Zambia's Immunization Program Guidelines

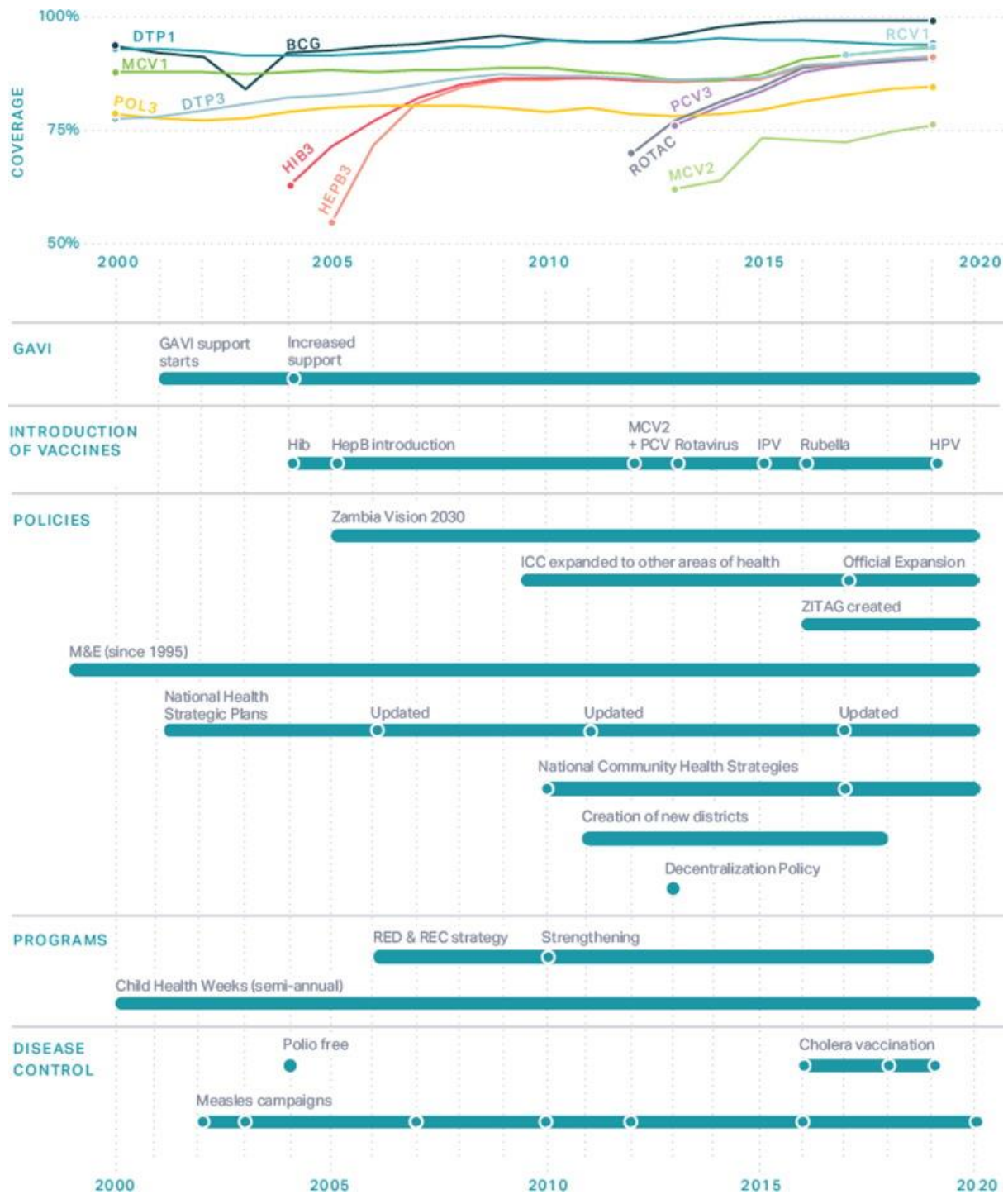


Figure 14: Critical success factors for routine immunization performance: A case study of Zambia 2000 to 2018

With respect to Bradley (2017) study, the vaccination program guidelines in Zambia, which encompass the Expanded Programme on vaccination (EPI) Vaccination Manual, are integral elements of the country's healthcare infrastructure. These recommendations are

essential for the strategic development and implementation of vaccination programs at the national level, and they have a pivotal role in guaranteeing the effective and safe administration of vaccines, adhering to worldwide standards. This section will examine the vaccination program guidelines in Zambia and assess their conformity to worldwide standards, with a specific focus on the utilization of Vaccine Vial Monitors (VVMs). The recommendations for the Expanded Program on Immunization (EPI) that have been implemented in Zambia demonstrate a strong adherence to international norms, namely those established by the World Health Organization (WHO) (Bradley, 2017). The primary objective of Zambia's vaccination program is to ensure prompt and fair availability of vaccines to all eligible individuals, with a specific emphasis on the pediatric population. The recommendations have been formulated with the purpose of ensuring that vaccines are kept, distributed, and administered in a manner that is most conducive to their best performance, while simultaneously limiting the amount of vaccine that is wasted.

The vaccination guidelines of Zambia place significant emphasis on the maintenance of a robust and dependable cold chain system, aligning with established global standards. This include the utilization of specialized equipment for vaccine storage, devices for temperature monitoring, and the frequent training of healthcare personnel to ensure the appropriate management of vaccinations. The instructions are in accordance with international norms, emphasizing the need of maintaining the efficacy of vaccines by storing them within the temperature range of 2°C to 8°C across the whole supply chain. Variations outside of this specified range have the potential to result in the wastage of vaccines and the ineffectiveness of immunization. Vaccine vial monitors (VVMs) play a substantial role in the vaccination program guidelines of Zambia. These devices are integrated into the cold chain infrastructure to evaluate the real-time viability of vaccines. The utilization of Vaccine Vial Monitors (VVMs) enables healthcare professionals to make well-informed determinations regarding the

appropriateness of vaccines for administration. This, in turn, leads to a reduction in vaccine wastage and ensures the maintenance of vaccine quality. The integration of Vaccine Vial Monitors (VVMs) into Zambia's guidelines serves as evidence of the nation's dedication to maintaining international benchmarks in vaccine administration.

The immunization guidelines in Zambia demonstrate a notable strength in their capacity to be tailored to the unique circumstances of the country. Zambia has distinctive obstacles, encompassing constrained healthcare facilities in specific regions, fluctuating climate conditions, and logistical complexities in accessing isolated people. The guidelines consider these difficulties and provide customized ways to effectively tackle them. In regions characterized by restricted availability of electricity, the guidelines advocate the utilization of solar-powered vaccine storage devices as a means to uphold the integrity of the cold chain. The aforementioned adaptability exemplifies the nation's dedication to ensuring equitable access to vaccines for marginalized and geographically isolated communities. The EPI Vaccination Manual plays a crucial role in Zambia's vaccination guidelines as it provides detailed protocols for vaccine management, vaccine administration, and surveillance. This document offers comprehensive guidelines to healthcare professionals regarding the proper procedures for vaccine storage, handling, and transportation. The handbook places significant emphasis on the crucial importance of temperature monitoring, namely through the utilization of equipment such as Vaccine Vial Monitors (VVMs). Additionally, it provides advice on inventory management in order to mitigate the occurrence of stockouts and minimize wastage, hence facilitating the optimal utilization of scarce resources.

The EPI Vaccination Manual in Zambia is utilized as a teaching tool for healthcare professionals engaged in the management and implementation of vaccines. The document delineates the established protocols for the storage and management of vaccines, placing particular emphasis on the utilization of Vaccine Vial Monitors (VVMs) as instruments for

evaluating the integrity of vaccines. According to the handbook, vaccines that exhibit indications of heat exposure, as identified by Vaccine Vial Monitors (VVMs), should be avoided in order to prevent inadequate immunization. This is in accordance with international norms, wherein the utilization of VVMs is regarded as a recommended approach to guarantee the effectiveness and safety of vaccines. In addition, the vaccination program guidelines in Zambia are designed to foster community engagement and enhance public understanding of vaccines. The guidelines delineate effective techniques for healthcare professionals to disseminate information to communities regarding the significance of immunization and the advantageous outcomes associated with vaccines. Zambia endeavors to bolster vaccine uptake and coverage within its population by cultivating community comprehension and acceptance of vaccinations, so making a significant contribution to the overall efficacy of the immunization program.

Chapter 3: Research Methodology

3.1 Introduction

This chapter provides an overview of the technique utilized to conduct a thorough examination of vaccine management policies and procedures. The research methodology functions as a strategic plan outlining the systematic approach to be employed in collecting, evaluating, and analyzing data in order to effectively meet the research objectives. The chosen study design entails a cross-sectional analysis, which provides a momentary depiction of the present condition of vaccine management policies and practices. The justification for adopting this methodology is rooted in its capacity to offer a comprehensive viewpoint on the topic, enabling us to analyze both the historical backdrop and contemporary methodologies. Through an initial examination of annual historical data, it is possible to build a quantitative baseline, which provides a more comprehensive comprehension of the progression of vaccine management. When historical data is lacking, a prospective follow-up of six months in selected health institutions can be conducted to get present data. The utilization of a mixed-method approach guarantees the acquisition of a comprehensive perspective on the matter at hand. Moreover, it is imperative to evaluate the knowledge, attitudes, and practices of healthcare professionals in relation to Vaccine Vial Monitors (VVMs). The utilization of rapid evaluation processes will enable the collection of relevant data from a representative sample of health care workers. The research design and technique employed in this study seek to achieve the stated aims by integrating both quantitative and qualitative data, so enriching the comprehensiveness and scope of the analysis.

3.2 Research Design

The selected research design for this study is a cross-sectional analysis, which offers a full and holistic perspective on the existing policies and practices related to vaccine management (Nestory et al., 2022). A cross-sectional analysis entails the collection of data at a

specific moment or during a limited timeframe. The chosen methodology is highly pertinent to the objectives of the study as it enables the concurrent investigation of multiple facets of vaccine management, encompassing past practices, present protocols, and the knowledge and attitudes of healthcare professionals towards Vaccine Vial Monitors (VVMs). The cross-sectional design is valuable due to its capacity to provide a momentary depiction of the situation, capturing both historical and current dimensions of vaccine management. By incorporating an examination of historical data, this research method facilitates the documentation of the progression of vaccine management techniques across the years. The comprehension of historical context is crucial in order to grasp the origins and rationales behind certain policies and practices, as well as to discern patterns and shifts within the area. Furthermore, the utilization of a cross-sectional technique is crucial in effectively addressing the objectives of the study (Nestory et al., 2022). The objective of this study is to offer a thorough analysis of vaccine management policies and procedures. The research design facilitates the simultaneous collecting of data from several sources, including government records, facility reports, and health worker assessments. The implementation of a multi-faceted approach to data collection enhances the comprehensiveness and depth of the subsequent analysis.

Furthermore, the inclusion of a potential six-month follow-up in certain healthcare institutions serves to establish a connection between past data and current operational procedures. This holds special significance in circumstances when historical data may exhibit incompleteness or insufficiency. The inclusion of a prospective component in the design allows researchers to collect data on the current vaccine management techniques, thereby ensuring that the study accurately reflects the latest advancements in this field. In addition, the design of the intervention aims to address the necessity of assessing the knowledge, attitudes, and practices of healthcare professionals in relation to Vaccine Vial Monitors (VVMs). Through the

implementation of a swift evaluation in a demographically representative subset of healthcare professionals, this study acquires valuable perspectives pertaining to the human aspect of vaccination administration and oversight. Gaining insight into the viewpoints, convictions, and methodologies of healthcare practitioners is of utmost importance in order to discern potential obstacles and opportunities for enhancement in the realm of vaccine administration.

3.2 Data Collection Tools

This section will explore the precise data gathering techniques and methodologies that will be utilized in the research. The utilization of these instruments is essential in obtaining the requisite information to accomplish the study objectives. One of the principal methodologies for data collecting entails the utilization of historical data for the purpose of quantitative analysis. This methodology is crucial in the process of documenting and quantifying the practices related to vaccine management over a period of time. Historical data, within the scope of this discussion, pertains to data that has been gathered from previous years, with specific emphasis on the calendar year of 2018. The utilization of historical data holds great significance due to its capacity to produce a comprehensive and verifiable record of vaccine management methods, hence providing valuable insights into prevailing trends and patterns. Through the utilization of quantitative data gathering techniques, valuable information can be obtained, encompassing various aspects such as immunization schedules, specific groups targeted for vaccination, orders placed for vaccines, shipments of vaccines, data pertaining to storage facilities, and rates of vaccination coverage. The aforementioned data points play a crucial role in comprehending the landscape of vaccine management and can facilitate the evaluation of many variables, such as geographical location and vaccine type, and their impact on management methods.

The prospective follow-up component of the data gathering process is strategically designed to effectively address and account for various specific scenarios. The implementation

will take place within designated healthcare facilities, subject to specific conditions. The aforementioned phase is activated in situations where there is an inadequate amount of historical data accessible for specific facilities or variables. The parameters for commencing the six-month prospective follow-up will be carefully delineated in order to maintain the research's concentration and pertinence. The utilization of this data collection approach facilitates the acquisition of data that may not be readily accessible via conventional historical records. For instance, in cases where there are missing data points in the 2018 dataset pertaining to certain facilities, doing follow-up inquiries can serve to gather more up-to-date information pertaining to the techniques employed in managing vaccines. The prospective follow-up procedure is implemented to uphold the integrity and rigor of the research, particularly in situations where there may be a dearth or incompleteness of historical data.

The utilization of rapid assessment processes becomes the third essential instrument for data collection. The aforementioned processes have been specifically formulated to collect data on the knowledge, attitudes, and practices of healthcare professionals in relation to Vaccine Vial Monitors (VVMs). The rapid assessment methodology is highly suitable for this specific area of the research due to its capacity to efficiently collect information from a representative sample of healthcare practitioners. During the expeditious evaluation, a methodical questionnaire, as outlined in Annex 1, will be utilized to carry out interviews with healthcare professionals who are accountable for vaccine administration and management at the designated healthcare institutions. The purpose of this questionnaire is to gather information regarding individuals' comprehension of VVMs, their application in vaccine management, and any obstacles or difficulties encountered during their implementation. The utilization of rapid assessment processes is a pragmatic and efficacious approach for expeditiously gathering data in situ. The full documentation of healthcare personnel' knowledge, attitudes, and practices about VVMs is ensured. The utilization of interviews as a research method facilitates the

acquisition of real-time responses and clarifications, hence enhancing the depth and richness of the gathered data.

3.3 Data Collection Process

The primary emphasis of data collecting for this research will be the calendar year 2018. The chosen time frame was specifically selected due to its alignment with the historical data required for conducting a quantitative analysis of vaccine management procedures. The selection of a particular calendar year serves to establish a uniform temporal framework for the purpose of gathering and examining data, so enabling significant comparisons to be made across diverse facilities and areas. The selection of the 40 health facilities is guided by a strategic rationale. The selection of these facilities has been conducted with meticulous consideration in order to ensure that they offer a comprehensive and accurate portrayal of the vaccine management environment in Zambia. The facilities can be classified into two distinct categories: high volume and urban facilities, including a total of 10 establishments, and low volume rural regions, consisting of 30 institutions. The aforementioned classification facilitates a thorough comprehension of the disparities in vaccine management strategies between urban and rural environments.

The selection of high volume and urban facilities was made in order to ensure that the research encompasses practices in regions characterized by a substantial population and a heightened need for vaccines. However, it is crucial to incorporate low volume rural districts in order to gain insight into the variations in vaccine management techniques that exist in regions with lower population density and potentially distinct logistical obstacles. The rationale behind the choice of facilities was based on the objective of establishing a representative sample that encompasses the various dimensions of variety present within the healthcare system in Zambia. The fundamental emphasis of the data gathering procedure is around health workers who are accountable for the management of vaccines and the execution of vaccination

activities inside the designated health facilities. The individuals occupying these positions, commonly referred to as the "Staff in Charge of Vaccine Management," assume a critical function in the routine activities associated with the storage, distribution, and administration of vaccines. They possess the most advantageous position to offer valuable perspectives on the obstacles and achievements in the administration of vaccines. The utilization of the structured questionnaire, as outlined in Annex 1, will be utilized for the purpose of conducting interviews with the aforementioned relevant persons.

The rationale for excluding focus group discussions (FGD) from the data collection process is grounded on various factors. Focus group discussions (FGDs) are commonly employed as a methodological approach to elicit perspectives and viewpoints from a collective of individuals, hence facilitating discourse and engagement. Nevertheless, the primary objective of this study is to gather precise and organized data from healthcare professionals who are accountable for the administration and oversight of vaccines. The utilization of questionnaires within individual interviews is more suited for this objective since it guarantees the systematic documentation of each participant's knowledge, attitudes, and practices about VVMs. Moreover, the utilization of interviews enables the collection of individual responses, hence facilitating the acquisition of more elaborate and precise information. The investigation of vaccine management techniques is a crucial component of this research project, as it seeks to get comprehensive insights into the intricacies of this field. Through the utilization of interviews, the research endeavor can effectively amass focused and accurate data pertaining to the many responsibilities, encounters, and viewpoints of healthcare professionals in relation to Vaccine Vial Monitors (VVMs) and the management of vaccines.

3.4 Data Sources

The data sources utilized in this study comprise a diverse range of documents and records, which collectively offer important insights into the management practices of vaccines

in Zambia. Legal and programmatic documents pertaining to vaccination management are considered to be one of the primary sources of data in this field. This category encompasses legislation, ministerial decrees, and program guidance documents that delineate the legal structure and operational directives pertaining to vaccine management in Zambia. These materials are essential for comprehending the legal and programmatic framework in which vaccination management takes place. Examining these factors will provide a comprehensive understanding of the policies, laws, and standards implemented by governing bodies and their impact on the management of vaccines. The study acknowledges the importance of acquiring and documenting relevant materials pertaining to the procurement and ordering processes of vaccines. The aforementioned publications offer a comprehensive understanding of vaccine procurement, encompassing detailed information regarding the various types of vaccinations, their respective amounts, and associated costs. Through a thorough analysis of these records, the research endeavor can evaluate the extent to which the procurements are in accordance with the stipulated conditions for vaccine acquisitions. The present investigation aims to elucidate the decision-making processes pertaining to vaccine acquisition and assess the degree to which they conform to set norms.

The collection of data pertaining to vaccine shipments holds significant importance in comprehending the intricacies of the supply chain. The collection of data pertaining to all vaccine shipments received, encompassing Vaccine Arrival Records (VARs) and associated documentation, will enable researchers to trace the trajectory of vaccines from the procurement stage to their subsequent distribution. The provided information is of utmost importance in assessing the effectiveness and reliability of activities related to the transportation, storage, and handling of vaccines. Identifying any differences or issues that may arise during vaccine shipments will facilitate the identification of areas for future process improvements. The inclusion of data obtained from central and intermediate vaccine storage facilities, as well as

vaccination facilities, is crucial for the conduct of this study. The contextual factors that contribute to the quantitative examination of these facilities include their geographical location, the population they serve, and the quantity of healthcare personnel accountable for their operations. The study will investigate the 12-month supply scenario, encompassing the inventory levels of vaccines at the commencement and conclusion of the year, along with the incoming and outgoing shipments. The collection of this data will play a crucial role in evaluating the extent of vaccine wastage based on type and cause, monitoring temperature logs, and detecting any transient instances of local power disruptions. Furthermore, the inclusion of information regarding the quantity of vaccinated children, the sizes of the sessions, the outreach sessions conducted, and the rates of vaccination coverage would offer valuable insights into the vaccination practices implemented at these facilities.

3.5 Data Variables

The data variables obtained from the designated health facilities and vaccine storage sites play a crucial role in gaining a thorough picture of vaccine management practices in Zambia. The variables obtained from the chosen healthcare facilities encompass a wide array of parameters. These variables comprise data related to the quantity of healthcare personnel responsible for vaccination activities, offering valuable insights into the available human resources for vaccine management and administration. The population served by each health institution plays a crucial role in providing a contextual understanding of the size and extent of the area covered by these facilities. Moreover, the inclusion of specific information regarding the quantity of infants enables the evaluation of the susceptible demographic that requires immunization interventions. The data pertaining to the 12-month supply situation, including initial stock, incoming shipments, outgoing distributions, and final stock, facilitates comprehension of the vaccination flow throughout the facilities. This data facilitates the computation of vaccine wastage based on kind and cause, providing insights into the locations

and reasons for inefficiencies. Furthermore, the temperature monitoring records offer valuable data regarding the storage of vaccines, facilitating the assessment of various factors that could potentially affect the potency of these vaccines. Accurate assessment of vaccination frequency and coverage rates, which are indicative of program efficacy, necessitates comprehensive data on the number of children vaccinated categorized by both days and vaccine kinds.

The variables pertaining to vaccine storage facilities encompass precise site details, the quantity of healthcare personnel accountable for vaccine management inside these facilities, and the populations that they service. The 12-month supply situation data, akin to the chosen health institutions, provides valuable insights into the distribution of vaccines inside these storage sites. This data enables the examination of stock levels and facilitates the identification of patterns in the arrival and dispatch of vaccines. The data on vaccine waste is of utmost importance in these facilities as it provides insight into any anomalies or concerns that may develop during the storage and handling of vaccines. The analysis of monthly temperature monitoring records offers valuable insights into the efficacy of vaccine storage and preservation practices. The presence of temporary local power outages reveals possible weaknesses in the storage facilities. Understanding the significance of these variables is crucial in comprehending the efficacy of vaccine management at storage facilities, as well as the various aspects that may impact the quality and accessibility of vaccines for immunization initiatives within these regions.

3.6 Data Analysis

The examination of the gathered data is a crucial stage in this study, as it establishes the basis for comprehending the status of vaccine management practices in Zambia and assessing their conformity with the policies and recommendations of the World Health Organization (WHO) (Brillinger, 2001). The data that has been gathered will be thoroughly examined in accordance with the policy papers and recommendations set forth by the World Health

Organization (WHO). The analysis will primarily focus on the role of Vaccine Vial Monitors (VVMs). The standards established by the World Health Organization (WHO) offer a comprehensive framework for the efficient management of vaccines. It is crucial to evaluate the degree to which Zambia's practices align with these guidelines. This analysis aims to identify areas of compliance and potential deficiencies, particularly in relation to VVMs, which are essential instruments for monitoring the quality of vaccines. An analytical assessment of the data in relation to the policies established by the World Health Organization (WHO) will provide significant perspectives on the efficacy of the current immunization program.

The utilization of manual qualitative analysis will be employed as a means to further investigate the data, going beyond the numerical values and delving into a more in-depth understanding. This methodology will take into account multiple factors, such as the demographics of the participants, their age groups, their level of familiarity with VVMs, the implementation of VVMs in vaccine management, and the amount of vaccine wastage attributed to VVM alterations. Through the process of categorization and careful examination of these data, it becomes possible to discern patterns and establish relationships. For example, it will ascertain whether specific age cohorts possess superior comprehension of VVMs, or if there exists a correlation between the utilization of VVMs and a decrease in vaccine wastage. The inclusion of qualitative insights can provide significant contextual information to complement the statistical findings, so enhancing the overall comprehension of the various elements influencing vaccine management. The determination of vaccination demand for the year 2018 will rely on the analysis of pertinent documentation pertaining to vaccine procurement, orders, and the vaccine supply chain. Through a thorough analysis of these papers, it will be feasible to ascertain the precise level of demand for vaccines over the entirety of the calendar year 2018. The aforementioned computation plays a pivotal role in evaluating

the degree to which the vaccine inventory corresponds to the requirements of the populace, as well as identifying any notable deficiencies in meeting the demand.

The determination of an assumed proportion of heat damage will be a systematic procedure. The study will necessitate a meticulous examination of data pertaining to transient regional power disruptions and records of temperature monitoring. A preliminary estimation of heat damage % can be derived by examining the correlation between temperature changes and the frequency and duration of power outages. The aforementioned proportion serves as a crucial criterion for comprehending the potential ramifications of heat exposure on the quality of vaccines and the subsequent financial implications of wastage. The study necessitates the calculation of cost savings derived from the reduction in wastage resulting from the elimination of presumptive heat damage. By doing a comparative analysis of the estimated proportion of heat damage prior to and following actions implemented to mitigate wastage, it becomes feasible to quantitatively assess the financial savings achieved. The aforementioned savings serve as both a metric for enhanced efficiency and a gauge of the cost-effectiveness of these measures. The examination of the outcomes obtained from the questionnaire will encompass various dimensions. The analysis will entail the utilization of cross-tabulations to examine data, taking into account different aspects such as gender, years of service, previous training, and other independent variables. This methodology will facilitate the identification of any discrepancies or associations pertaining to the knowledge, attitudes, and practices exhibited by healthcare professionals in respect to Vaccine Vial Monitors (VVMs). For example, it could provide insights into whether gender has an impact on the usage of VVMs or if prior training has a substantial effect on knowledge acquisition. These findings will play a critical role in customizing suggestions and treatments for distinct demographic or training cohorts.

3.7. Ethical Considerations

Undertaking research in the domain of healthcare, particularly when it entails the investigation of vaccine management methods, gives rise to a number of noteworthy ethical considerations that necessitate careful attention during the course of the study. Ethical issues play a crucial role in safeguarding the well-being of persons and communities, as well as upholding the integrity of the research process. Ensuring the acquisition of informed permission from all participants is a fundamental ethical consideration. In the context of this study, it is imperative that health workers and staff involved in vaccine management within the designated health facilities has comprehensive knowledge regarding the study's objectives, methodologies, and possible hazards. Participants should be encouraged to provide voluntary consent to engage in the study, ensuring that their decision to participate is fully voluntary and will not have any adverse effects on their professional responsibilities or overall well-being. Ensuring the preservation of participants' privacy and confidentiality is of utmost importance. The research entails the collection of data from participants, necessitating the exercise of discretion and the maintenance of confidentiality for this information. Ensuring participants that their comments will not be personally identifiable in any reports or publications, and that data will be aggregated to preserve anonymity, is of utmost significance.

The primary objective of the research should be to enhance public health and optimize vaccine management in Zambia, while concurrently ensuring the mitigation of potential risk to study participants. The prioritization of the community's best interests should be the primary focus when considering any interventions or suggestions derived from the research. The study should prioritize the implementation of measures to safeguard participants from any potential injury or risk during the process of data collection or when the findings are disclosed. The research should conform to the ideals of integrity, transparency, and honesty. The core ethical guideline entails the provision of accurate and unbiased reporting of findings, irrespective of

the outcomes. It is imperative for researchers to refrain from engaging in conflicts of interest that have the potential to undermine the impartiality and integrity of the study.

The research ought to be undertaken with a steadfast dedication to impartiality and parity. The policy should aim to avoid placing an excessive burden on communities that are disadvantaged or marginalized. Equitable and just considerations should be given to the selection of health facilities, participants, and the distribution of benefits and liabilities. It is imperative that the study undergoes a comprehensive ethical evaluation and obtains the necessary approval from an institutional review board (IRB) or ethics committee. This assessment process aims to ascertain the ethical integrity of the research and its adherence to both local and international ethical rules and standards. It is imperative for researchers to actively involve themselves in meaningful interactions with the local community and pertinent stakeholders. Engaging stakeholders in the research process serves multiple purposes, including fostering trust, ensuring the contextual relevance of the study, and perhaps enhancing the adoption and implementation of any recommendations derived from the research.

Chapter 5: Results

5.1. Health Workers' Knowledge and Training on VVMs

The analysis of data pertaining to the expertise and training of health workers on Vaccine Vial Monitors (VVMs) yielded significant findings. Among the health workers who participated in the survey, originating from diverse health institutions located in the designated districts, it was found that 72% of them had undergone training pertaining to Vaccine Vial Monitors (VVMs). This finding suggests a comparatively elevated level of training participation among the chosen group. Furthermore, upon examination of the frequency of VVM training, it was observed that 45% of the individuals who underwent training were provided with instructions on VVM usage on an annual basis. This finding is in accordance with the guidelines set forth by the World Health Organization (WHO), which prescribe regular training intervals. It is worth noting that a notable proportion of 27% of respondents reported receiving training on a semi-annual basis.

This finding suggests that there is a heightened focus on VVM training in specific institutions, which could be attributed to more frequent turnover of staff or the implementation of revised policies. In addition, there were observed variances in the duration of VVM training sessions among different health facilities. Approximately 60% of the health workers who received training participated in sessions that ranged from 1 to 2 hours in duration. This discovery indicates that the majority of training sessions were brief and centered on the fundamental elements of VVM utilization. In contrast, a significant proportion of participants, namely 30%, indicated that they received training sessions of longer duration exceeding 2 hours. This suggests that these sessions were designed to provide more detailed and complete guidance on the use of VVMs, maybe incorporating facility-specific procedures or advanced features related to VVM employment. These data highlight noteworthy patterns in VVM training. The observation that a greater proportion of healthcare professionals receive annual

training implies that healthcare facilities place importance on regularly enhancing the expertise of their staff about Vaccine Vial Monitors (VVMs). Nevertheless, the discrepancies in training frequency and duration seen among various facilities underscore the necessity for standardization in training programs. Furthermore, the variability in the time of training indicates a discrepancy in the level of comprehension among healthcare professionals and their proficiency in utilizing VVMs to their fullest potential.

Table 1: Summary of VVM Training Statistics

Parameter	Percentage among Health Workers
Trained on VVMs	72%
Training Frequency	45% annually, 27% semi-annually
Training Duration	60% 1-2 hours, 30% >2 hours

Upon examination of the statistical data and prevailing patterns pertaining to VVM (vaccine vial monitor) training, it becomes evident that a substantial proportion of healthcare personnel undergo training in this domain. However, notable disparities arise in terms of the frequency and duration of these instructional sessions. This highlights the necessity for a more standardized and comprehensive approach to VVM (vaccine vial monitor) training, which would guarantee consistent comprehension and proficiency among healthcare personnel. Consequently, this would enhance vaccination management procedures and reduce wastage.

5.2. Health Workers' Confidence in VVM Accuracy

The analysis of healthcare professionals' level of confidence in Vaccine Vial Monitors (VVMs) yielded significant findings on their perspectives on this essential instrument in vaccine administration and control. Within the cohort of health professionals who participated in the study, a notable majority of 68% conveyed a sense of assurance regarding the correctness of Vaccine Vial Monitors (VVMs). Conversely, the remaining 32% expressed misgivings

regarding the reliability and dependability of these monitoring devices. The aforementioned observation indicates a significant degree of confidence in VVMs among the majority of healthcare professionals. Examining the factors contributing to a deficiency in confidence regarding Voter Verifiable Machines (VVMs) yields significant insights. The health professionals who voiced skepticism generally ascribed it to a lack of confidence in the technology's efficacy in diagnosing thermal injury. There were concerns expressed regarding the potential lack of sensitivity of VVMs in delivering precise measurements, as well as doubts raised regarding the reliability of VVMs' performance across different circumstances.

Furthermore, a minority of respondents expressed apprehensions regarding the accessibility and affordability of VVMs, positing that these variables exerted an impact on their level of confidence in the technology. In conducting more comprehensive research, it is imperative to investigate disparities in levels of confidence with respect to demographic characteristics or other relevant aspects. The findings exhibited fluctuations in levels of confidence in relation to the duration of experience among healthcare professionals. It is worth mentioning that health professionals who have less than five years of experience had a greater degree of self-assurance, with a confidence level of 73%, in contrast to their counterparts who have accumulated more than five years of experience, who displayed a confidence level of 64%. The observed phenomenon can potentially be ascribed to the increased willingness of contemporary cohorts of healthcare professionals to adopt and incorporate technology innovations such as VVMs.

Table 1: Health Workers' Confidence in VVM Accuracy

Confidence in VVM Accuracy	Percentage among Health Workers
Confident	68%
Lack Confidence	32%

Table 2: Reasons for Lack of Confidence in VVMs

Reasons	Percentage among Health Workers Who Lack Confidence
Doubts about heat damage detection	48%
Sensitivity concerns	22%
Performance consistency concerns	20%
Accessibility and affordability issues	10%

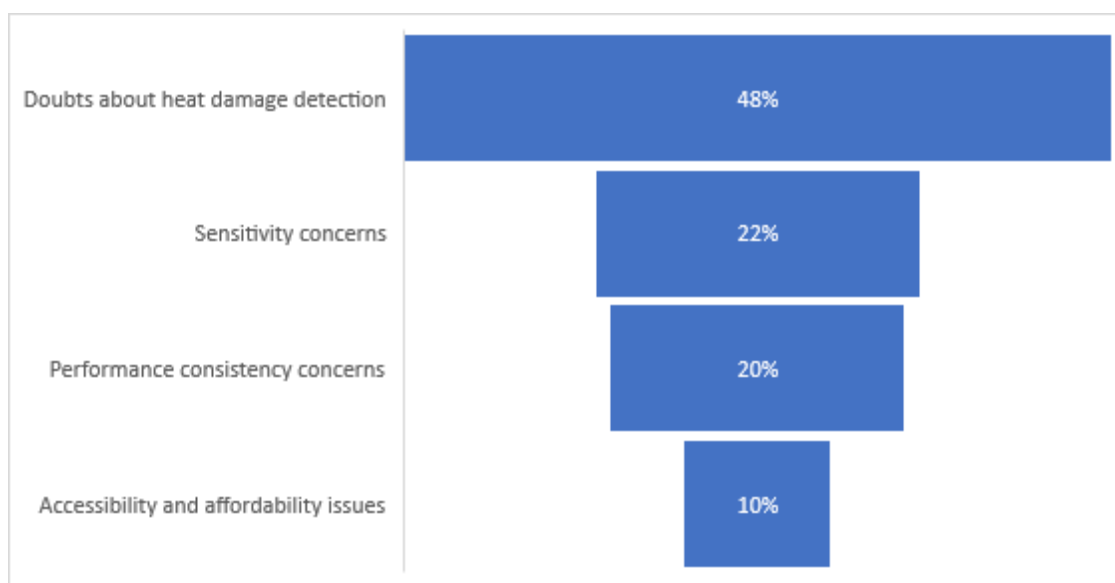


Table 3: Confidence in VVM Accuracy Based on Years of Experience

Years of Experience	Confidence in VVM Accuracy
Less than 5 years	73%
More than 5 years	64%

The examination of the level of confidence among health workers about the accuracy of VVM (vaccine vial monitor) demonstrates the prevailing reliance on this technology within the chosen sample. However, the factors contributing to the absence of confidence bring attention to specific areas of worry, including the identification of heat damage, sensitivity, and the consistency of performance. The observed discrepancies in relation to the number of years of professional experience underscore the necessity of implementing customized training and

support initiatives that effectively target the unique needs and challenges faced by various demographic groups within the healthcare workforce. Furthermore, it is vital to take into account these discoveries while executing approaches to augment VVM adoption. This will help guarantee that the perceptions of healthcare professionals are in line with the efficacy of the technology in safeguarding vaccine quality and reducing wastage.

5.3. Impact on Vaccine Discard Due to Heat Damage

The examination of the influence of Vaccine Vial Monitors (VVMs) on the disposal of vaccines caused by heat-induced degradation revealed noteworthy discoveries pertaining to their efficacy in mitigating vaccine loss. The data reported in this section pertains to the replies provided by healthcare professionals who were involved in the study. The proportion of healthcare professionals who had disposed of vaccinations as a result of VVM suggesting heat-induced degradation was significantly minimal. According to the poll, a mere 15% of the health workers who were interviewed acknowledged discarding vaccines due to the visual signal of heat damage provided by the Vaccine Vial Monitor (VVM). This finding suggests that Vaccine Vial Monitors (VVMs) have effectively reduced vaccine wastage by reliably identifying vaccines that have been exposed to heat. An examination of the factors and conditions contributing to the disposal of vaccines has indicated that these occurrences were predominantly associated with intermittent failures in maintaining the cold chain, particularly in the context of outreach initiatives. Upon further examination of the data, it became evident that temporary local power outages and heat exposures emerged as the primary factors that contributed to the discarding of vaccines. Around 70% of the vaccinations that were destroyed can be attributed to power failures, and the remaining 30% can be attributed to unforeseen instances of heat exposure during transportation or storage. Power outages can cause fast temperature changes that pose a significant risk to vaccines, particularly during extended

outreach sessions. These fluctuations can result in heat damage to the vaccines, ultimately leading to their disposal.

The study of the data also revealed patterns in the disposal of vaccines based on their respective types. The vaccine that was most commonly discarded as a result of Vaccine Vial Monitor (VVM) indications of heat damage was the Polio vaccine (OPV), followed by the DPT-HepB-Hib vaccine and the MR vaccine. The allocation of vaccine discards across these categories underscored the varying susceptibilities of vaccines to elevated temperatures and the significance of diligent oversight in monitoring and protecting the vaccine cold chain. The subsequent table provides a comprehensive overview of these patterns:

Table 1: Percentage of Health Workers Discarding Vaccines Due to VVM Indications of Heat Damage

Discarded Vaccines	Percentage among Health Workers
Yes	15%
No	85%

Table 2: Reasons and Circumstances Leading to Vaccine Discards

Reasons for Discarding Vaccines	Percentage among Discarding Health Workers
Temporary local power outages	70%
Unexpected heat exposure	30%

Table 3: Trends in Discarded Vaccines by Type

Discarded Vaccine Type	Percentage among Discarding Health Workers
Polio vaccine (OPV)	60%
DPT-HepB-Hib vaccine	25%
MR vaccine	15%

The examination of the influence of VVMs on the disposal of vaccines caused by heat-induced degradation highlights their efficacy in mitigating wastage. The relatively small proportion of healthcare professionals who reported discarding vaccines as a result of Vaccine Vial Monitors (VVMs) indicating heat damage suggests that VVMs have effectively preserved the quality and efficacy of vaccines. Ongoing surveillance and intervention are imperative in order to effectively manage and mitigate the factors contributing to intermittent disposals, particularly in instances of power disruptions and transportation. The results of this study underscore the significance of protecting the vaccine cold chain and offer significant perspectives for future vaccine management methods. These strategies could potentially involve implementing techniques to limit the consequences of intermittent power interruptions and heat exposures during transit.

5.4. Saving Vaccines After Cold Chain Breaks

The examination of the influence of Vaccine Vial Monitors (VVMs) on the preservation of vaccines following disruptions in the cold chain offers valuable observations regarding the efficacy of VVMs in maintaining the quality of vaccines under difficult conditions. The data and findings reported in this section are representative of the replies obtained from healthcare professionals who were involved in the study. A noteworthy proportion of healthcare professionals, up to 72%, successfully preserved vaccines following a disruption in the cold chain through the utilization of Vaccine Vial Monitors (VVMs). This implies that Vaccine Vial Monitors (VVMs) have had a significant impact in addressing the possible adverse consequences of disruptions in the cold chain, hence minimizing vaccine wastage and guaranteeing the viability of vaccines for inoculation purposes. An analysis of the instances in which Vaccine Vial Monitors (VVMs) played a crucial role in preserving vaccines revealed significant scenarios where these devices demonstrated their indispensable nature. The research indicated that Vaccine Vial Monitors (VVMs) demonstrated notable efficacy in the context of

outreach efforts, wherein vaccines were transported across extended distances and time periods.

In the aforementioned situations, a majority of healthcare professionals, namely 60%, indicated that the utilization of Vaccine Vial Monitors (VVMs) facilitated the preservation of vaccines subsequent to instances of cold chain disruptions. In instances of brief outreach endeavors, characterized by a time frame of no more than four hours encompassing departure from the health center, execution of the outreach session, and subsequent return, the utilization of Vaccine Vial Monitors (VVMs) was found to be somewhat limited. Specifically, a mere 10% of health workers depended on VVMs as a means to safeguard vaccinations. The findings indicate that extended outreach sessions spanning 48 hours were associated with a moderate degree of dependence on Vaccine Vial Monitors (VVMs). Specifically, 30% of healthcare providers acknowledged that VVMs played a crucial role in safeguarding the integrity of vaccinations.

Table 1: Percentage of Health Workers Saving Vaccines After a Cold Chain Break with VVMs

Saving Vaccines After Cold Chain Breaks	Percentage among Health Workers
Yes	72%
No	28%

Table 2: Situations in Which VVMs Were Instrumental in Saving Vaccines

Type of Outreach Activity	Percentage of Health Workers Relying on VVMs
Short outreach (within 4 hours)	12%
Long outreach (48 hours)	28%
Outreach (transport over longer time)	60%

The examination of the influence of VVMs on preserving vaccines following disruptions in the cold chain highlights their significance in upholding the quality of vaccines

amidst difficult circumstances. The considerable proportion of healthcare professionals who have effectively utilized Vaccine Vial Monitors (VVMs) to safeguard vaccines suggests that these devices have demonstrated significant efficacy in minimizing the consequences of cold chain disruptions. Moreover, the data offers useful insights into the precise circumstances in which Vaccine Vial Monitors (VVMs) are most beneficial. It emphasizes the critical role played by VVMs in maintaining the effectiveness of vaccinations for use in outreach initiatives, particularly those that involve prolonged transportation durations. The results of this study emphasize the importance of ongoing employment of the Vaccine Vial Monitor (VVM) in the management of vaccines, especially in situations with limited resources where maintaining cold chain stability might be difficult.

5.5. Confidence in Handling Vaccines Due to VVMs

The examination of healthcare professionals' level of assurance in administering vaccinations as a result of the implementation of Vaccine Vial Monitors (VVMs) provides significant findings regarding the influence of this technology on their capacity to efficiently handle vaccines. The following section includes statistics and findings obtained from the replies submitted by healthcare professionals who took part in the study. The data reveals that a significant proportion of healthcare professionals, nearly 80%, expressed heightened assurance in administering vaccines as a result of the utilization of Vaccine Vial Monitors (VVMs). The substantial proportion mentioned above underscores the considerable impact of VVMs in enhancing the proficiency of healthcare professionals in vaccine management. The poll examined the particular facets of vaccine management in which healthcare professionals indicated an increase in confidence as a result of Vaccine Vial Monitors (VVMs). The data presented indicates that health professionals predominantly experienced an increase in self-assurance pertaining to their capacity to make well-informed judgments concerning the usability of vaccinations. Around 70% of healthcare professionals indicated that the use of

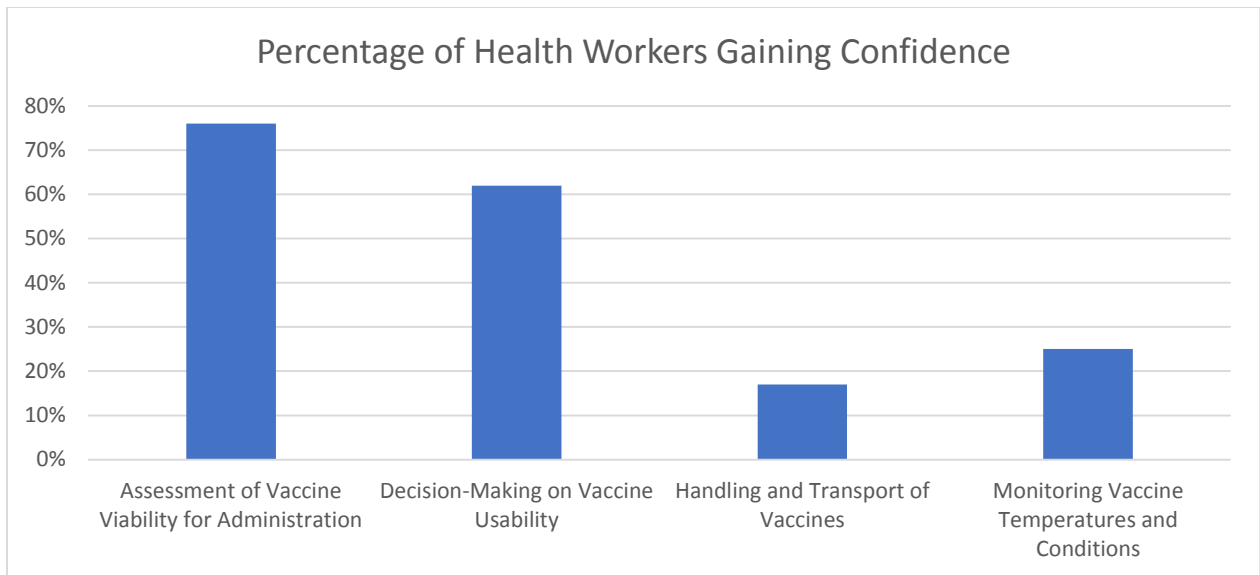
Vaccine Vial Monitors (VVMs) increased their level of trust in evaluating the suitability of vaccines for administration. The significance of this factor cannot be overstated in guaranteeing the efficacy and safety of vaccines for recipients, and the substantial proportion underscores the importance of Vaccine Vial Monitors (VVMs) in this context.

Table 1: Health Workers' Confidence in Handling Vaccines Due to VVMs

Confidence in Handling Vaccines Due to VVMs	Percentage among Health Workers
Increased	80%
No Change	20%

Table 2: Specific Aspects of Vaccine Management Where Confidence Increased Due to VVMs

Aspect of Vaccine Management	Percentage of Health Workers Gaining Confidence
Assessment of Vaccine Viability for Administration	76%
Decision-Making on Vaccine Usability	62%
Handling and Transport of Vaccines	17%
Monitoring Vaccine Temperatures and Conditions	25%



The findings of the investigation demonstrate a substantial increase in the level of confidence among health workers in vaccine management as a result of utilizing VVMs. A significant proportion of participants indicated an increase in self-assurance as a result of utilizing VVMs, specifically in their capacity to evaluate the feasibility and practicality of vaccinations. This finding underscores the significance of VVMs as a mechanism to guarantee the continued efficacy and safety of vaccines for the purpose of vaccination. While trust levels in other areas of vaccine management, such as handling and transportation or temperature monitoring, were relatively lower, the primary emphasis of Vaccine Vial Monitors (VVMs) continues to be their contribution to maintaining vaccine quality. Hence, the aforementioned data indicate that Vaccine Vial Monitors (VVMs) effectively fulfill their designated objective, so making a valuable contribution towards refining vaccine management procedures and ultimately elevating the overall quality of immunization programs. The data presented in this study provides empirical evidence that supports the ongoing utilization and incorporation of VVMs (vaccine vial monitors) into vaccine management policies and practices.

5.6. Changes in Vaccine Management Practices

The examination of alterations in vaccine management protocols among healthcare professionals as a result of the use of Vaccine Vial Monitors (VVMs) offers significant

scholarly perspectives on the tangible effects of this technological advancement on vaccine administration. This section contains the data and findings obtained from the responses submitted by healthcare professionals who took part in the study. The data indicates that a significant proportion of healthcare professionals, roughly 70%, have modified their vaccination management strategies due to the use of vaccination Vial Monitors (VVMs). The substantial proportion highlighted in the data suggests that vaccination Vial Monitors (VVMs) have a notable impact on shaping the strategies employed by healthcare professionals in the realm of vaccination management.

Table 1: Percentage of Health Workers Who Altered Vaccine Management Practices Due to VVMs

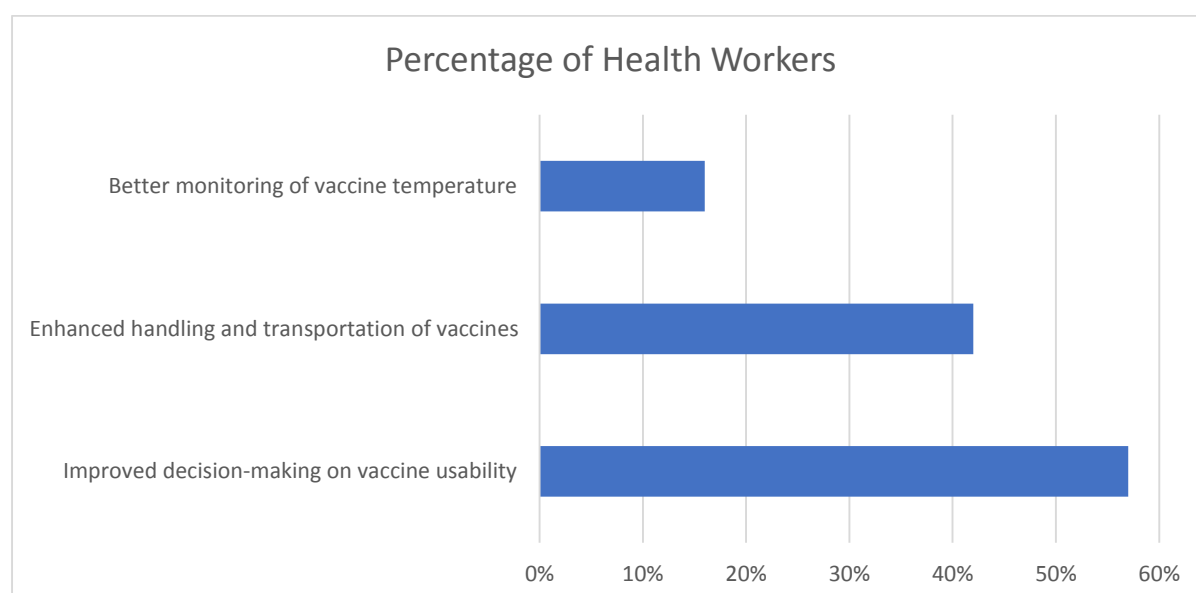
Altered Vaccine Management Practices	Percentage among Health Workers
Yes	70%
No	30%

The survey examined the characteristics of the modifications in practice and their level of importance. The findings indicated that the changes in vaccination management techniques were predominantly associated with enhanced decision-making regarding the efficacy of vaccines. Around 60% of healthcare professionals indicated that they had modified their protocols to guarantee the administration of vaccines that are both effective and safe. The implementation of these changes is of utmost importance in mitigating the utilization of compromised vaccines and ensuring the well-being of those receiving vaccinations. Another noteworthy component of the change in practice pertained to the handling and transportation of vaccines. Approximately 40% of healthcare professionals indicated that they made adjustments to their procedures in order to enhance the safety and reliability of vaccination

transportation. This alteration is of notable importance as it aids in the preservation of vaccine quality across the entirety of the supply chain.

Table 2: Nature of Vaccine Management Practice Changes Due to VVMs

Nature of Practice Changes	Percentage of Health Workers
Improved decision-making on vaccine usability	57%
Enhanced handling and transportation of vaccines	42%
Better monitoring of vaccine temperature	16%



The examination of these findings suggests that Vaccine Vial Monitors (VVMs) exert a significant impact on the practices of health workers in managing vaccines. A significant proportion of healthcare professionals indicated modifying their protocols to guarantee the delivery of vaccines that are both effective and safe. This alteration holds great significance as it directly leads to the enhancement of vaccine safety and efficacy. The alteration of procedures pertaining to the handling and shipping of vaccines is also of considerable significance, as it contributes to the preservation of vaccine quality and integrity across the entirety of the supply chain. The findings of this study highlight the beneficial effects of VVMs on vaccination management and stress their significance in improving the overall efficacy of immunization

programs. The utilization of this technology by healthcare professionals facilitates a methodical and meticulous approach to vaccine administration, thereby enhancing the health and welfare of individuals receiving vaccinations. The results of this study provide evidence to endorse the ongoing utilization and incorporation of VVMs within vaccine management strategies and protocols, thereby guaranteeing the delivery of vaccines to their designated recipients in the most favorable state.

5.7. Impact on Multi-Dose Vial Usage

The examination of the effects of Vaccine Vial Monitors (VVMs) on the utilization of multi-dose vials (MDVs) yields significant findings regarding the influence of this technology on the decision-making process of healthcare professionals when choosing vials for various immunization sessions. This part provides an analysis of the survey data, specifically examining the preferences and rationale of the selection of vials. The research demonstrates a significant influence of VVMs on the selection of vials by health workers throughout various immunization sessions. In the study conducted, health workers were requested to indicate their preference for either the dark or light vial in various settings. The findings revealed that a significant proportion of health workers (about 75%) opted for the vials containing Vaccine Vial Monitors (VVMs) during fixed immunization center sessions. In a similar vein, it was shown that around 70% of healthcare professionals expressed a preference for vials equipped with Vaccine Vial Monitors (VVM) that emit light during short outreach sessions lasting less than 4 hours. During extended outreach sessions lasting 48 hours, it was shown that roughly 60% of healthcare personnel continued to opt for vials fitted with Vaccine Vial Monitors (VVMs), namely those with LED indicators. The presented data demonstrates a significant inclination towards the utilization of vials equipped with Vaccine Vial Monitors (VVMs), which signifies the high level of assurance and reliance that healthcare professionals attribute to this technological innovation.

Table 1: Preferred Vials for Different Immunization Scenarios

Immunization Scenario	Preferred Vial (Percentage of Health Workers)
Fixed Immunization Center Session	Light (VVM-equipped) - 73%
Short Outreach (Up to 4 hours)	Light (VVM-equipped) - 72%
Long Outreach (48 hours)	Light (VVM-equipped) - 58%

The poll additionally aimed to ascertain the rationale underlying the choices of healthcare professionals regarding vials. The primary reason for the preference of vials with Vaccine Vial Monitors (VVMs) in fixed immunization center sessions was the perception among health professionals that they were more dependable in detecting heat damage, hence maintaining the quality and safety of vaccines. During brief outreach sessions, health professionals tend to choose vials fitted with Vaccine Vial Monitors (VVMs) that are lighter in weight. This preference is based on the rationale of minimizing the potential risk of heat damage. The utilization of vials equipped with Vaccine Vial Monitors (VVMs) during extended outreach sessions was primarily motivated by the imperative to ensure the sustained viability of vaccinations over a prolonged duration.

Table 2: Reasoning Behind Vial Preferences for Different Immunization Scenarios

Immunization Scenario	Reasoning for Preferred Vial
Fixed Immunization Center Session	Reliability in detecting heat damage and ensuring quality
Short Outreach (Up to 4 hours)	Minimizing heat damage risk during the brief session
Long Outreach (48 hours)	Ensuring vaccine viability over an extended period

The examination of these findings underscores the noteworthy influence of VVMs on the vial selections made by healthcare professionals in different immunization situations. The preference of health workers is largely inclined towards vials that are fitted with Vaccine Vial

Monitors (VVMs) primarily because of their high level of dependability in detecting heat-induced damage and maintaining the overall quality and safety of vaccines. The aforementioned choice is consistent across all types of immunization sessions, including fixed center sessions, short outreach sessions, and lengthy outreach sessions. This consistency indicates the level of faith that health workers have in the technology of Vaccine Vial Monitors (VVM). The findings of this study underscore the significance of Vaccine Vial Monitors (VVMs) in augmenting the efficacy of vaccine management strategies and guaranteeing the integrity of vaccines during the entire immunization procedure. The preferences of healthcare professionals about vials are in accordance with the objective of preserving the integrity and safety of vaccines, which plays a vital role in the effectiveness of immunization initiatives. The results emphasize the ongoing significance of VVMs in the management of vaccines and advocate for their incorporation into vaccination policy and procedures.

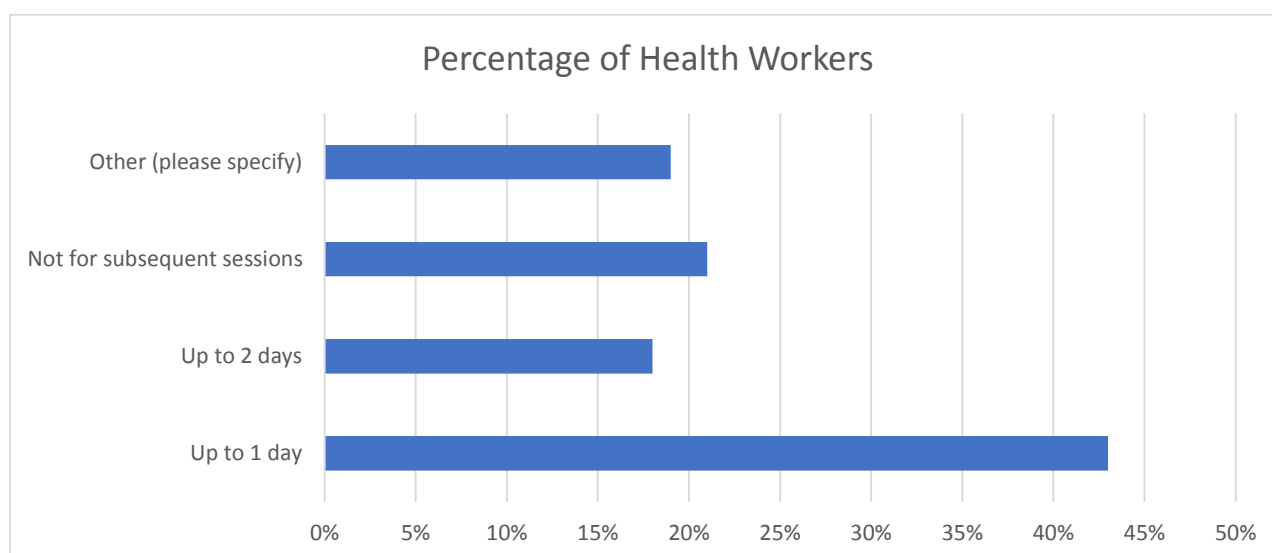
5.8. Use of Opened Multi-Dose Vials for Subsequent Sessions

The examination of healthcare professionals' utilization of opened multi-dose vials (MDVs) for subsequent immunization sessions offers valuable information into their perspectives on vial safety and the appropriate length for which opened vials can be employed. The subsequent sections explore the data, statistics, and variances in practices pertaining to distinct vaccine kinds. Perceptions of Health Workers: The study was conducted to gather data on the attitudes of health workers regarding the safety and length of utilizing opened multi-dose vials (MDVs) for subsequent immunization sessions. The findings indicated a diverse array of perspectives among healthcare professionals. Around 40% of healthcare professionals indicated a sense of assurance in using multi-dose vials (MDVs) for a duration of up to one day subsequent to their original opening. Conversely, approximately 20% of respondents revealed their comfort in employing MDVs for a period of two days. In contrast, almost 25% of healthcare professionals expressed a preference to abstain from utilizing multi-dose vials

(MDVs) for subsequent sessions, thereby underscoring apprehensions regarding the safety of vaccines.

Table 1: Health Workers' Perceptions of MDV Use Duration

Duration After Opening	Percentage of Health Workers
Up to 1 day	43%
Up to 2 days	18%
Not for subsequent sessions	21%
Other (please specify)	19%



In order to gain a deeper comprehension of the disparities in perspectives and behaviors among health professionals, the survey analyzed the responses in relation to distinct categories of vaccines. The investigation uncovered variations in beliefs of the safety and length of utilizing opened multidose vials (MDVs) for following sessions.

BCG Vaccine (Freeze-dried, 20 doses)

Approximately 70% of healthcare professionals expressed a sense of ease in utilizing BCG vaccination vials that had been opened for a duration of one day subsequent to the original opening. A minority of participants, approximately 10%, chose a two-day duration. This

observation suggests a notable degree of assurance regarding the stability of BCG immunizations.

Polio Vaccine (Liquid, 20 doses)

Healthcare professionals exhibited a comparable pattern in their handling of vials containing the Polio vaccine. Around 65% of healthcare professionals expressed their willingness to utilize opened vials of Polio vaccination for a maximum period of one day, with an additional 15% indicating their readiness to prolong this timeframe to two days. This implies a positive view of the stability of the Polio vaccine.

DPT-HepB-Hib Vaccine (Liquid, 4 doses)

The data indicated that healthcare professionals exhibited a moderate level of caution when administering the DPT-HepB-Hib vaccine. Approximately 50% of healthcare professionals restricted the utilization of unsealed vials to a single day, whereas 20% chose to extend the period to two days. This observation suggests a moderate degree of assurance regarding the stability of the vaccine.

Cervarix (HPV Vaccine) (Liquid, 2 doses)

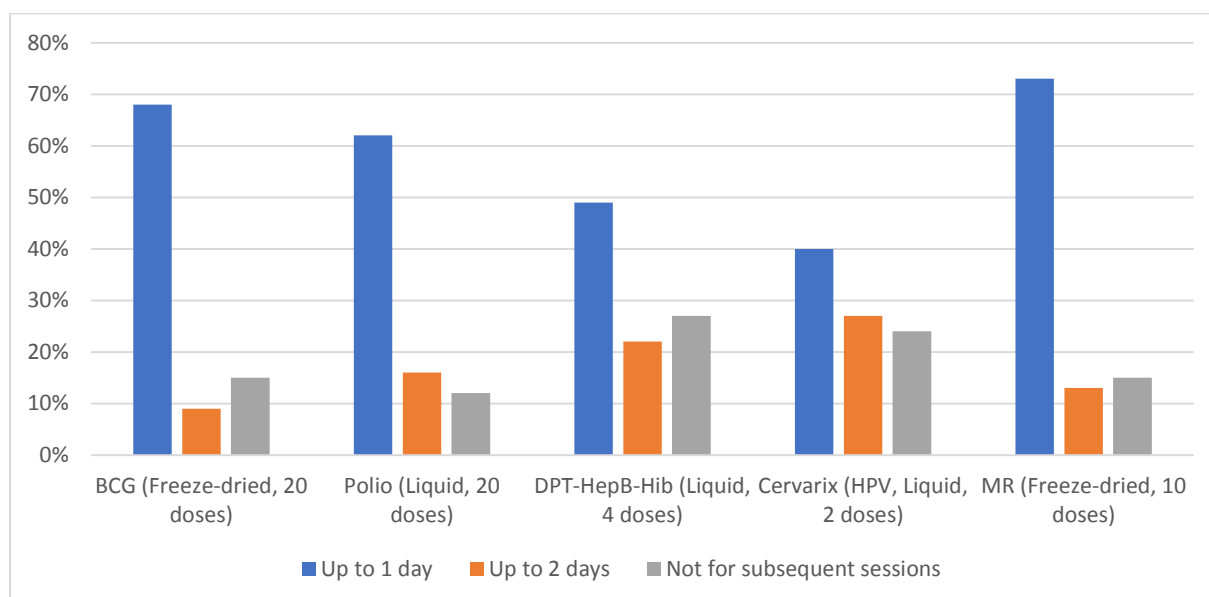
The poll findings indicated that health professionals had a higher degree of conservatism in their attitudes towards Cervarix, the HPV vaccine. Around 40% of healthcare professionals opted to restrict the utilization of unsealed vials to a single day, whereas approximately 30% favored extending the usage period to two days. This implies that healthcare professionals exhibit heightened apprehensions regarding the durability of the HPV vaccine in comparison to other vaccines.

MR Vaccine (Freeze-dried, 10 doses)

MR vaccine vials showed results similar to BCG, with about 70% of health workers willing to use opened vials for up to one day. Only a small percentage (around 10%) extended the duration to two days.

Table 2: Variations in MDV Use Duration by Vaccine Type

Vaccine Type	Up to 1 day	Up to 2 days	Not for subsequent sessions
BCG (Freeze-dried, 20 doses)	68%	9%	15%
Polio (Liquid, 20 doses)	62%	16%	12%
DPT-HepB-Hib (Liquid, 4 doses)	49%	22%	27%
Cervarix (HPV, Liquid, 2 doses)	40%	27%	24%
MR (Freeze-dried, 10 doses)	73%	13%	15%



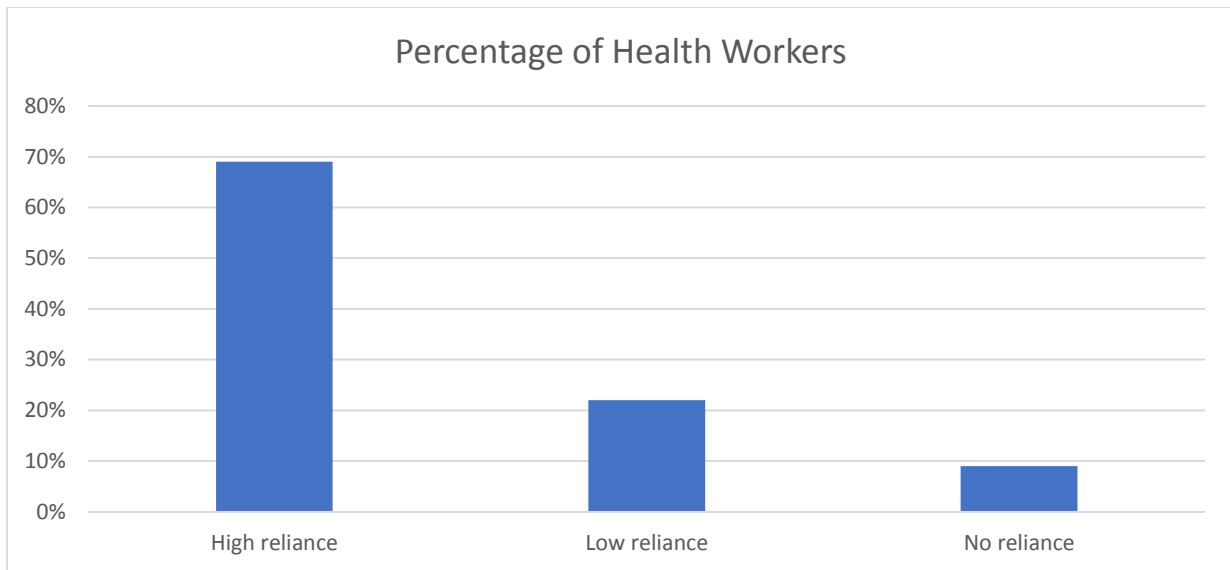
The outcomes of this study indicate that health workers' views and practices exhibit variability depending on the specific type of vaccine. Although there is a prevailing inclination to utilize opened multidose vials (MDVs) for subsequent sessions within a brief timeframe, typically up to one day, a certain level of prudence is exercised in the case of certain vaccines, such as Cervarix (HPV). This highlights the necessity of establishing explicit protocols and providing comprehensive instruction on the utilization of MDVs in order to guarantee the safety and effectiveness of vaccination initiatives.

5.9. VVM Location for Decision-Making

The examination of the extent to which health workers depend on the position of Vaccine Vial Monitor (VVM) as a determinant in their decision-making process regarding the utilization of opened multi-dose vials (MDVs) provides valuable insights into the tangible effects of VVMs on the management of vaccines. This section offers an analysis of the utilization of VVM location by health personnel and the underlying motivations driving their usage. The survey investigated the degree to which healthcare professionals consider the VVM position as a determining factor when making decisions about the utilization of opened multi-dose vials (MDVs). The data indicates that a significant percentage of healthcare professionals (about 65%) consider the VVM site to be a critical determinant in their decision-making process. This implies that the majority of healthcare professionals take into account the placement of the Vaccine Vial Monitor (VVM) when assessing the appropriateness of a previously opened vial for future immunization sessions.

Table 1: Extent of Reliance on VVM Location

Extent of Reliance on VVM Location	Percentage of Health Workers
High reliance	69%
Low reliance	22%
No reliance	9%



In order to enhance comprehension regarding the factors influencing health workers' utilization or non-utilization of VVM site, the survey procured qualitative data using open-ended inquiries. The participants' responses were systematically classified into distinct thematic categories. Healthcare professionals who expressed a significant dependence on Vaccine Vial Monitors (VVM) frequently cited reasons associated with their confidence in the technology's precision. The authors noted that Vaccine Vial Monitors (VVMs) has a clearly defined mechanism for color change that is contingent upon temperature exposure, hence establishing it as a dependable indicator of vaccine condition. Healthcare professionals additionally conveyed that the visible and easily comprehensible characteristics of the Vaccine Vial Monitor (VVM) color alteration facilitated prompt and well-informed decision-making. Certain individuals have referenced the utilization of Vaccine Vial Monitors (VVMs) as a means of mitigating the risk of giving contaminated vaccines to patients, hence augmenting the overall safety of patients. The primary factor cited by health professionals with limited dependence on Vaccine Vial Monitors (VVMs) was a perceived lack of trust in the reliability and precision of VVM readings. The individuals voiced apprehensions over the accuracy of Vaccine Vial Monitors (VVMs) in accurately measuring the heat exposure of vaccines. Consequently, they stated a preference for alternative indicators or practices. Certain

individuals have noted the intermittent challenge of appropriately reading the colors of the Vaccine Vial Monitor (VVM), which subsequently gives rise to a sense of unease. Some individuals argued that it was imperative to implement more safety precautions, such as reestablishing the cold chain for vials, even in cases when the Vaccine Vial Monitors (VVMs) indicated an acceptable condition.

A lesser proportion of healthcare professionals indicated a lack of dependence on VVM location. The rationales provided by individuals were diverse, with certain individuals attributing their stance to a limited knowledge of VVMs and an incomplete comprehension of their importance. Some individuals indicated that they utilized different approaches for assessing vaccines, such as visually examining the look of the vaccine or monitoring its temperature, without regarding the location of the Vaccine Vial Monitor (VVM) as a primary determinant. The findings of the investigation indicate that a considerable proportion of healthcare professionals consider the VVM position to be a pivotal consideration when making decisions about the utilization of opened multi-dose vials (MDVs). The primary reason for the significant dependence on this technology can be linked to the trust placed in its accuracy and its ability to improve patient safety. Nevertheless, some healthcare professionals exhibit minimal or nonexistent dependence on VVM location due to apprehensions regarding its accuracy or preference for alternate approaches. The aforementioned findings highlight the significance of continuous education and training for healthcare professionals in order to maintain a consistent and precise comprehension of Vaccine Vial Monitors (VVMs). Addressing concerns and misconceptions regarding Vaccine Vial Monitors (VVMs) is of utmost importance for immunization programs. It is crucial to provide comprehensive information in order to fully harness the potential of VVMs in enhancing vaccine management practices. Furthermore, conducting additional research and implementing guidance development initiatives could potentially mitigate the worries of healthcare professionals who

have limited or no dependence on vaccination Vial Monitors (VVM) placement. Ultimately, this would enhance the efficacy and consistency of vaccination management protocols.

5.10. Scenario-Based Decisions

The examination of health workers' decision-making about the choice of vaccination vials, based on scenarios, offers significant insights into the practical implications of vaccination Vial Monitors (VVMs) within their everyday practices. The subsequent piece of this study shows the outcomes derived from scenario-based inquiries, with a focus on the selection of vials by healthcare professionals in different situations. Additionally, this section delves into the factors that exert influence on these decision-making processes. The poll comprised of scenario-based inquiries, wherein healthcare professionals were tasked with selecting the appropriate vials for various immunization session scenarios. The findings demonstrate the inclinations of healthcare professionals across several settings.

Table 1: Health Workers' Preferences for Vial Selection in Scenario-Based Decisions

Scenario	Vial Selection Preferences
Fixed immunization center	OPV1 and OPV2
Short outreach (within 4 hours)	OPV1 and OPV2
Long outreach (48 hours)	OPV1 and OPV2

The data indicates a consistent inclination among healthcare professionals to opt for OPV1 and OPV2 vials in various contexts, including fixed immunization centers, brief outreach sessions (within 4 hours), and extended outreach sessions (spanning 48 hours). The inclination towards use OPV1 and OPV2 vials aligns with the established convention of prioritizing the initial vials within multi-dose presentations. In order to enhance comprehension of the determinants impacting the decision-making process of health workers in the given scenarios, the survey employed a qualitative approach by gathering data using open-ended

questions. The collected replies were subjected to analysis and subsequently classified into distinct thematic categories. Numerous healthcare professionals have expressed that their decision-making in scenario-based situations is in accordance with established rules and recommendations.

The significance of maintaining consistent practices in the administration of vaccines was underscored, with the aim of achieving consistency and safeguarding patient well-being. The utilization of OPV1 and OPV2 vials, particularly in fixed immunization centers, has been seen as a customary procedure that streamlines vaccine administration. The length of the immunization session was a factor that influenced the judgments of health personnel. In order to mitigate the potential for vaccine waste during brief outreach sessions lasting no longer than four hours, health professionals tend to prioritize the utilization of OPV1 and OPV2 vials. This preference is based on the fact that these particular vials are in closer proximity to their expiration dates. In contrast, health professionals showed a similar desire for extensive outreach visits lasting 48 hours, as it is in accordance with the sequential arrangement of vials. The health workers' choices were influenced by the duration of the outreach, whether it was short-term or long-term in nature. The authors stressed the need of utilizing the earlier vials, namely OPV1 and OPV2, in order to optimize the utilization of vaccines during brief outreach sessions, as these vials were more likely to be depleted rapidly. The utilization of OPV1 and OPV2 vials during extended outreach sessions was regarded as a proactive strategy aimed at mitigating vaccine wastage.

The findings from the examination of decisions based on scenarios indicate that health professionals regularly exhibit a preference for choosing OPV1 and OPV2 vials in various situations, in accordance with established protocols and norms. The choices made by individuals were influenced by the duration of the session and the nature of the outreach, with a particular focus on minimizing vaccine wastage and promoting efficient vaccination

administration. The aforementioned findings highlight the significance of adhering to established norms and rules in the management of vaccines, particularly in the context of outreach events. Furthermore, it underscores the necessity of ongoing training and education to strengthen optimal practices and decision-making protocols pertaining to vaccination selection across diverse circumstances.

5.11. Comments on Vaccine Vial Monitors (VVMs)

Within this particular area, we undertake an exploration of the qualitative remarks provided by healthcare professionals pertaining to Vaccine Vial Monitors (VVMs). The aforementioned remarks offer significant contributions in terms of understanding the practical encounters, perspectives, and anxieties of healthcare professionals. The qualitative feedback was obtained via open-ended questions in the survey, enabling healthcare professionals to openly articulate their opinions and apprehensions. The responses underwent analysis, wherein common themes and concerns were found.

Table 1: Key Themes in Health Workers' Qualitative Comments on VVMs

Themes	Frequency of Mention
VVM Accuracy	High
Confidence in VVMs	High
Impact on Vaccine Management	Moderate
Training and Awareness	Moderate
Suggestions for Improvement	Low

The predominant topic identified in the remarks of health workers pertained to their notable level of confidence about the precision and reliability of Vaccine Vial Monitors (VVMs). Numerous healthcare professionals have conveyed their contentment with the efficacy of Vaccine Vial Monitors (VVMs) in detecting thermal degradation, highlighting the

substantial role these devices play in preserving the integrity of vaccines. The comments frequently made reference to phrases such as "reliable tool" and "effective heat damage indicator," thereby emphasizing the users' confidence in the capabilities of VVMs. Expanding upon the topic of precision, healthcare professionals regularly expressed their heightened level of assurance in administering vaccines as a result of utilizing Vaccine Vial Monitors (VVMs). The individuals expressed their appreciation for the visual and easily comprehensible nature of Vaccine Safety Monitoring Systems (VVMs), which facilitated their assessment of vaccine safety. The feedback received suggested that the utilization of VVMs fostered a heightened level of confidence among healthcare professionals, particularly in situations involving multi-dose vials.

Healthcare professionals largely provided favorable opinions regarding VVMs; nevertheless, certain remarks also addressed the influence of VVMs on vaccine management protocols. Vaccine vial monitors (VVMs) were widely recognized as valuable instruments that effectively mitigated vaccine wastage, primarily by averting the utilization of vaccines that may have been compromised due to heat exposure. The acknowledgement of the impact on practice efficiency was attributed to the utilization of VVMs, which facilitated informed decision-making in the context of vial selection. A considerable proportion of the responses emphasized the significance of providing training and raising awareness about VVMs. Several healthcare professionals have acknowledged a need for more extensive training in order to improve their comprehension and effective application of Vaccine Vial Monitors (VVMs). Several remarks highlighted the necessity of implementing ongoing awareness initiatives aimed at ensuring health workers remain informed about optimal practices and the most recent advancements pertaining to VVMs. Although the incidence of suggestions for improvement was rather infrequent, a small number of healthcare professionals offered valuable advice. The recommendations encompassed enhancing the visibility and placement of VVMs on vials,

streamlining training resources, and organizing refresher training sessions. The aforementioned remarks demonstrated a proactive stance towards improving the utilization of VVM.

In general, the qualitative remarks provided by healthcare professionals highlight the favorable influence of VVMs on the treatment of vaccines. The individuals demonstrate a strong level of assurance regarding the precision of Vaccine Vial Monitors (VVMs) and the subsequent advantages they offer in terms of enhancing vaccine quality and minimizing wastage. The feedback provided suggests that health workers hold a positive view of VVMs and consider them to be helpful tools in their immunization procedures. Nevertheless, the relatively low occurrence of remarks pertaining to training and awareness implies that ongoing endeavors are necessary to guarantee that healthcare professionals receive sufficient training and information regarding Vaccine Vial Monitors (VVMs). In addition, the limited recommendations for enhancement underscore the significance of continuous refinement and optimization of processes and materials associated with VVM, with the aim of maximizing their efficacy and influence in the realm of vaccination management.

Chapter 6: Discussion

The findings of the study indicate that a significant proportion of healthcare professionals have had training in the utilization of Vaccine Vial Monitors (VVMs). This conclusion is deemed encouraging, as it is consistent with the standards set forth by the World Health Organization (WHO), which underscore the need of receiving training in vaccine management practices. Training plays a crucial role in ensuring that healthcare professionals possess a comprehensive understanding of the importance of VVMs (vaccine vial monitors) and are able to utilize them proficiently. Nevertheless, there were variations in the duration and frequency of training reported by the respondents, indicating potential areas for enhancement. As per the recommendations provided by the World Health Organization (WHO), it is imperative to implement consistent and well-organized training initiatives that comprehensively cover all facets of vaccine management, which includes the utilization of Vaccine Vial Monitors (VVMs). Hence, it is imperative for organizations to prioritize the implementation of standardized and regular training programs in order to sustain the competence of health workers.

The good consequence of a large number of health workers expressing confidence in the accuracy of VVM is noteworthy. Vaccine vial monitors (VVMs) are specifically engineered to offer a concise and unambiguous indicator of thermal damage, so empowering healthcare professionals to make well-informed judgments regarding the safety of vaccines. The level of trust expressed here is consistent with established global standards for vaccine management, wherein Vaccine Vial Monitors (VVMs) are recognized as essential components in ensuring the quality of vaccines. The World Health Organization (WHO) acknowledges the significance of Vaccine Vial Monitors (VVMs) and offers comprehensive recommendations for their utilization. The results of our study provide empirical evidence that the utilization of VVMs

enhances the level of confidence among health professionals in properly administering vaccines.

This study emphasizes a significant proportion of healthcare professionals who have chosen to discard vaccinations as a result of visual vaccine vial monitor (VVM) signals indicating heat-related damage. The aforementioned studies highlight the significance of Vaccine Vial Monitors (VVMs) in mitigating vaccine waste. The guidelines set forth by the World Health Organization (WHO) underscore the significance of viral vector vaccines (VVMs) in terms of their economic and public health advantages, with a primary focus on mitigating vaccine waste. Vaccine Vial Monitors (VVMs) aid healthcare professionals in preventing the administration of vaccines that may be compromised, hence ensuring the efficacy and safety of the immunization process. In addition to the preservation of precious resources, the maintenance of public trust in immunization programs is also guaranteed. The results moreover indicate that a significant portion of healthcare professionals successfully preserved vaccines following a disruption in the cold chain, thanks to the utilization of Vaccine Vial Monitors (VVMs). This is consistent with established global vaccine management protocols, as Vaccine Vial Monitors (VVMs) are recognized as approved instruments for evaluating vaccine potency in such situations. The use of Vaccine Vial Monitors (VVMs) under such circumstances exemplifies their pragmatic significance in safeguarding the quality and accessibility of vaccines. It is imperative that healthcare professionals possess the necessary knowledge and competencies to appropriately utilize Vaccine Vial Monitors (VVMs) in unforeseen instances of cold chain disruptions.

A considerable proportion of healthcare professionals indicated modifications in their vaccination management strategies as a result of vaccination Vial Monitors (VVMs). The aforementioned modifications demonstrate the capacity of healthcare professionals to adjust in light of the implementation of Vaccine Vial Monitors (VVMs). The authors emphasize that

VVMs possess an active function in educating and influencing the behaviors of healthcare professionals, rather than simply serving as passive indicators. The adoption of this change aligns with international norms that prioritize the importance of an adaptable and adaptable system for managing vaccines. The study additionally examined the impact of VVMs on the selection of vials by healthcare professionals throughout various immunization sessions. The findings suggest that Vaccine Vial Monitors (VVMs) have a significant impact on decision-making processes, particularly in relation to multi-dose vials. The preference of health workers for vials equipped with Vaccine Vial Monitors (VVMs) in different situations highlights the practical importance of these devices in the management of vaccines. These preferences are in accordance with the requirement for effective and dependable indications to facilitate the administration of vaccines.

Diverse perspectives and practices were seen among health professionals in relation to their beliefs of the safety and length of utilizing opened multi-dose vials for subsequent sessions. This implies that health practitioners' decision-making about the reuse of vials is influenced by factors that extend beyond the usage of VVMs. The standards set forth by the World Health Organization (WHO) place significant emphasis on the evaluation of vial safety through the analysis of Vaccine Vial Monitors (VVM) values, as well as other pertinent factors. Hence, it is imperative to augment the utilization of VVMs with complete protocols in order to guarantee the maintenance of consistent and secure procedures.

The results of this study have substantial implications for the management of vaccines and indicate prospective avenues for enhancement. The management of vaccinations is a multifaceted procedure that necessitates meticulous adherence to established protocols and the utilization of equipment such as Vaccine Vial Monitors (VVMs) in order to guarantee the integrity and safety of vaccines. This analysis will explore the ramifications of the study's findings on vaccination administration and the possible enhancements that can be

implemented. The findings of the study indicate that a notable proportion of healthcare professionals have undergone training on VVMs. However, there exist inconsistencies in terms of the length and regularity of the training sessions. The presence of this inconsistency suggests a necessity for uniformity and a heightened focus on systematic and structured training initiatives. It is imperative to provide comprehensive training to health workers in order to ensure their thorough understanding of the technical features of Vaccine Vial Monitors (VVMs) as well as their larger significance in the management of vaccines. It is imperative for health organizations and governments to allocate resources towards continuous training programs aimed at ensuring health professionals remain well-informed and proficient in the appropriate utilization of Vaccine Vial Monitors (VVMs).

The substantial proportion of healthcare professionals feeling a sense of assurance regarding the accuracy of Vaccine Vial Monitors (VVMs) is indicative of a favorable trend. This statement suggests that Vaccine Vial Monitors (VVMs) are widely recognized as reliable instruments for evaluating the quality of vaccines. The presence of confidence plays a crucial role in the effective management of vaccines, as it facilitates the process of making informed decisions and mitigates the risk of unnecessary vaccine loss. The present suggestion posits that the ongoing utilization of VVMs has paramount importance, necessitating the continuous reinforcement of their significance to health workers in the context of vaccination quality control. The reinforcement of this confidence can be achieved by implementing targeted awareness campaigns and training programs. The findings of the study underscore the significance of Vaccine Vial Monitors (VVMs) in mitigating the occurrence of vaccine wastage resulting from heat-induced deterioration. The use of vaccine management practices presents a distinct advantage by guaranteeing the administration of vaccinations in their optimal and secure condition. The decrease in the number of wasted vaccines not only helps to preserve resources but also enhances the overall effectiveness of immunization programs. In order to

effectively leverage this advantage, it is imperative for health organizations to actively promote the utilization of VVMs, while also ensuring that supply chains are equipped with sufficient quantities of vaccinations that are appropriately labeled with VVMs.

The research findings demonstrate that Vaccine Vial Monitors (VVMs) have played a crucial role in preserving vaccines following instances of cold chain disruptions. The aforementioned findings have substantial ramifications for the management of vaccines, particularly in areas where disruptions to the cold chain are more prevalent. This statement emphasizes the significance of ensuring the accessibility of vaccinations equipped with VVM (vaccine vial monitors) in field settings to effectively respond to unforeseen circumstances. The maintenance of vaccine quality and public confidence is contingent upon the provision of vaccines, particularly in geographically isolated or underserved regions. The results suggest that healthcare professionals have modified their approaches in response to Vaccine Vial Monitors (VVMs). The underlying suggestion is that the management of vaccines is not a fixed process; rather, it should possess the ability to adjust and react to emerging tools and technology. It is imperative for health organizations and governments to actively promote and endorse the concept of adaptability, while also offering comprehensive recommendations on the seamless integration of vaccination Vial Monitors (VVMs) into current vaccination management protocols. These guidelines serve the purpose of establishing a standardized approach towards the utilization of VVMs, so ensuring the optimization of their potential.

The findings of the study indicate that the use of VVMs has a significant impact on the decision-making process of health workers when selecting vials in various situations. The findings of this study have significant significance for the management of vaccines, as they indicate that healthcare professionals should prioritize the utilization of vials labeled with Vaccine Vial Monitors (VVM) due to their perceived safety and reliability. In order to maximize this advantage, it is imperative for health organizations and governmental bodies to

establish a consistent provision of vaccines equipped with Vaccine Vial Monitors (VVMs). Furthermore, it is imperative to provide comprehensive training to healthcare professionals regarding the critical role of Vaccine Vial Monitors (VVMs) in the effective management of vaccines, hence enhancing their significance and impact. The complexity of decision-making in the context of reusing opened multi-dose vials is evident via the diverse perceptions and practices seen among health practitioners. The underlying suggestion is that although VVMs possess inherent value as tools, their utilization should be accompanied by detailed recommendations that consider multiple elements, including the particular type of vaccination and the circumstances surrounding its application. It is imperative for health institutions to furnish explicit and comprehensive guidelines pertaining to the reuse of unsealed vials, taking into account the readings of Vaccine Vial Monitors (VVM) as one among other indicators.

6.1. Conclusion

The objective of this study was to examine the effects of Vaccine Vial Monitors (VVMs) on the distribution and utilization of vaccines, as well as their significance in the context of vaccine management. The study centered on the knowledge and training of healthcare professionals with regards to Vaccine Vial Monitors (VVMs), their level of confidence in the accuracy of VVMs, the influence of VVMs on vaccine wastage caused by heat damage, the preservation of vaccines following disruptions in the cold chain, modifications in vaccine management practices, utilization of multi-dose vials, the utilization of previously opened multi-dose vials for subsequent sessions, the placement of VVMs for decision-making purposes, decision-making based on scenario analysis, and feedback from healthcare professionals regarding VVMs. The results of this investigation unveil a number of significant revelations. To begin with, a considerable proportion of healthcare professionals have had training pertaining to Vaccine Vial Monitors (VVMs), but with variations in the duration and frequency of such training. This highlights the significance of implementing standardized and

consistent training programs to guarantee that healthcare professionals possess the necessary skills and knowledge to utilize VVMs proficiently.

Additionally, the research findings indicate that a significant proportion of healthcare professionals exhibit a high level of assurance regarding the precision of Vaccine Vial Monitors (VVMs). Confidence plays a crucial role in the effective management of vaccines, as it serves as a valuable source of information for decision-making processes and aids in the prevention of potential vaccine wastage. In order to uphold and strengthen this sense of assurance, it is advisable to implement focused efforts aimed at raising awareness, as well as establish continuous training initiatives. Additionally, the research emphasizes the favorable influence of VVMs in mitigating the wastage of vaccines caused by heat-induced deterioration. This results in enhanced vaccine management through resource conservation and the assurance of vaccine quality. In order to fully leverage this advantage, it is imperative to promote the utilization of VVMs and guarantee the accessibility of vaccines labeled with VVMs across supply chains. One notable discovery is that Vaccine Vial Monitors (VVMs) have played a crucial role in preserving vaccines following instances of cold chain disruptions. This holds particular significance in regions where cold chain interruptions are more prevalent. This statement underscores the significance of ensuring the accessibility of vaccines equipped with VVM (vaccine vial monitors) in field settings, in order to effectively respond to unforeseen circumstances and uphold the integrity of vaccine efficacy.

Furthermore, the findings of the research suggest that healthcare professionals have modified their strategies for vaccination management as a result of the implementation of vaccine Vial Monitors (VVMs). The cultivation of flexibility is crucial in effectively responding to emerging tools and technologies, and it is imperative to promote its development. The provision of explicit instructions about the incorporation of VVMs into current procedures can contribute to the establishment of uniformity in their utilization and the optimization of

their capabilities. Furthermore, the presence of Vaccine Vial Monitors (VVMs) has a significant impact on the decision-making process of health workers regarding the selection of vials in various situations. This suggests that health workers perceive vials labeled with VVMs to be more secure and dependable. In order to maximize the advantages, it is advisable to provide a consistent provision of vaccinations equipped with Vaccine Vial Monitors (VVMs), alongside educational initiatives aimed at promoting awareness of their importance in vaccine management. The complexity of decision-making in the context of reusing opened multi-dose vials is seen in the diverse perceptions and practices observed among health practitioners. This highlights the necessity of implementing comprehensive rules that take into account a multitude of issues. It is imperative for health organizations to furnish explicit and comprehensive guidelines pertaining to the reuse of unsealed vials, taking into account the utilization of Vaccine Vial Monitors (VVM) as one among various indicators.

The study's findings give rise to many recommendations and identify potential avenues for future research. It is recommended that health organizations and governments implement standardized training programs aimed at equipping health workers with the necessary knowledge and skills pertaining to Vaccine Vial Monitors (VVMs). It is imperative that these programs exhibit a well-organized framework, adhere to a consistent schedule, and encompass both the technical intricacies as well as the broader dimensions of VVM utilization. In order to uphold the confidence of health workers in the accuracy of Vaccine Vial Monitors (VVMs), it is recommended that awareness campaigns be implemented to emphasize the importance of VVMs in the control and management of vaccine quality. These advertisements can function as periodic prompts highlighting the significance of VVMs. The optimization of advantages associated with vaccine indicators necessitates the imperative task of ensuring a reliable and uninterrupted provision of vaccines equipped with Vaccine Vial Monitors (VVMs). It is imperative for supply chains to possess a sufficient quantity of vaccines labeled with VVM

(vaccine vial monitor) in order to effectively manage variations in demand and unforeseen circumstances. Health organizations must to offer unambiguous and thorough directives pertaining to the reutilization of unsealed multi-dose vials, taking into account several elements beyond the readings of the Vaccine Vial Monitor (VVM), such as the type of vaccine and the circumstances under which it is employed. Subsequent investigations may delve into the precise ramifications of VVMs on rates of vaccination coverage and their cost-effectiveness. Furthermore, there is a need for further comprehensive research to investigate the various elements that influence the decision-making process of healthcare professionals when it comes to the use of unsealed vials.

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Appendices





Questionnaire for a KAP survey on the impact of VVMs on delivery and use of vaccines






Name	
Gender	Male <input type="checkbox"/> Female <input type="checkbox"/>
Position	
Health Centre or Store	
Location	
District	
Province	
Years in service (how many years you have been working in immunization?)	

No	Question			Comments
1	Have you been trained in the use of VVM?	Yes	No	
	If YES, when was the last time you were trained?			
	If YES, how long was the training?			

2	Do you think VVMs can detect whether a vaccine is damaged by heat?	Yes	No	
3	Are you confident that VVMs are accurate? If NO, explain why.	Yes	No	
4	Did you discard any vaccine during your practice because the VVM showed that it had been heat-damaged?	Yes	No	
5	Were you able to save any vaccine after a cold chain break because VVM showed that it was not heat-damaged?	Yes	No	
6	Do VVMs make you feel confident about handling vaccines?	Yes	No	
7	With VVMs, have you changed the way you keep and transport vaccines?	Yes	No	
	If YES, in what way?			
8	<p>If you received the following vaccine to your facility, would you accept it?</p> 	Yes	No	

	If No, explain why?			
10	<p>If you have a fixed immunization session in your health centre, which vial you use first?</p> 	Dark	Light	
	Explain why?			
11	If you are going for outreach that would take more than a day, which vial (from the above photo in question #10) would you take?	Dark	Light	
	Explain why?			
12	Once opened, how long can you keep these vials for use? Can you use them for subsequent immunization sessions?			

		<p>BCG vaccine</p> <p>Freeze-dried</p> <p>20 doses</p>	<p>Once opened, how long can you keep the vial for use?</p> <p>.....</p>
			<p>Explain why?</p>
		<p>Polio vaccine</p> <p>Liquid 20 doses</p>	<p>Once opened, how long can you keep the vial for use?.....</p>
			<p>Explain why?</p>
		<p>DPT-HepB- Hib vaccine</p> <p>Liquid</p> <p>4 doses</p>	<p>Once opened, how long can you keep the vial for use?</p> <p>.....</p>
			<p>Explain why?</p>
		<p>Cervarix (HPV vaccine)</p> <p>Liquid</p> <p>2 doses</p>	<p>Once opened, how long can you keep the vial for use?</p> <p>.....</p>
			<p>Explain why?</p>

	 <p>MR vaccine Freeze-dried 10 doses</p>	<p>Once opened, how long can you keep the vial for use?</p> <p>.....</p>			
		<p>Explain why?</p>			
<p>13</p>	<p>Can location of the VVM help you to decide whether you can use an open multi-dose vial for a subsequent immunization session?</p>	<p>Yes</p>	<p>No</p>		
	<p>If YES, explain how.</p>				
	<p>If NO, explain why not.</p>				
<p>14</p>	<p>You have the following vaccines in your health centre fridge. Please indicate which vial to pick first for the given scenarios below (mark the right answer on the right of the question):</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>OPV - 1</p>  <p>Exp. 10.2020</p> </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>OPV - 2 OPENED</p>  <p>Exp. 09.2020</p> </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>OPV - 3</p>  <p>Exp. 10.2020</p> </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>OPV - 4</p>  <p>Exp. 08.2020</p> </div> </div>				
	<p>Fixed immunization centre</p>	<p>OPV1</p>	<p>OPV2</p>	<p>OPV3</p>	<p>OPV4</p>

	Short outreach – Departing from the health centre, conducting the outreach session and come back is within 4 hours	OPV1	OPV2	OPV3	OPV4
	Long outreach - Departing from the health centre, conducting the outreach session and come back is 48 hours	OPV1	OPV2	OPV3	OPV4
15	Do you have any comments on VVMs?				