IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Design and Development of Portable Refrigerated Vaccine Storage Device by Using Thermal Energy

Avadhut A. Mali*[1],Prathmesh R. Nikam*[2],Shreyas V. Kamble*[3],Piyush A. Joshi*[4],Chaitanya N. Kumbhar*[5],Rohit R. Wadingekar*[6],Rohit P. Choudhari*[7] and Paresh M. Wadekar*[8]

[*1,2,3,4,5,6,7]Undergraduate, Department of Mechanical Engineering, AnnasahebDange Collage of Engineering and Technology, Ashta.Pin. 416301, Maharashtra, India.

[*8]Assistant Professor, Department of Mechanical Engineering, AnnasahebDange Collage of Engineering and Technology, Ashta.Pin. 416301, Maharashtra, India.

Abstract: Vaccination is one of the most effective disease prevention strategies when implemented properly across all sections of the at-riskpopulation. The system used for keeping and distribution vaccines in good condition is called as “cold chain”. Cold chain is a system of storing and transporting vaccine at the recommended temperature range(2°C-8°C) from manufacturing to the point of use. When vaccines are preserved bellow or above the prescribed temperature range its potency may lose. This paper explores the system of portable refrigerated vaccine storage device by using Phase Change Material(PCM).In this experimental work, an attempt has been made to reduce temperature fluctuation occurred by power cut OFF as well as because of frequently opening and closing the door of system.The main objective of this system to improve cooling performance of system and maintain constant temperature of system by using Phase Change Material(PCM) which is essential for Vaccine Storage. This experimental setup is portable to transfer Vaccine from one place to another place.The experiment shows that the evaporator temperature remainsconstant in range of (2°C-8°C) when PCM is used.

Keywords: Cold Chain, Vaccine, PCM, Fluctuation, Cooling Performance.

I INTRODUCTION

The System used for keeping and distributing vaccines in good condition is known as the "cool chain." Cold Chain is an arrangement of putting away and shipping vaccines at the required temperature range (2°C-8°C) from the mark of assembling to point of utilization [1].The preservation of vaccines at required temperature (2°C to 8°C) is helpful according to two perspectives (1) Economical Point of View: The expense of a solitary vaccine may go up to $285, which is extravagant. In old vaccine system ordinarily 2-3 vaccines will be damaged in one box during the entire day in summer season. Every year, a great many rupees worth of vaccines is damaged in the India because of improper transportation of vaccine and storage. (2) Health perspective: The harmed vaccine is extremely unsafe for patients. Individuals can pass on utilization of such damaged vaccine[2].Vaccines are sensitive biological substances that gradually loose their potency with time and this loss of potency can be increases when stored out of temperature range[3]. Vaccine stockpiling plate or boxes can hinder refrigerator wind stream, making regions pockets of colder or hotter air. Vaccines stored in specific areas, for example, close to the refrigerator cooling unit, might be kept essentially colder than if set in the main body of the refrigerator. From the above discussion it is concluded that a refrigeration system which is portable, eco-friendly, economical and consuming less amount of electricity should be designed and that will be a better option for vaccine storage and is cold chain.

Energy storage is the key technology that can be utilized to tackle this emergency. Thermal Energy Storage (TES) technology is a sort of successful techniques to improve the thermal energy management efficiency and mitigate the inconsistency between supply and deemand energy. TES technology utilizing phase change materials (PCMs), which can reversibly store and delivery a lot of thermal energy[4], is an effective technology to improve the energy emergency and environmental issues. Thermal energy can be stored in the form of sensible heat storage,latent heat storage and chemical reaction storage. Contrast with sensible heat storage and thermo-chemical storage, latent heat storage with phase change materials (PCMs) has benefits like high energy density and little temperature swing during liquidation and solidification. Latent heat storage (LHS) with PCM as TES media has caused incredible interest among scientists because of its higher energy storage density and smaller temperature variation. Vaccine transporters are protected holders that, when fixed with coolant packs, keep vaccines and diluents cold during transportation [5]. They are more modest than cold boxes and are simpler to convey when strolling. They are utilized for moving vaccines from health facilities with refrigeration to outreach session where refrigeration and ice are not accessible. They are regularly conveyed by a single health worker by walking or by different methods, where the consolidated excursion time and inoculation movement goes from a couple of hours to an entire day. The vaccine storage limit of antibody transporters is somewhere in the range of 0.1 and 5.0 liters.

IILITERATURE REVIEW

L D saraswati, et.al[1]: Cold chain is a system to keep up vaccine in certain temperature, to guarantee the vaccine has strong state, from the maker to the individual being vaccinated. Infrastructure of cold chain comprises of cool room, cooler, refrigerator, cool box, cool pack, vaccine transporter, and generator. The cold chain is significant for public vaccination programs in tropical climate countries. Preferably, high inclusion of vaccine results in high immunity. Good practices to maintain proper vaccine storage and handling can ensure that the full benefit of immunization is realized.

MagaliCattinaet.al[2]: Each year, more than 1.5 million people die from a disease that could have been prevented with vaccination. In order to maintain their full potency,vaccines need to be stored between 2°C to 8°C and this effect is apply to whole cold chain. However more than 25% of vaccines is annually wasted,primarily due to the inability to maintain the optimal temperature range along the cold chain.

Martin NdinakieYakum et.al[3]: Immunization is the most precious gift that a health care worker can give a child and it remains the most cost effective preventative health intervention presently known. Vaccinesare sensitive biological substances that lose their potency if they are stored above or below recommended temperature. Consequently, a proper storage of vaccines at the recommended temperature conditions is vital so that vaccine's potency is retained up to the moment of administration.

Avesahemad S. N. Husainy, et.al[4]: In recent decades, though there have been improvement made to the productivity of agriculture processes, losses and wastage of food is still common. In emerging countries like India, still the problem of power outage exists which affects the performance of refrigeration systems. Therefore, food quality, energy consumption and compressor durability are all affected by a power outage. In the ordinary the compressor works in ON-OFF mode. The refrigerant present inside the evaporator coil takes the cabinet heat during compressor ON mode. And during the OFF mode of the compressor, the temperature within the evaporator cabin starts rising because of heat released by the food and due to ambient situations. This compressor ON and OFF makes a temperature fluctuation within the evaporator section that decreases the quality of the food. Using phase change materials mixed with nanoparticles as a latent heat thermal energy storage system could be a novel option for performance enhancement of the refrigeration system by increasing heat transfer of the evaporator.

Yi Zhao, et.al.[5]: According to the temperature prerequisites of drug cold chain coordination, the aim is to develop phase change materials with a phase transition temperature of 2 °C ~ 8 °C. In this investigation, a mixed solution of tetradecane (TD) and laurel liquor (LA) was chosen as the base fluid. Taking into account the low thermal conductivity of organic phase change materials, extended graphite (EG) was added to TD-LA to improve the thermal conductivity. This study also develops another kind of cold storage device for vaccine, which can monitor real time temperature of vaccine on the user's phone.

III EXPERIMENTATION AND OBSERVATIONS

Fig.No.1 (a) PCM enclosed in cooling pack (b) Actual set-up front view

In the conventional cold chain facilities the compressor works in on-off mode. During compressor on mode the refrigerant of the evaporator coil takes the cabinet heat from the cabin resulting in providing cooling effect to the cabinet and its occupant. During the off mode of the compressor, the temperature inside the evaporator cabin starts rising due to heat released by the vaccines and also due to ambient conditions. This on and off makes a temperature fluctuation (temperature rapidly rise and drop) inside the evaporator cabinet which ultimately decrease the grade of vaccines. The physical and chemical changes caused the loss of quality of the product. Use of thermal storage mitigates the gap between demand and supply. So different phase change material like Silica Gel, Water, KCl are used for maintain constant temperature inside the cabinet for longer duration of time even though power outage and temperature exists. The VCRS system implemented in the setup maintains the optimum temperature of 2-8 degree Celsius inside the cold box, when there is availability of power. The Phase Change Materials are maintained at their particular freezing point so that they can be implemented during the power outage conditions. During power cut-off conditions, the PCM containers are kept in the cold box so that they can transfer the cooling effect to the vaccines and vaccines will constantly be maintained at the temperature of 2-8 degree Celsius.Phase change materials (PCMs) based thermal energy storage (TES) has proved to have great potential in various energy-related applications. The high energy storage density enables TES to eliminate the imbalance between energy supply and demand.The use of PCM provides higher heat storage capacity and more isothermal behavior during charging and discharging compared to sensible heat storage. Using Phase Change Materials (PCM) as a latent heat thermal energy storage (TES) system could be a new option for performances improvement of any refrigerating system by increasing heat transfer of the evaporator and reducing efficiency losses of the compressor. These materials when used in a particular composition inside the cooling pads and in kept in the besides the evaporator coil can improve the performances of refrigerating system by increasing its compressor cut-off time and thereby minimizing electrical energy usage. The main objective is to improve the performance, cooling time period, storage capacity and to maintain the constant cooling effect for more time during power cut off hours using phase change material.

TABLE 1. Comparison of reading of silica gel with and without considering effect of door opening

Time (in Hr:Min:Sec)	T1 (In Degree Celsius) Cabinet temperature	T1(In Degree Celsius) Cabinet temperature with effect of door opening
0:00:00	0	0
0:02:00	-1	1
0:12:00	0	2
0:25:00	1	2
1:00:00	1	3
1:30:00	2	3
2:00:00	2	3
2:30:00	2	4
3:00:00	2	4
3:30:00	2	4
4:00:00	2	5
4:30:00	2	5
4:51:00	2	5
5:00:00	2	6
5:30:00	2	6
6:00:00	3	6
6:30:00	3	7
7:00:00	4	7
7:30:00	4	7
8:00:00	4	7
8:30:00	4	8
9:00:00	4	8
9:30:00	4	9
10:00:00	4	9
10:30:00	5	10
11:00:00	5	10

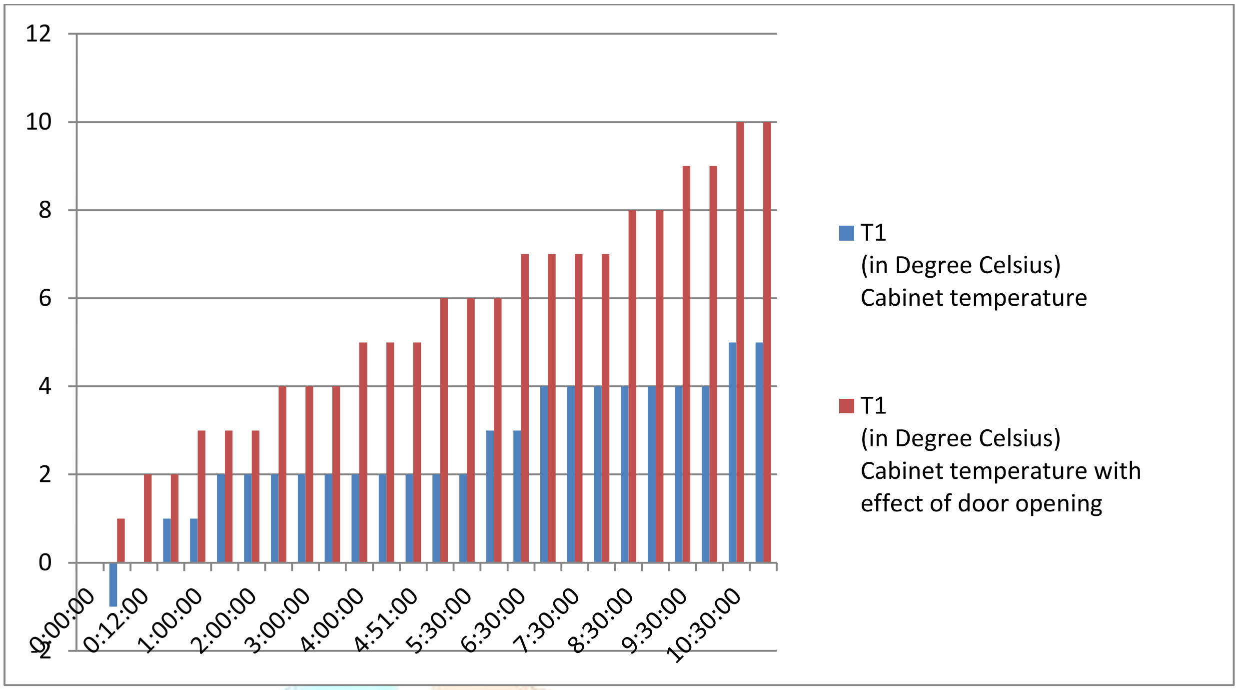

FIGURE 2. Time vs Cabinet temperature when Silica gel as a PCM with and without considering effect of door opening

TABLE 2.With KCL (5%) as a PCM and without opening door

Time (in Hr:Min:Sec)	T1 (in Degree Celsius) Cabinet temperature	T2 (in Degree Celsius) PCM Temperature
0:00:00	-3	-3
0:30:00	-2	5
0:41:00	-1	5
1:06:00	1	5
1:30:00	2	4
3:02:00	3	4
3:47:00	4	4
4:38:00	5	5
5:34:00	6	10
6:32:00	8	11
7:13:00	8	11
7:34:00	8	11
8:00:00	8	11
8:25:00	8	11
8:25:00	9	12

TABLE 3. With KCL (10%) as a PCM and without opening door

Time (in Hr:Min:Sec)	T1 (in Degree Celsius) Cabinet temperature	T2 (in Degree Celsius) PCM Temperature
0:00:00	-3	-2
0:30:00	-2	4
0:41:00	-2	4
1:06:00	-1	4
1:30:00	-1	5
3:02:00	1	6
3:47:00	2	6
4:38:00	3	6
5:34:00	3	6
6:32:00	4	7
7:13:00	4	8
7:34:00	4	8
8:00:00	5	9
8:25:00	6	10
8:25:00	7	11

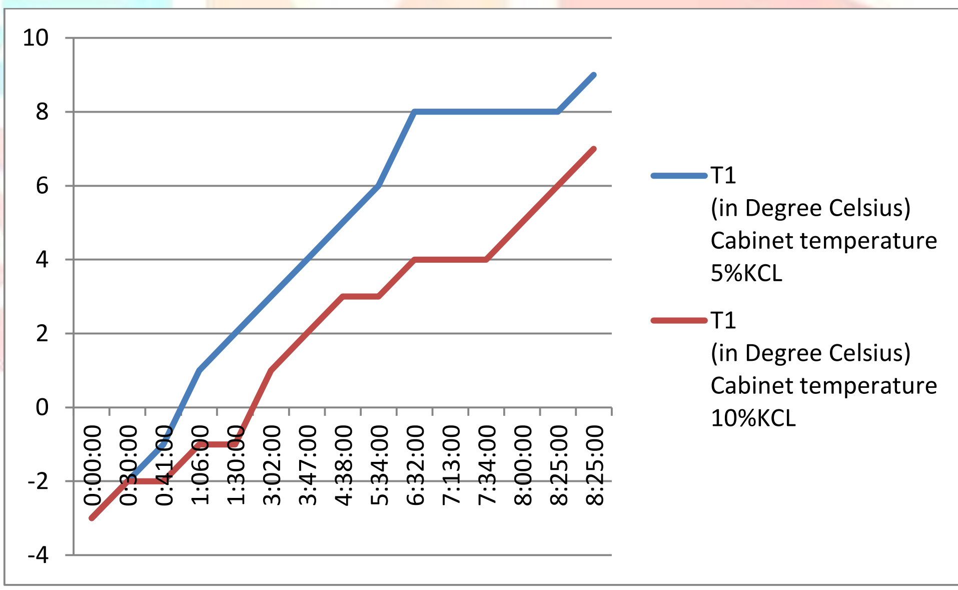

FIGURE 3. Comparison of temperature between 5% KCL as a PCM and 10% KCL as a PCM

TABLE 4.With water as a PCM and without opening door.

Time (in Hr:Min:Sec)	T1 (in Degree Celsius) Cabinet temperature	T2 (in Degree Celsius) PCM Temperature
0:00:00	0	5
0:13:00	1	5
0:23:00	2	5
0:46:00	3	5
1:17:00	4	6
2:03:00	5	6
2:46:00	6	6
3:22:00	7	7
4:06:00	7	8
4:37:00	7	8
4:57:00	7	9
5:17:00	7	9

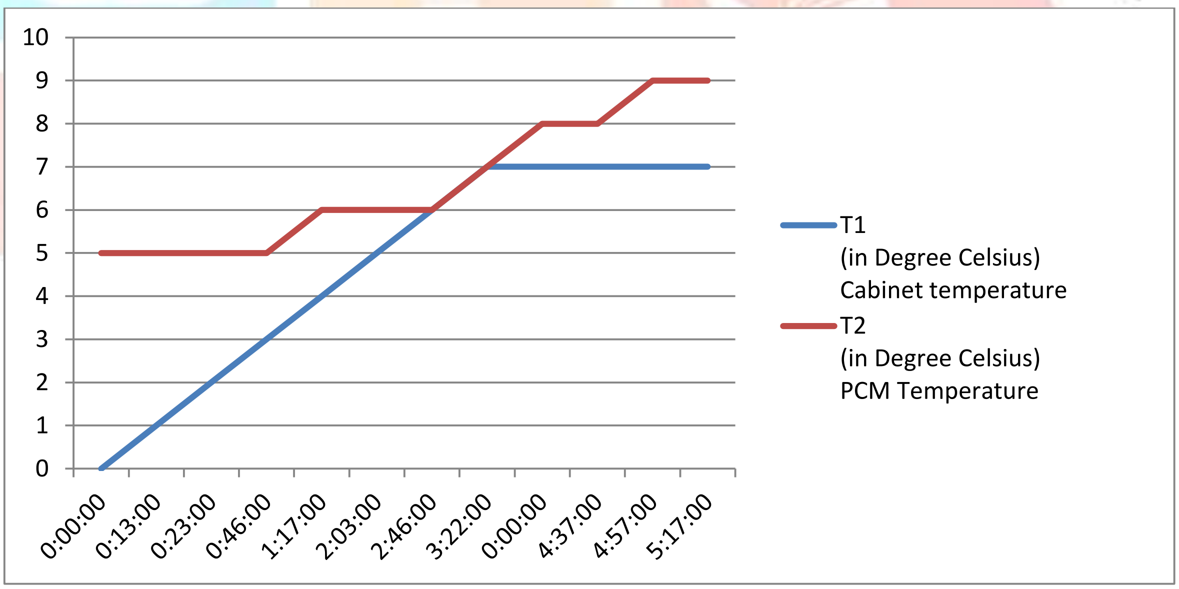

FIGURE 4. Temperature distribution of cabinate Water as a PCM

TABLE 5.Comparison of various PCM with normal set up

Time(Hr:Min:Sec)	Cabinet temperature T (In degree Celsius) NORMAL SET UP	T1 (in Degree Celsius) Cabinet temperature SILICA PCM	T1 (in Degree Celsius) Cabinet temperature 5%KCL PCM	T1 (in Degree Celsius) Cabinet temperature 10%KCL PCM	T1 (in Degree Celsius) Cabinet temperature with water PCM
0:00:00	0	0	-3	-3	0
0:03:00	2	-1	-2	-2	1
0:06:00	3	0	-1	-2	2
0:10:00	4	1	1	-1	3
0:16:00	5	1	2	-1	4
0:23:00	6	2	3	1	5
0:28:00	6	2	4	2	6
0:33:00	8	2	5	3	7
0:39:00	9	2	6	3	7
0:43:00	10	2	8	4	7
0:49:00	11	3	8	4	7

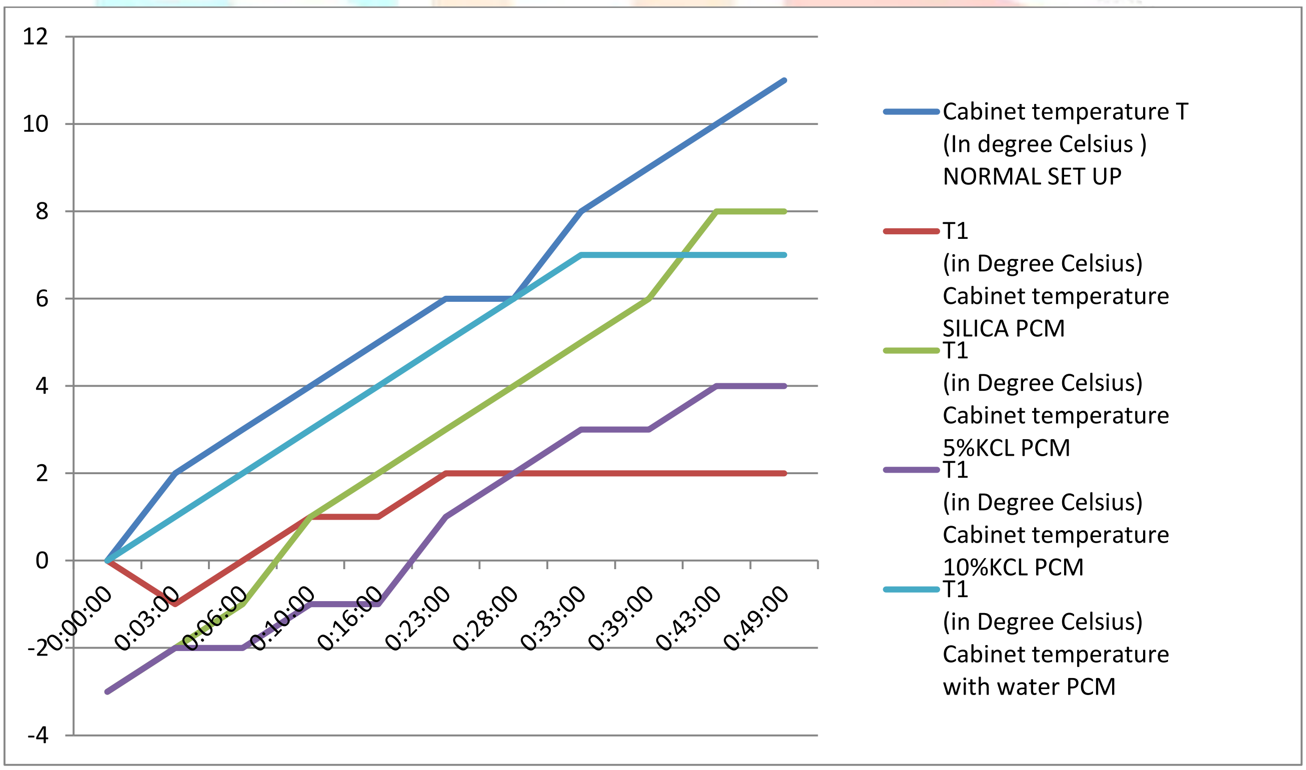

FIGURE 5. Comparison of various PCM with normal setup

IV Conclusion

Experimentation had been carried out on Refrigerated vaccine storage container to investigate the performance of a refrigeration vaccine container using different combinations and mass fractions of PCM during power outages. Experiments were carried out under different mass fraction of KCl (5% & 10%), Silica gel and H2O phase change material. The number of compressor on -off cycle within a certain periodic time for different PCMs and without PCM can be pointed up. Use of Silica gel it has been possible to maintain evaporator cabinet temperature from 30C for 4 to 5 hrs. Use of KCl 5% it has been possible to maintain evaporator cabinet temperature from 80C for 4 to 5 hrs. Use of KCl 10% it has been possible to maintain evaporator cabinet temperature from 40C for 4 to 5 hrs. Using water as PCM and certain thermal load it is found that the 70C for 4 to 5 hrs. While without out use of PCM continuous temperature drops takes places. For vaccine storage it is necessary to maintain temperature 2 to 80C. During the compressor running the refrigerant takes the chamber heat by free convection in case of without PCM, which is slower heat transfer process in respect to conduction process. But PCM most of the heat in the cabinet is stored in the PCM during compressor running time. Moreover, due to high operating pressure and temperature of the evaporator the density of the refrigerant vapor increases, as a result the heat extracted from the evaporator by the fixed volumetric rate compressor is higher than without PCM. From experimentation, it has been proven that the use of thermal storage in vaccine storage maintained a constant temperature for a longer duration of time.

REFERENCES

1. "Performance analysis of vapour compression and vapour absorption refrigeration units working on photovoltaic power supply", Sharma, N.K., Singh H., Sharma M.K. and Gupta, B.L., International Journal of Renewable Energy Research,2016.
2. "Evaluation of the Cold-Chain for Oral Polio Vaccine in a Rural District of India", Samant Y., Lanjewar H., ParkerD., Block L.,Tomar G. S., & B. Stein. Public Health Reports, 122(1), 112–121. doi:10.1177/003335490712200116, , 2007.
3. "The origins of the vaccine cold chain and a glimpse of the future",Lloyd J. and Cheyne J., Vaccine, 35(17), pp.2115-2120, 2017.
4. "Reducing Temperature Fluctuation of Refrigeration System by Incorporating Nano-Phase Change Materials", Avesahemad S. N. Husainy, Gajanan. V. Parishwad, Siddhanath V. Nishandar, AIP Conference Proceedings 2335, 040010 (2021), 2021.
5. "Experimental study on a solar photovoltaic DC refrigerator In Applied mechanics and materials", Xi, Guan & Cai, Chun & Li, Jian & Deng, Yong, (Vol. 316, pp. 109-112). Trans Tech Publications Ltd. 2013.
6. "Using solar-powered refrigeration for vaccine storage where other sources of reliable electricity are inadequate or costly", McCarney S., Robertson J., Arnaud J., Lorenson K. and Lloyd J., Vaccine, 31(51), pp.6050-6057, 2013.
7. "Development of Composite phase change cold storage material and its application in vaccine cold storage equipment".Yi Zhao,Xuelai Zhang, Xiaofeng Xu, Shihua Zhang,J.Energy storage,10.1016/j.est.2020.101455,2020

8. "Solar Vaccine Refrigerator by using Phase Change Material", Anjappa S B, D.R.Partha Sarathi, Y.Srinath, N. Venkatramanareddy",IJEAT,2249-8958,Volume-8,2019.
9. "Improving knowledge on vaccine storage management in general practices: Learning effectiveness of an online-based program, Anika Thielmann , Marie-Therese Puth , Birgitta Weltermann,Department of Medical Biometry, Informatics and Epidemiology, Faculty of Medicine, University of Bonn, Venusberg-Campus 1, 53127 Bonn, Germany,2020.
10. "COVID Vaccine Transport, Storage and Distribution: Cold Chain Management to Ensure Efficacy", Michael Rusnack,Department of Pharmaceuticals, American Pharma Technologies Inc, Boise, Idaho, United States,2020.
11. "Influence of Cold Chain Supply Logistics on the Safety of Vaccines. A Case of Pharmaceutical Distributors in Nairobi County", Monicah W. Njuguna, Dr. Christopher J Mairura, Dr. Kepha Ombui, International Journal of Scientific and Research Publications, Volume 5, Issue 6, June 2015 1 ISSN 2250-3153,2015.
12. "Visual inspection of vaccine storage conditions in general practices: A study of 75 vaccine refrigerators",AnikaThielmann,MarieTheresePuth,BirgittaWeltermann,PLoSONE14(12):e0225764. https://doi.org/10.1371/journal.pone.0225764,2019.
13. "Vaccine storage and handling Knowledge andpractice in primary care physicians offices", Monica Naus, Can Fam Physician 1995;41:1169-1176,2014.
14. "The status of refrigeration techniques for vaccine storage and transportation in low-income settings", Magali Cattina(MSc.), Sashidhar Jonnalageddaa(MSc.), Solomzi Makohliso(PhD), Klaus Schönenbergera,b (PhD), EssentialTech Centre, Ecole Polytechnique Fédérale de Lausanne, Station 10, 1015 Lausanne (Switzerland).
15. "Vaccine storage and cold chain monitoring in the North West region of Cameroon: a cross sectional study", Martin Ndinakie Yakum, Jerome Ateudjieu, Ebile Akoh Walter and Pierre Watcho, BMC Research Notes (2015) 8:145 DOI 10.1186/s13104-015-1109-9,2015.