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Smart Cold Chain Monitoring and Alert System for Vaccine Carrier

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Abstract—

This paper proposes a concept to solve the cold chain temperature instability present in a vaccine carrier. Vaccines transported from a healthcare centre are heat and light sensitive. On exposure to variant temperature and light there is a permanent damage to vaccines. In order to avoid the effects of temperature in vaccines, a lab-based real time internet monitoring and alert mechanism were tested. The device updates the temperature of the vaccine carrier through a graphical representation to the healthcare centre and the health care workers over the internet. The Proposed results show that real-time monitoring of vaccine temperatures via the internet is feasible. Field based studies are conducted to validate the lab finding.

Keywords- *Vaccine carrier; Cold chain; Microcontroller; Temperature control; Health centre.*

INTRODUCTION

Vaccination is the most important preventive tool in public health. The immune strength of pregnant women, infants and children are enhanced through vaccination. Immunization of children is facing difficulty due to the unavailability of safe vaccines, mostly damaged due to temperature fluctuation. Nearly one-third of children are found unvaccinated in developing and underdeveloped countries. According to a nation-wide survey taken in India, there were about 26 million infant deaths due to defective vaccines. Among those vaccinated, only 61 percentage of the infants received major vaccinations [3]. Vaccines are stored in healthcare centres, with the help of refrigerators and they are protected and monitored from temperature fluctuations and light exposure. The stored vaccines are distributed among the field workers with the aid of vaccine carriers for vaccinating the individuals. The vaccine carrier maintains temperature between +2ºC to +8ºC for various types of vaccines [16].

Depending upon the tolerance level of the vaccines provided by the manufacturer's standard, it has to be properly handled. In the current scenario, when a health worker carries the vaccine carrier to a remote village, there is a loss of vaccine potency due to the effect of temperature alterations. Also, frequent opening of vaccine carriers and interruptions in electrical supply leads to temperature fluctuations. We propose a real-time monitoring of temperature logs using the internet.

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VACCINE TRANSPORTATION SYSTEM

Vaccine transportation is performed as per manufacturer recommended guidelines. When vaccines are transported from storage units there is an influence of external temperature affecting the safety of the vaccine.

Various Stages in Vaccine Transportation

Vaccine transportation can be classified into three stages (see Figure 1) based on the distribution and storage of vaccines [2].

Primary stage: Vaccine manufacturer ships the manufactured vaccines over the air under specified conditions. Vaccine packages are stored by the medical storage department in freezer rooms.

Intermediate stage: Vaccines stored in the medical storage department are further transported to various regional vaccine storage departments where the vaccines are stored in large refrigerators under uninterrupted power supply and monitoring.

Peripheral stage: From the regional vaccine storage department they are further distributed to the health centres. Health workers make use of vaccine carriers to vaccinate the children in various parts of the country.

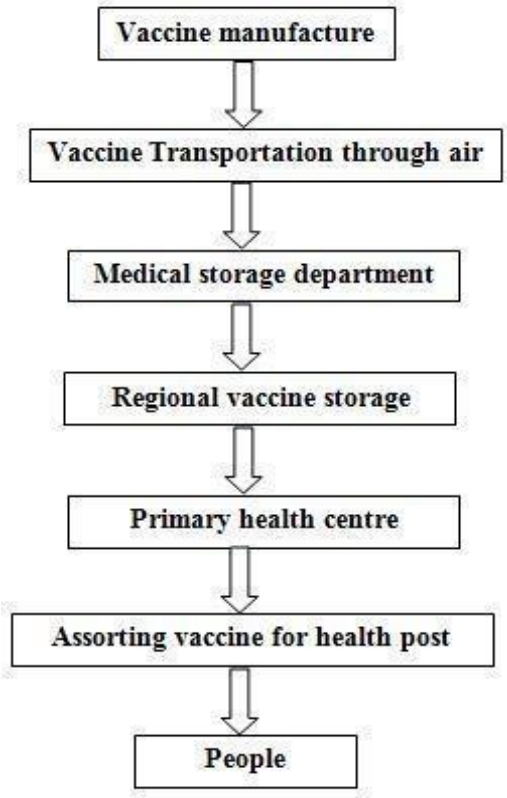

Figure 1. Flow chart for vaccine transportation system

EFFECTS OF VACCINE FAILUR

Nearly 70% of vaccines are temperature sensitive. It loses immunization capacity due to the sudden change in temperature from its specified rating (see Figure 2). India is one of the major manufacturers and users of vaccines in the world. A 2013 World Health Organization (WHO)

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study in India showed that around 75% of freeze- sensitive vaccines had been damaged by the time they made it through the supply chain. So it is necessary to prevent vaccine wastage [14].

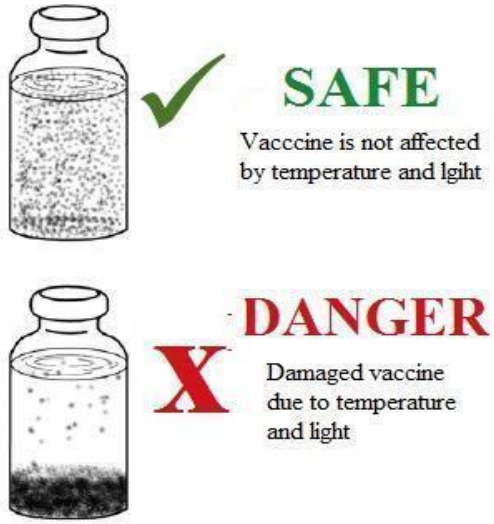

Figure 2. Temperature effect in vaccines

CURRENT SCENARIO IN VACCINE CARRIERS

Vaccine carriers are used for carrying vaccines from health care centres to various parts by health care workers. Vaccines are usually stored in old boxes and they are transferred using vaccine carriers to outreach sites by health care workers. Vaccine carriers are smaller when compared to cold boxes which makes it easy for health workers to carry. Vaccine carriers must maintain internal temperature ranging from +2ºC to +8ºC based on the type of vaccine being carried for vaccination [13].

Table 1. Comparison of cold box and vaccine carrier

S.NO	Cold Box	Vaccine Carrier
1.	Stable temperature is maintained	Variation of temperature due to the influence of outdoor conditions
2.	Large quantity of vaccines is stored	Less quantity of Vaccines is stored
3.	It is not portable	It is portable
4.	Data logger and Alert system is present	Absence of data loggers and alert system

Present vaccine carriers have a cold life with the help of frozen ice packs or cool water packs for the duration of 18 to 50 hours at +43ºC of outdoor temperature. Life of a cold chain is maintained when the lid is under closed state. Due to the influence of external temperature, there can be rapid effects of change in temperature which may be left unnoticed by a health care worker. Rise or decrease in temperature from manufacture specified standard rating could degrade the vaccine, making it unusable. Therefore, it is important to make sure that the vaccines are safe during the time of vaccination.

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Cold box contains a data logger in order to monitor and alert the workers of the health care centre. In case of vaccine carriers there is an absence of monitoring and data logging system, which leads to frozen state or damage of vaccine due to temperature effect. The proposed system enhances the efficiency of vaccine carriers and helps avoid damage of vaccines.

PROPOSED MONITORING DEVICE FOR VACCINE CARRIERS

Vaccination is disrupted due to the failure of the cold chain in the vaccine carrier. In order to avoid the cold chain problem, we developed and tested a modular device which monitors the internal state of the vaccine carrier. Modular based Internet of Things (IoT) temperature monitoring and data logging system is embedded into the vaccine carrier which is connected to the mobile phone that stores and transmits the real time data to the control and monitoring division. This helps in keeping track of the vaccine transportation and distribution system.

Desirable features in the proposed vaccine carrier

- Graphical user interface for simplified user monitoring.
- Alarm system for vaccines undergoing change in temperature.
- Alert signal under open state of lid in vaccine carrier.
- Real time data from vaccine carriers are monitored by healthcare centres.
- There is no external supply needed for the data logger.
- The device is modular and compact in nature.
- Health care centres can monitor the location of the vaccine carrier over the internet.
- Safety of vaccines is assured.
- Proposed device communicates with the phone in order to send the real time data.
- Compact redesigning of cold box to make use of this modular monitoring device.

WORKING OF PROTOTYPE

The working of this prototype is mainly controlled by the microcontroller, which consists of following segments

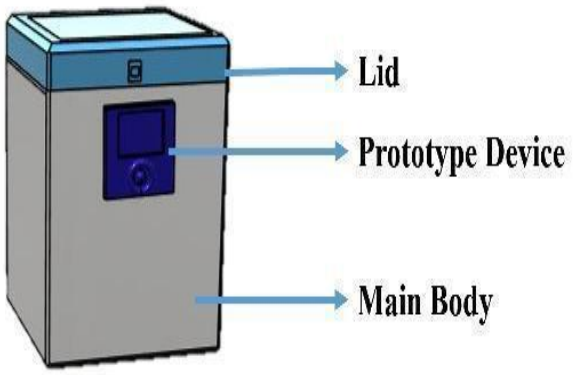

Figure 3. Prototype design

Monitoring System: Temperature is monitored by an internal sensor, which collects the temperature logs of the vaccines throughout its operation. The data collected from the proposed device is sent to the assigned health care workers via mobile phones from which the position of the vaccine carrier as well as the collected data is sent to the healthcare monitoring system, with the help of GPS and internet connectivity.

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Alert System: Vaccine carriers consist of the following alert system, they are:
Interval based alarm: The cold chain in vaccine carriers remains constant, until it is exposed to the environmental conditions. During the vaccination period there is a prolonged opening of vaccine carriers, which leads to sudden loss of specified temperature. To prevent this, a time interval based alarm system is used to warn the workers to close the lid, once the vaccine is used.
Phone Notifier: During the transportation of the vaccine there can be a change of temperature in the vaccine carrier which is notified to the health care centre and the worker's phone.
Data logging System: Data logger is used to send the collected data from the vaccine carriers in real time to the healthcare centre.

Features:
- Instant monitoring
- Easy to log the data
- Manual data logging is eliminated
- Accuracy level of the data obtained is high
- Logged data are stored in the cloud
- Can be accessed by any electronic device connected over the internet
- Future reference from the data history could enhance the existing system
- Data cannot be tampered

GUI (Graphical User Interface): The interface is made simple for any user to understand and interact to make sure the vaccine carrier is safe to carry vaccines and check the battery condition of the device.
Features:
- Real time data can be viewed
- User can set the specified temperature for the vaccines needed to be carried
- Battery status is displayed for next cycle charge
- Cold chain cycle can be estimated by the user
- Appearance of emergency symbols being displayed could warn the healthcare worker

Battery Status and Usage: Battery is compact in nature to power smaller devices which can run for days, based on the usage of the device. The battery characteristics are based on size, safety, cost and life cycle. Based on the preference of the proposed device, a lithium-ion polymer battery is used.
Features:
- Performance of battery is improved from previous generations of battery
- Number of charge cycle is more
- Lighter in weight and size
- Temperature does not affect battery charge storage
- Can be recycled for future use

BLOCK DIAGRAM OF PROPOSED SYSTEM

Figure 4. Shows the working framework of the vaccine carrier. The framework mainly consists of Wi-Fi based microcontroller, sensors, display and battery controller. The Wi-Fi microcontroller device is connected to the internet through the workers phone which transmits collected data and GPS location of the vaccine carrier to the health care centre remotely. The lid lock sensor present in the vaccine carrier assures the closed condition to avoid the damage of vaccines, if not it alerts the health care worker visually as well as through sound to take further action to safeguard the vaccines. The battery controller monitors if the proposed device works under all field work conditions. The display shows the working status of the sensor, Wi-Fi connection, battery and other peripheral sensors found in the vaccine carrier [8].

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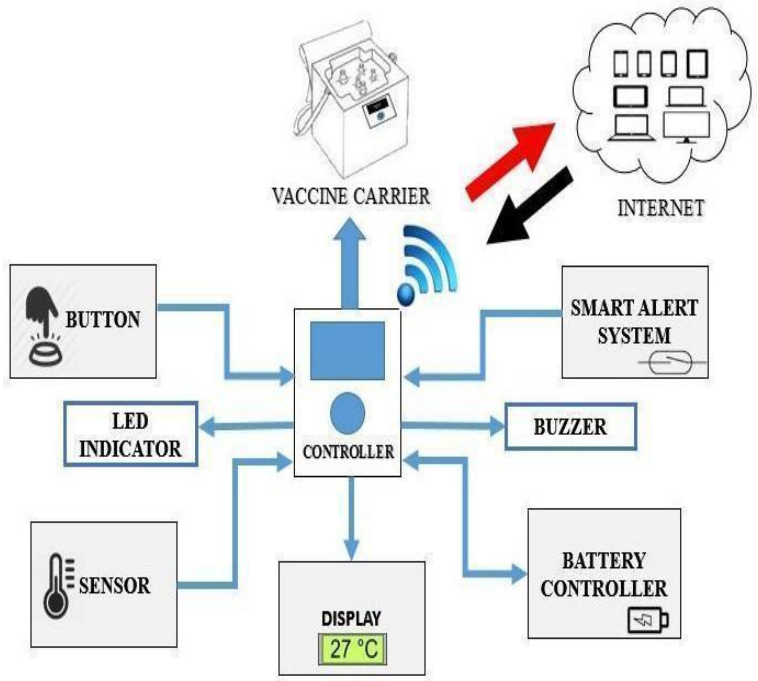

Figure 4. Block diagram of proposed system

RESULT

The laboratory results show the status of the temperature under three different conditions. The first graph (Figure 5) shows the temperature variation in the environment over a 24 hour period. The second graph (Figure6) explains how the temperature is maintained from +2ºC to +8ºC under the closed state of the vaccine carrier. Figure 7 represents the temperature changes under the opening and closing of the vaccine carrier lid.

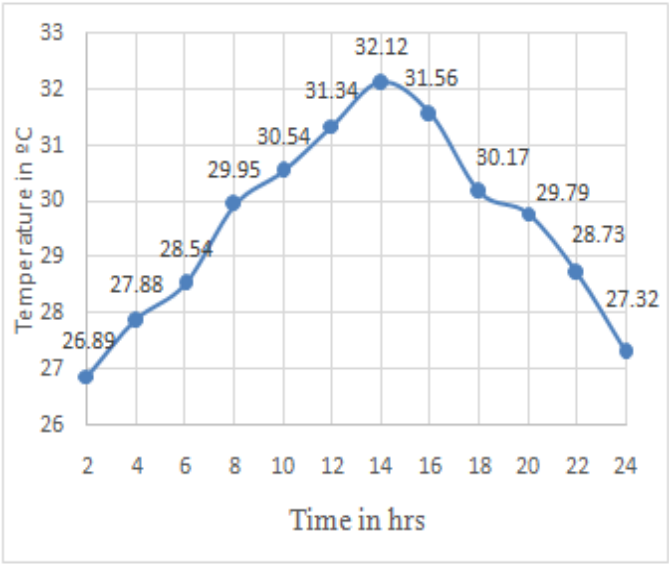

Figure 5. Environment temperature monitoring

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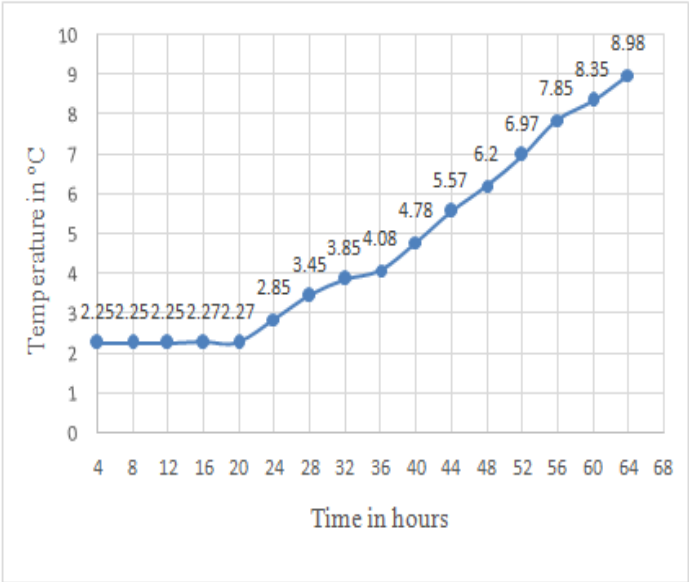

Figure 6. Vaccine carrier temperature in closed state

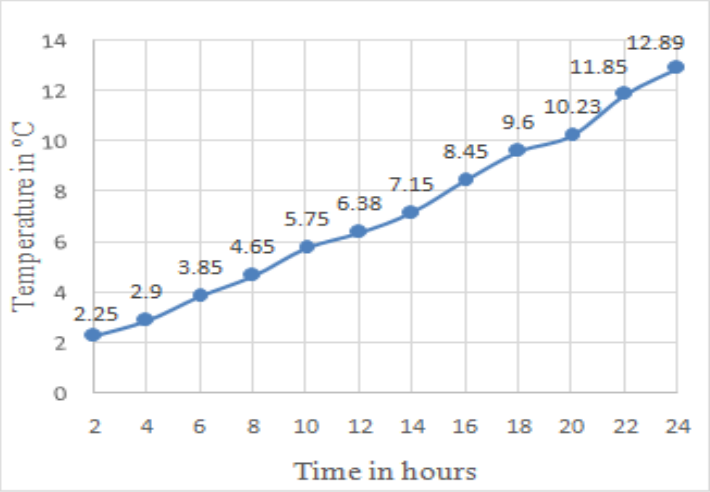

Figure 7. Variation of temperature in opening and closing of vaccine carrier

DISCUSSION:

The present vaccine carrier utilises a low-cost, innovative technology to maintain the temperature and to monitor the status of the temperature variation in the vaccine carrier. If vaccines are not properly stored under specified temperature, it may become lethal for the individuals who get vaccinated. To prevent this problem, it is important to monitor, record and alert the health worker in real time regarding the internal condition of the vaccine carriers. The proposed system has the features of data logging remotely and an alert system for health care centres and workers in real time. It also has an alert system for temperature instability and frequent opening of vaccine carriers. Data obtained is visually displayed to the health care worker for prompt response.

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CONCLUSION:

Our results show that last-mile vaccine cold-chain monitoring is possible with a low-cost, innovative monitoring and alert system. Further studies in the field are needed to validate the findings in the laboratory.

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