International Journal of Medical Science and Health Research

Vol. 4, No. 03; 2020

ISSN: 2581-3366

How Effective Are Solar Energy Refrigerators in the Conservation of Vaccines in the EPI Program of the Center Region of Cameroon?

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Abstract

Introduction. Cameroon is prone to regular electricity cuts and the choice of mixed (electricity/gas) refrigerators for the preservation of vaccines in rural areas to date appears to show some limits. Solar energy refrigerators were acquired and installed in the center region to overcome the irregularities observed in temperature control. The main objective of this study was to evaluate how effective these refrigerators were in vaccine conservation.

Method. We conducted a descriptive cross-sectional study during which data were collected from refrigerators installed in 16 health facilities and also from 30 healthcare providers in the vaccination and logistic services of the EPI program of the center region.

Results: Twenty-four (80%) of the thirty refrigerators installed were of Domestic TWC 40 SDS brand and 5 or 16.66% were of SunDanzers brand. The two types of refrigerators maintained an average storage temperature of 5.47±0, 36 ° C (min = 4.90 ° C, max = 6.00 ° C) which is ideal for the conservation of vaccines and both worked consecutively for 12 months without alteration. Temperature monitoring by personnel was ineffective as only 37.93% of the health facilities had twice daily manual temperature records prior to data collection. We observed that 52% of the health facilities with functional solar refrigerators used them for mixed purposes and not for vaccine conservation only. Except for the storage of vaccines in the appropriate compartments, no other storage rules prescribed by the manufacturers of the refrigerators were respected. Apart from monthly cleaning of the interior of the solar refrigerators which was noted in only 60.07% of cases, no other indicator of preventive maintenance set by the manufacturers measured up to 20%. Only 80% of Domectic brand of refrigerators used the recommended refrigerant fluid known as R600a, which is described as "new generation" refrigerant. About 5% of SunDanzer brand of refrigerators still used R134a, a refrigerant which has been prohibited for use according to UE n°517/2014 regulations.

Conclusion: Solar refrigerators installed in health districts of the Center Region of Cameroon allowed for effective conservation of vaccines. Effort should be made, in their maintenance, temperature management and appropriate storage.

Keywords: solar, energy, refrigerator, vaccine, temperature.

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BACKGROUND/JUSTIFICATION

Infectious diseases have regressed dramatically all over the world mainly due to vaccination. The latter is a fundamental right of children and is one of the greatest successes of medicine. Through the control of infectious diseases, the health of children has improved significantly [1]. However, equity in the geographical delivery of healthcare services remains insufficient in resource limited countries such as Cameroon. The introduction of several new vaccines and expansion of immunization coverage and equity across the nation is one of the country's major goals as included in Cameroon's Comprehensive Multi-Year Plan 2015-2019 (CMYP). Progress towards these goals are threatened by longstanding weaknesses in our Cold Chain System (CCS). For example, the results of the 2013 cold chain inventory indicated that 40% of health facilities in Cameroon were equipped with obsolete equipment and that 22% of health facilities had damaged equipment. Since then, there has only been precarious progress in reorganizing the cold chain system. This caused the expanded program on immunization (EPI) and its partners to conduct a complete cold chain inventory (CCI) at all the levels of the health pyramid, with the overall objective to obtain valuable information on the availability and condition of the equipment in the system. This was to facilitate planning for repairs, maintenance and replacement, as well as to ensure that available capacity met with the demand forecast made until 2021 [2]. The results of this study showed, among other things, that; 1) there were weaknesses in health services delivery, 3.2% of health facilities were non-functional, 2) weaknesses in immunization services as 14.3% of health facilities did not provide immunization services due to weaknesses in the cold chain, 3) 42% of the structures that vaccinated did not have functional cold chain equipment, a weakness that seemed to have had a negative impact on the provision of immunization services, 4) weaknesses in the use of cold chain equipment, none of the 30 staff interviewed was trained in the use of fridge-tags at the time of the inventory, 5) weaknesses in electricity coverage, 41% of the structures offering EPI services were located in areas not covered by electricity (33%) or in areas receiving less than eight hours of electricity per day (8%) [2].

The energy crisis that the country has been going through from year to year caused the ministry of public health in collaboration with its country-based technical and financial partners to consider the use of solar energy refrigerators as alternative source of energy supply. This was already suggested during the 2013 inventory that aimed to equip the areas not covered by electricity or receiving less than 8 hours of electricity per day with solar energy refrigerators [2]. Preliminary studies to evaluate performance (the proper functioning) of solar energy equipment in real situation before use are recommended and most countries do that in pilot studies [3]. To align with this recommendation, Cameroon acquired some solar refrigerators in 2016 and 23 were installed in the health districts located in the Center region. We carried out this study to evaluate how effective the installed solar energy refrigerators were in vaccine preservation.

METHODOLOGY

It was a descriptive cross-sectional study. Data were collected in December 2018 and January 2019 from 30 health facilities in 16 health districts of the Central Region. These facilities have

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had solar energy refrigerators installed. Data was also collected from staff in the vaccination and logistics section of Central Regional EPI program.

1. DATA FROM SOLAR ENERGY REFRIGERATORS.

We evaluated the refrigerators in terms of temperature monitoring; monitoring of equipment, arrangement and storage, and the availability of follow up of preventive maintenance monitoring.

a. TEMPERATURE MONITORING

We checked to ensure that the vaccine storage temperature remained within the recommended ranges, i.e. between + 2 ° C and + 8 ° C in the refrigerators compartments and between -25 ° C and -15 ° C in cold rooms. and freezers. We followed – up to detect any storage temperature that were out of these ranges during transportation.

b. MONITORING OF EQUIPMENT

We identified if the refrigerators were designed to maintain a temperature between +2 and +8 degrees centigrade and equipped with thermometers that recorded the minimum and maximum temperatures reached. We checked if the thermometers were located outside the refrigerators to allow for access to temperature information without having to open the refrigerators and if the thermometer probes were placed in the center of the refrigerators. We verified if there was temperature control through the presence of a standard manual temperature record chart attached to the door or lid of each vaccine refrigerator with twice daily temperature recordings and made sure that readings taken every day came from the same temperature monitor. We verified if the personnel responsible for this task read the Fridge-tag 2 and noted down the data on the chart. In the absence of a Fridge-tag 2, we checked the built-in digital display thermometer and if necessary, the rod thermometer. Saving temperatures according to these procedures was a guarantee that the refrigerator was well controlled and that regular readings took place. This helped to identify performance curves, sometimes even before alarms were triggered automatically.

c. MONITORING VACCINE STORAGE

We verified the keeping of vaccines in good condition, avoiding exposing them to damaging temperatures as much as possible because it is important to store them properly in the cold chain equipment.

Below is the proper Storing of Vaccines and Solvents in a Front Opening Vaccine Refrigerator (Vertical)

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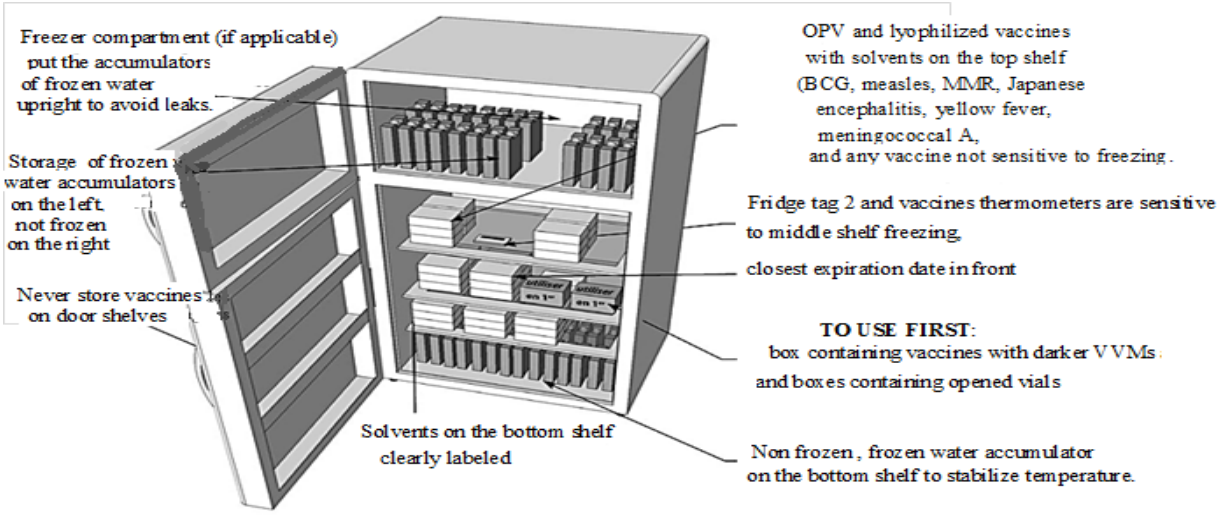

Figure 1: Illustration of how to store vaccines and solvents in a front-opening vaccine refrigerator

Source Adapted from WHO, 2nd Training module: Vaccinal cold chain p. 30 (OMS, 2012).

- We verified if EPI rules governing the use of front-opening refrigerators were respected. These rules include:
  - Never placing vaccines or solvents on the shelves of the door because the temperature will not be low enough to store vaccines and vaccines will be exposed to room temperature every time the door is opened.
  - Never putting freeze-sensitive vaccines in contact with or near the refrigerator evaporator plate.
  - Placing water accumulators or plastic bottles filled with colored water in the reserved space below the bottom shelf; this makes it possible to stabilize the temperature in the event of a power failure.
  - Placing vaccine vials against measles, MR, BCG, OPV, yellow fever, anti-meningococcal A conjugates - and / or any other vaccines that are not tampered with by freezing - on the top shelf.
  - Placing Td, TT, HepB, DTP + HepB + Hib, HPV, Rotavirus - and / or other freeze-sensitive vaccines - on the middle and bottom shelves.
  - Storing solvents next to the freeze-dried vaccines with which they were supplied on the appropriate shelf. In case of lack of space on the shelf, placing the solvents on the bottom shelf, clearly labeled for easy identification in relation to the vaccines with which they are associated

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Below is the Storage of vaccines and solvents in a chest refrigerator (horizontal with baskets)

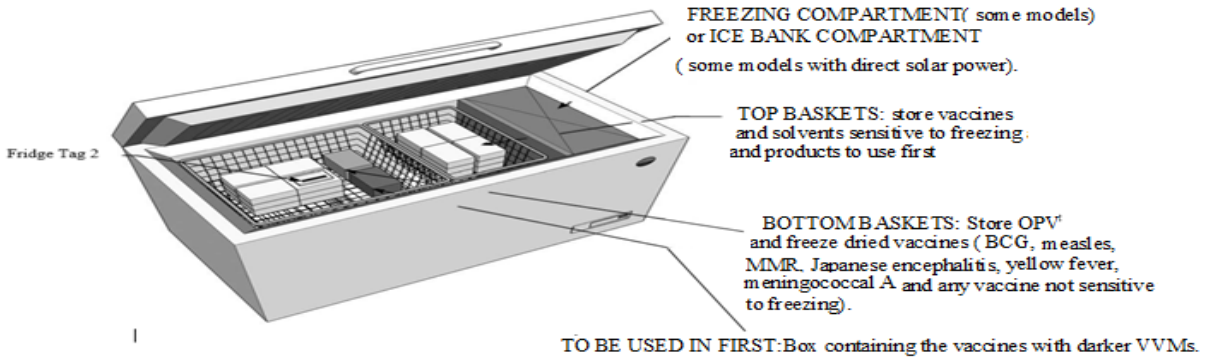

Figure 2: Illustration of vaccine and solvent storage in a sideboard refrigerator (horizontal with baskets)

Source: Adapted from EPI 2016

Some EPI rules that govern the use of chest refrigerators were verified:

- Not removing frozen water accumulators from the Ice bank compartment in the direct power solar models
- Not storing vaccines outside the baskets provided
- Not leaving the lid open
- Using first the boxes containing the opened vaccine vials
- Always storing vaccines and solvents in the baskets provided for this purpose, and never outside the baskets.
- Storing MR vaccine, BCG, OPV, yellow fever, and / or other vaccines that are not degraded by freezing in the baskets.
- Using the top baskets to store products for immediate use and to store solvents and vaccines Td, TT, HepB, DTP + HepB + Hib, HPV, Rotavirus and/or any other freeze-sensitive vaccine.
- Never putting freeze-sensitive vaccines in the baskets because, for some models, there is a risk of freezing in these areas.
- Storing the solvents near the freeze-dried vaccines with which they have been supplied. If this is not possible, check that the solvents are clearly labeled so that they can be easily identified in relation to the vaccines with which they are associated.

d. MONITORING THE PREVENTIVE MAINTENANCE OF COLD CHAIN EQUIPMENT

We looked for the system of control and monitoring called maintenance. This is a set of actions intended to maintain or restore equipment in a state or under safe operating conditions to perform

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a required function. Maintenance therefore aims to: - ensure the availability of equipment; improve the accessibility and quality of vaccines; optimize costs (financial objectives); optimize working conditions and safety; preserve the environment; enhance the image of the EPI. We verified both preventive and corrective maintenance. The former was performed to reduce the probability of equipment failure. Corrective maintenance was performed to identify, isolate, and rectify a fault so that the failed equipment, machine or system could be restored to an operational condition within the tolerances or limits established for in-service operations.

2. INTERVIEWS OF HEALTHCARE PROVIDERS

These were staff responsible for managing the EPI activities at the level of the health facilities. We interviewed them on data monitoring, temperature control, storage and arrangement activities, and preventive maintenance activities of the devices. We collected from 30 of them and stored in a digital tablet using the Kobo Toolbox software.

3. DATA COLLECTION AND ANALYSIS

We collected data from the refrigerators using the Kobo Toolbox software on a digital tablet and observation grids. Instantaneous temperature readings of refrigerators in the cold chain system were made using a probe thermometer, the 'Indoor Thermometer with hygrometer TA 298' brand. The thermometer measured indoor temperatures in the range: -10 ° C ~ +50 ° C (-14 ° F ~ +122 ° F) and outside range: -50-70 degrees with a temperature accuracy of ± 1.0 ° C. We interviewed EPI staff using a provider administered questionnaire that was designed, tested and adapted for the study. The data collected were analyzed using Epi-info Version 7.2 software and tables and figures were drawn using Microsoft Excel software.

4. AUTHORIZATION

We received authorization number 1702/L/MINSANTE/SG/DRSP-CE/GTRPEV on the 5th December 2018 to carry out the study.

RESULTS

TYPE OF SOLAR REFRIGERATOR

Table I: Distribution of solar refrigerator types from the slow CC of the EPI of the Center Region

	Enrollment	Rate
Domectic TCW 40R SDD	24	80,00%
Sundanzer BFRV 55 SDD	5	16,66%
Other (electric, kerosene and gas refrigerators)	1	3,34%

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As shown in the table above, slow CC solar refrigerators of the EPI Center were essentially made up of the Domectic TCW 40R SDD brand (80%) followed by the SunDanzer brand refrigerators (16.66%).

SPONTANEOUS ABILITY TO STORE VACCINES.

Table II: Assessment of Central EPI Slow CC Temperature Monitoring

	Mean ± SD	Minimum	Maximum
Temperature displayed by the digital dial of the device (n = 28)	**5,78±2,86°C**	**4,60°C**	**20,20°C**
Temperature displayed by the digital dial of the corrected device (n = 27)	**5,25±0,44°C**	**4,60°C**	**6,70°C**
Instantaneous temperature measured with the control thermometer (n = 28)	**5,47±0,36°C**	**4,90°C**	**6,00°C**
High alarms since the last 03 months (n = 30	**25**	**1**	**20**
Low alarms since the last 03 months (n = 30)	**0,0±0,0**	**4,90**	**6,00**
Number of breakdown / shutdown in the last 12 months (n = 30)	**0**	**0**	**0**

In the light of the above table, the EPI slow CC solar refrigerators in the Center region stored vaccines at an average temperature of 5.25 ± 0.44 ° C, with a minimum range of 4.60 ° C and maximum of 6.70 ° C.

CORRECT OPERATION AND MANAGEMENT OF THE COLD CHAIN.

EXCLUSIVE USE OF SR FOR VACCINE PRESERVATION (N = 29)

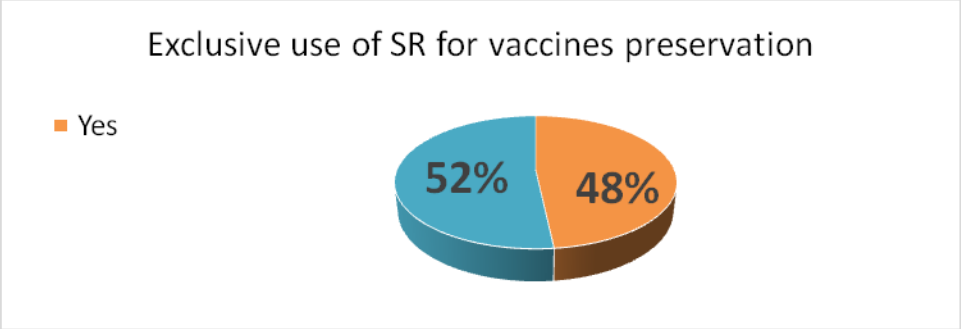

Figure 3: Proportion of slow CC solar refrigerators used exclusively for vaccine storage

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As shown in Figure 3 above, 52% of health facilities with a functional solar refrigerator did not use them exclusively for vaccine storage.

OTHER PRODUCTS STORED IN SR (N = 15)

Table III: Other Products stored in the EPI Slow Cold Chain

Product	Facilities	Number	Frequency (%)
Medicine	15	15	100 %
Medicine and food	15	07	46.67%
	15	01	6.67%
Medicine and biological products			
Lab, drugs and reagents	15	02	13.33%

For the non-vaccine products stored in the SRs, 100% were medicines, 46.67% were both medicines and foodstuff, 13.33% were medicines and laboratory reagents, and 6.67% were biological samples.

CORRECT STORAGE

Table IV: Storage of vaccines in solar refrigerators

Variables	Modality	Number	Frequency (%)
Were all vaccines stored in the refrigerator baskets provided for this purpose?	Yes	29	100%
	No	00	00%
Were vaccine packets arranged in well-ordered rows?	Yes	00	00%
	No	29	100 %
Were special provisions made for the storage of frost-sensitive vaccines	Yes	00	00 %
	No	29	100 %
Were the vaccine packets arranged in orderly rows in the refrigerator baskets provided for this purpose?	Yes	00	00 %
	No	29	100 %
Had there been a space of about 2 cm between the rows to ensure the circulation of air?	Yes	00	00 %
	No	29	100 %
Were the different vaccines arranged separately to facilitate their identification?	Yes	00	00 %
	No	29	100 %
Temperature control equipment (fridge tag, freeze tag, record 3M)	Yes	12	41,38 %
	No	17	52,62 %

All vaccines were stored in the baskets provided for this purpose, no special provision was made for the storage of drugs in the solar refrigerators. The storage rules prescribed by the

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manufacturer were not respected. Temperature control equipment was available only in 41.38% of solar refrigerators on the slow CC of the EPI Center.

OPERATION AND CORRECT MANAGEMENT

Table V: Results of the correct management of the CC

Variables	Modalities	Number	Frequency (%)
Was twice daily manual temperature recording up to 88% as recommended?	Yes	11	37,93 %
	No	18	62,07 %
Was there a Built-in thermometer with digital display?	Yes	00	00%
	No	29	100%

All the refrigerators did not have a built-in thermometer with digital display and only 37.93% had twice daily temperature recording of up to 88%.

PREVENTIVE MAINTENANCE

Table VI: Preventive Maintenance of Center EPI Slow CC Solar Refrigerators

Variables	Modalities	Staff	Frequency (%)
HF where the drain hole was opened daily to empty the refrigerator from its water (n = 29)	Daily	1	3,45 %
	Less than 3 times a week	20	68,97 %
	Never	3	13,34 %
	Do not know what to do	5	17,24 %
HF where the refrigerator air filter was cleaned with soap and water (n = 29)	At least once a month	3	10,34 %
	Less than once a term	12	41,38 %
	Never did it	5	17,24 %
	Do not know what to do	9	31,03 %
HF where the interior of the solar refrigerator was cleaned with soap and water (n = 29)	At least once a month	18	60,07 %
	Less than once a term	10	34,48 %
	Never did it	1	3,45 %
	Do not know what to do	0	00 %
HF where the solar panels feeding the refrigerator were cleaned (n = 29)	Once per trimestre	00	00%
	Less than once a term	1	3,45 %
	Never did it	24	82,76 %
	Do not know what to do	4	13,79 %
HF where the procedures/protocols to	Yes	6	20%

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Variables	Modalities	Staff	Frequency (%)
follow in case of breakage of the cold chain were posted on/near the refrigerator (n = 30)	No	24	80%
Was the staff responsible for the management of the CC of the HF trained in preventive maintenance? (N = 30)	Yes No	00 29	00% 100%
Did the HF have a management guide for the cold chain and vaccines (Standard and EPI standard ...)? (n = 30)	Yes No	8 22	26,67 % 73,33 %

Modalities for preventive management were not respected by the staff interviewed.

Table VII: Variation of the maintenance parameters according to the Health Facility category

Variables	Modalities	CHF	Category 4	Category 5	Category 6	Effectives
HF where the drain hole was opened daily to empty the refrigerator from its water (n = 29)	Everyday	1			0	1 (3,45%)
	Less than 3 times per week	0	1	1	18	20 (68,97 %)
	Has never done it	1	0	1	1	3 (13,34 %)
	Do not know they should do it	0	1	3	0	5 (17,24 %)
HF where the refrigerator air filter was cleaned with soap and water (n = 29	At least once per month	1	0	1	1	3 (10,34 %)
	At least once per trimester	0	1	1	10	12 (41,38 %)
	Has never done it	1	1	1	2	5 (17,24 %)
	Does not know what to do	0	0	2	7	9 (31,03 %)
Health facility where the interior of the solar refrigerator is cleaned with soap and water(n=29)	At least once per month	1	1	2	14	18 (60,07 %)
	At least once per trimester	1	1	3	5	10 (34,48 %)
	Has never done it	0	0	0	0	1 (3,45 %)
	Does not know what to do	0	0	0	0	0 (0 %)
Health facility where the solar plates supplying the refrigerator are cleaned (n=29)	Once per trimestre	0	0	0	0	0 (0 %)
	At least once per trimester	0	0	0	1	1 (3,45 %)

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Variables	Modalities	CHF	Category 4	Category 5	Category 6	Effectives
	I have never done it	2	2	5	15	24 (82,76 %)
	I didn't know it should be done.	0	0	2	2	4 (13,79 %)
Health facility where the procedures to be followed in the event of cold chain failure are posted on/near the refrigerator (n=29)	Yes	2	2	1	1	6 (20%)
	No	0	0	0	24	24 (80%)
Has the staff responsible for the cold chain management of the health facility been trained in preventive maintenance? (n=29)	Yes	0	0	0	0	0 (0%)
	No	2	2	5	16	29 (100%)
Does the health facility have a guide to manage the cold chain and vaccines (EPI norms and standards...)? (n=29)	Yes	2	2	2	2	8 (26,67 %)
	No	0	0	3	19	22 (73,33 %)

Maintenance parameters were not respected irrespective of the category of the health facility c

DISCUSSION

MONITORING OF STORAGE TEMPERATURES

Vaccines are one of the most useful and effective advances of modern medicine [4]. They are biological products used to develop active immunity. They may consist of attenuated or inactivated live bacteria viruses, fragments of these entities or their products, as well as several other ingredients that promote their stability and efficacy [5]. However, vaccines are very fragile and particularly sensitive to temperature variations and all vaccines should be stored at temperatures between 2 ° C and 8 ° centigrade [6]. Maintaining the optimal temperatures from manufacture to use, or cold chain, is therefore essential [7]. It is also important that at all levels of the cold chain, the equipment used for the storage and preservation of vaccines should guarantee a temperature of between 2 ° C and 8 ° C and personnel in charge should ensure that this works out well. According to EPI recommendations, vaccines should be stored in a pharmaceutical refrigerator equipped with a minima-maxima or continuous-recording thermometer [8, 9, 10]. In our study, all of the functional solar panel refrigerators reviewed had an integrated digital display thermometer and 96.55% of the refrigerators displayed temperatures readings recommended by the WHO. We noted that only 41.38% of the refrigerators were equipped with a temperature control device (fridge tag, freeze tag, sheet 3M). This was more than the 3.2% of continuous temperature recording reported in a Congolese study by Matthieu et al [11]. Instantaneous sampling of vaccine storage temperatures in solar refrigerators in this study showed no significant difference in average temperatures from the digital display of the built-in refrigerator thermometers (5.25 ± 0.44 ° C; 4.60 ° C, max: 6.70 ° C Vs 5.47 ± 0.36 ° C,

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min 4.90 ° C, max: 6.00 ° C), demonstrating that solar refrigerators in the health facilities selected for the study complied with WHO standards (+ 2 ° C- + 8 ° C).

Refrigerators intended for vaccine storage are supposed to be used exclusively for the purpose. The results of this study revealed that 52% of health facilities with functional solar refrigerators were not using them exclusively for the preservation of vaccines, but also for other products, including medicines.

Manual temperature readings are a crucial aspect of temperature monitoring in the cold chain. It is recommended that staff in charge of cold chain management should stick to twice daily manual temperature recordings on a sheet placed on the door or lid of every refrigerator. Readings taken every day should always come from the same temperature monitor; the personnel responsible for this task must read the Fridge-tag 2 and note down the data on the chart. In the absence of a Fridge-tag 2, they should check the built-in digital display thermometer or, if necessary, the rod thermometer. We collected data on the existence of the manual temperature record sheets for the quarter preceding the survey. It showed that only 37.93% of health facilities recorded temperatures by fridge-tag or manually twice daily the month preceding the data collection. Only 1 out of 29 Health facilities registered a shortage of temperature data sheets for that quarter. This finding was much lower than the 71% of temperature recording reported in a similar study carried out in the Democratic Republic of Congo where the effectiveness of vaccine management and quality of immunization services in the EPI was evaluated from temperature recordings of five years [11]. Earlier in 2013 in the same country, Pascal Bédard and Jean Rémi Valiquette noticed that vaccines were stored in a specialized commercial refrigerator in 51% of pharmacies only, whereas a minimum-maximum thermometer was present in 73% of cases, but only 50% of respondents checked the temperature twice a day [12]. It was conclude the observations were due to insufficient monitoring of temperature by the assigned staff.

CORRECT STORAGE

To keep vaccines in good condition, and to avoid exposing them to damaging temperatures as much as possible, it is important to store them properly in the cold chain equipment. Manufacturers of solar energy refrigerators for vaccine storage in collaboration with health professionals have defined rules for vaccine storage. In our study, which included 80% Domectic TWC 40 solar refrigerators and 16.66% Sundanzer solar refrigerators, we found out that, except for the fact that all vaccines were all stored in the refrigerator baskets provided for the purpose, the vaccine packages were not arranged in well-ordered rows; no special provision was made for the storage of frost-sensitive vaccines; the vaccine packets were not arranged in well-ordered rows in the refrigerator baskets provided for this purpose and no space of about 2 cm was left between the rows to ensure the circulation of air. The different vaccines were not arranged separately to facilitate their identification as recommended. We also observed that, on the contrary to the recommendations of norms and standards of the EPI for the preservation of vaccines in their original containers, staff in the cold chain management systems kept vaccines in containers that they preferred (metals, plastic plates, non-degradable plastic packaging, cardboard), or put them without packaging in the refrigerator baskets. In 2017, Matthieu et al., in DR Congo found during the assessment of vaccine storage and transportation that only 25% of health facilities did thet satisfactorily. Our results reflect the inadequacies in vaccine and cold chain management, correct storage quality, and weaknesses in the physical safety of vaccines.

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PREVENTIVE MAINTENANCE

Preventive maintenance aims to reduce the probability of equipment failure. Systematic preventive maintenance is performed at pre-established time intervals or according to a defined number of usage units but without prior control of the condition of the property. The European Norm, NF EN 13306 X 60-319 lays emphasis on this. Preventive maintenance is done without controlling the general condition of the equipment although a specific component can be changed. Conditional preventive maintenance is based on a predetermined type of event: self-diagnosis, information of a sensor, measurement, etc. [8]. We collected systematic preventive maintenance data according to the schedule provided by the manufacturer of solar refrigerators. The results showed that apart from the monthly cleaning with water and soap of the interior of the solar refrigerators, 60.07% of cases, no other preventive maintenance indicator reached 20%. The results were far from the findings of Matthieu et al., who's 2017 evaluation of the preventive maintenance system of the vaccine management fleet, revealed that all maintenance indicators were zero. Given that solar panels do not function efficiently "maintenance free" with dirt, dust and bird droppings on them, the photovoltage module reduce the solar light intensity that gives strength to the solar refrigerators when this happens. This leads to reduced efficacy of the solar cold chain and does not guarantee optimum temperatures for vaccine storage. No staff responsible for cold chain management in the facilities we reviewed was trained in the preventive maintenance of solar refrigerators which is a fundamental condition for the proper functioning of solar energy refrigerators [3]. The evaluation report of vaccine management by the Ministry of Health and AIDS in Ivory Coast, presented a target achievement rate of 88% in the capacity building of cold chain managers [13]. The usual drawbacks of solar-powered refrigerators are the lack technical expertise for their maintenance combined with incessant theft of equipment. To overcome these, special attention over the choice of equipment, its installation, management, and the efficacy of temperature monitoring as well as maintenance and repair work are recommended [3]. A management guide for vaccines and cold chain (EPI Norms and Standards) was available in only 26.67% of the health facilities that we visited, a finding similar to what Yakum et al., and Akoh et al, reported from the North West and West regions of Cameroon in 2015 and 2016 respectively pointing out that the national EPI norms and standards were only met in 33.9% and 71.4% health facilities in these regions [14, 15].

It is strongly recommended that a copy of the procedures to be followed in case of breakages in the cold chain be kept nearby the refrigerator containing the vaccines [10]. These instructions and the forms to be filled in case of any breakages in the cold chain must be pasted not far from the refrigerators. The results of our study showed that only 20% of the health facilities that we visited had protocols to follow in case of breakages in the cold chain displayed near the refrigerators. This gives credence to the reinforcement of preventive maintenance measures in our health facilities.

The impact of refrigerants on the environment is a major world challenge. The ozone depletion potential (ODP) and the global warming potential (GWP) are two indicators of the quality of the environment. In our study, refrigerators run by electricity (Sibir refrigerators) and solar refrigerators of SunDanzer brand used R134a (tetrafluoroethene) as refrigerant. However, the

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ODP over 100 years of R134a is nil, and its GWP is 1430, very far from the reference value of 1 of CO_2 [16]. The Kyoto protocol « the conference of the parties» decided that the calculated GWP in the second evaluation report of intergovernmental panel on climate change (IPCC) must be taken in account in order to convert the various greenhouse gas emissions into comparable units of CO_2 equivalent, during the global calculations of sources and wells. This explains why solar refrigerators of Domestic Brand TWC 40R SDD use the fluid refrigerant "isobutene", said to be of "new generation" which is safer for the environment. It has no action on stratospheric ozone and has little impact on the greenhouse effect, although dangerous because of its flammability [17]. Thus, it appears wiser to recommend refrigerators using R600a rather than R134a which respect the environment and conform to the UE n°517/2014 regulations which plans to ban R134a importation by 2020 [18].

CONCLUSION

The objective of the study was to evaluate the effectiveness of vaccine storage monitoring in solar energy refrigerators in 16 health districts of the Center region of Cameroon. In the light of the results obtained, we can conclude that solar energy refrigerators installed in the health facilities enabled the proper conservation of vaccines. However, measures should be taken to improve on the storage quality of vaccines, maintenance and temperature monitoring. Refrigerators with refrigerants providing a better protection to the environment like R600a and a freezer compartment for water accumulation are highly recommended.

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