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Vaccine Wastage in the Littoral Region, Cameroon:  
Differences Between Rural and Urban Health  
Districts and Policy Implications

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# Vaccine Wastage in the Littoral Region, Cameroon: Differences Between Rural and Urban Health Districts and Policy Implications

Directed by: Professor Sunjoo Kang

A Master's Thesis

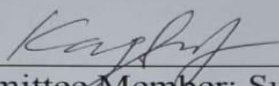
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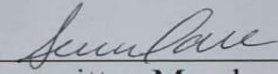
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## **Dedication**

I dedicate this thesis to my wife; **Mrs. Sophie Nkenyi**, to my children; **Britney Nkenyi, Glaucia Nkenyi and Rhema Nkenyi** and to my parents **Andrew and Deborah Nkenyi**, for providing me with unconditional love, support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

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**Rene Nkenyi**

## Table of Content

Table of Content.....	i
List of Figures .....	v
List of Tables.....	vi
List of Abbreviations .....	vii
Abstract .....	ix
I. Introduction .....	1
1.1. Background .....	1
1.2. Statement of the problem .....	4
1.3. Significance of the study .....	5
1.4. Research questions .....	5
II. Literature Review .....	7
2.1. Vaccination.....	7
2.2. History of the Expanded Program of Immunization .....	8
2.3. History of the Expanded Program of Immunization in Cameroon.....	8
2.4. EPI targeted diseases in Cameroon.....	9
2.5. Vaccination implementation strategy in Cameroon .....	13
2.5.1. Routine Immunization.....	13

2.5.2.	Additional vaccination strategies .....	15
2.6.	The EPI vaccination calendar for infants in Cameroon .....	15
2.7.	Vaccine wastage.....	15
2.7.1.	Types of vaccine wastage.....	16
2.7.2.	Wastage factor .....	19
2.7.3.	Factors affecting vaccine wastage .....	19
2.8.	Relationship between vaccine wastage and immunization coverage .....	23
2.9.	Reducing vaccine wastage .....	28
2.9.1.	Changing the vial size .....	28
2.9.2.	Vaccine vial monitor (VVM) .....	28
2.9.3.	Multidose vial policy .....	29
2.9.4.	Earliest-expiry-first-out principle .....	30
2.9.5.	Improved procurement practices .....	30
2.9.6.	Optimizing immunization session frequency with session size and vial size ..	30
2.9.7.	Prevention of freezing.....	30
2.9.8.	Safe immunization practices .....	31
2.9.9.	Improved vaccine management practices .....	31
2.9.10.	Prevention of submergence of vials in water .....	31
III.	Methods .....	32
3.1.	Study design .....	32

3.2.	Study setting .....	32
3.3.	Study Participants .....	36
3.3.1.	Inclusion criteria .....	36
3.3.2.	Exclusion criteria .....	36
3.4.	Data source and data collecting process .....	36
3.5.	Variables and the sources of data.....	37
3.6.	Calculation of wastage rate and data analysis.....	40
3.6.1.	Calculation of Vaccine coverage and vaccine wastage rate.....	40
3.6.2.	Data analysis .....	40
3.7.	Ethical considerations .....	41
3.8.	Limitations of the study .....	41
IV.	Results.....	43
4.1.	Relationship between immunization coverage and vaccine wastage .....	47
4.2.	Urbanization and effect on vaccine wastage rate .....	49
4.2.1.	Urbanization and Vaccine wastage factor .....	50
4.2.2.	Vaccine categories and wastage .....	54
4.3.	Effect of season on vaccine wastage rate .....	55
4.3.1.	Vaccine wastage factor and seasons.....	57
4.3.2.	Vaccine categories and wastage .....	58
V.	Discussion.....	61

VI.	Conclusion .....	68
VII.	References.....	70
VIII.	Appendix .....	79
	Ethical Authorization.....	79

## List of Figures

<b>Figure 1.</b> Diagrammatic presentation of the various types of immunity .....	7
<b>Figure 2.</b> Relationship between vaccine wastage and immunization coverage.....	24
<b>Figure 3.</b> More relationship between vaccine wastage and immunization coverage .....	25
<b>Figure 4.</b> The Littoral region and the other 9 health regions of Cameroon .....	33
<b>Figure 5.</b> Vaccine wastage rates for various vaccines comparing 2016 and 2017 .....	47
<b>Figure 6.</b> Variations between vaccine coverage and vaccine wastage for BCG, IPV and Measles in 2016 .....	48
<b>Figure 7.</b> Variations between vaccine coverage and vaccine wastage for BCG, IPV and Measles in 2017 .....	48
<b>Figure 8.</b> Vaccine wastage comparing rural and urban health districts in 2016.....	49
<b>Figure 9.</b> Vaccine wastage comparing rural and urban health districts in 2017.....	50
<b>Figure 10.</b> Comparison of vaccine wastage factor between rural and urban health districts	51
<b>Figure 11.</b> Vaccine wastage between rural and urban health districts comparing 2016 and 2017 .....	54
<b>Figure 12.</b> Vaccine wastage comparing the dry and the rainy season in 2016.....	55
<b>Figure 13.</b> Vaccine wastage comparing the dry and the rainy season in 2017.....	56
<b>Figure 14.</b> Vaccine wastage comparing 2016 and 2017 between the dry and the rainy seasons .....	56
<b>Figure 15.</b> Comparison of vaccine wastage factor between the dry and the rainy seasons .....	57

## List of Tables

<b>Table 1.</b> Targets for vaccination coverage and VWR in 2017 and Vaccination coverage in Cameroon for some Vaccines .....	4
<b>Table 2.</b> EPI vaccination calendar of Cameroon from 2015 till date .....	17
<b>Table 3.</b> Types of vaccine wastage.....	18
<b>Table 4.</b> Problematic time trend relationships between immunization coverage and vaccine wastage.....	26
<b>Table 5.</b> EPI 2017 estimated population for the littoral region, Cameroon.....	35
<b>Table 6.</b> Variables in the study .....	38
<b>Table 7.</b> A comparison of children vaccinated and vaccine used between rural and urban districts as well as between dry and the rainy season .....	45
<b>Table 8.</b> Wastage rate and wastage factor for different vaccines in the Littoral region in between 2016 and 2017.....	46
<b>Table 9.</b> Vaccine wastage rates for various vaccines comparing rural and urban health districts .....	52
<b>Table 10.</b> Differences in vaccine rate classified into route of administration and type of vaccine, comparing rural and urban health settings .....	53
<b>Table 11.</b> Statistical differences in vaccine wastage comparing the dry and the rainy seasons .....	59
<b>Table 12.</b> Differences in vaccine rate classified into route of administration and type of vaccine, comparing the dry and the rainy seasons .....	60

## List of Abbreviations

AFP	Acute Flaccid Paralysis
AIDS	Acquired Immune Deficiency Syndrome
ATT	Ante Tetanus Toxoids
BCG	Bacillus Calmette Guérin
CTG	Central Technical Group
DPT	Diphtheria -Pertussis-Tetanus
EPI	Expanded Program on Immunization
GAVI	Global Alliance for Vaccines and Immunization
HPV	Human Papiloma Virus
IPV	Inactivated Polio Vaccine
IVI	International Vaccine Institute
KB	Koch's Bacillus
LIC	Low Income Countries
MDVP	Multi-dose Vial Policy
MR	Measles and Rubella
MoPH	Ministry of Public Health
MOV	Missed Opportunity to Vaccinate
MPA	Minimum Package of Activities
OCEAC	Organization for the Coordination of Endemic Disease Control in Central Africa
OPV	Oral Polio Vaccine
OVP	Open Vial Policy
PCV	Pneumococcal Conjugate Vaccine
PENTA	Diphtheria, Pertussis, Tetanus Hepatitis B and Hemophilus influenza type b

PHC	Primary Health Care
RDPH	Regional Delegate of Public Health
SIAs	Supplementary Immunization Activities
TB	Tuberculosis
UN	United Nations
UNICEF	The United Nations Children's Fund
VPDs	Vaccine Preventable Diseases
VVM	Vaccine vial monitor
VWF	Vaccine Wastage Factor
VWR	Vaccine Wastage Rates
WHO	World Health Organization

## Abstract

**Introduction:** Vaccination is a major and cost-effective public health intervention in the prevention of infectious diseases, especially in children. Availability of vaccine is a prerequisite for high vaccination coverage and vaccine wastage renders vaccines less available for use. In Cameroon, the Expanded Program of Immunization (EPI) vaccinates all children less than 5 years free of charge but the vaccination coverage has consistently remained below target. Distribution of vaccines are based on the target population size and some ‘wastage norms’ but wastage rates may differ from locality to locality. This study seeks assess vaccine wastage rates and compare it between various settings in the Littoral Region of Cameroon.

**Methods:** This was a record based analytical study carried out in the Littoral Region of Cameroon using the 2016 and 2017 immunization data. Health districts were classified as ‘urban’ or ‘rural’ based on their remoteness. Vaccine wastages and vaccine wastage factor were calculated and compared between the rainy and the dry seasons.

**Results:** A total of 2851527 doses of vaccines were used to vaccinate 2640077 children during the two years. Vaccine wastage was highest in BCG (32.19%), then MR (19.05%) and yellow fever (18.34%). The single-dose vaccine vials had negative vaccine wastage rates (VWR). February and November always experienced a decrease in vaccination coverage and over the months, whenever vaccination coverage decreases VWR increases and vice versa. VWR for all vaccines were higher during the dry season, except in 2016, where the VWR for lyophilized vaccine were higher in the rainy season. VWR were continuously higher in the rural districts.

**Conclusion:** Vaccine wastage greatly differs between rural and urban health districts but also between the dry and the rainy season with most of the wastage occurring in the rural districts and surprisingly during the dry season where climatic conditions are more favourable.

**Keywords:** *Vaccine wastage, Rural and Urban District, Dry and Rainy Season, Littoral, Cameroon*

## I. Introduction

### 1.1. Background

A number of ways exist to protect children as they grow up, some of which include, proper dressing, proper positioning of electrical appliances in the house and the use of seat belts in vehicles. However, when it comes to protection against childhood diseases, the medical community strongly recommends vaccination(1,2). Vaccines are second only to safe water in reducing mortality and not even antibiotics has had such an effect on morbidity and mortality(2,3).

Worldwide, vaccines are available to prevent many diseases in people of all ages(4). For childhood diseases, the primary vaccine preventable diseases (VPDs) for which vaccines are readily available are diphtheria, invasive diseases caused by the *Haemophilus influenza* type b (Hib) bacterium, measles, poliomyelitis (polio), rubella (“German” measles), tuberculosis (TB), tetanus, mumps, varicella (chickenpox), pertussis (whooping cough) pneumococcal infections, and diarrhea with rotavirus(3,4).

Although infectious diseases is not only a thing of the developing countries, the situation is much worse in there where VPDs cause more than 10 million DALYs and vaccination coverage still remains uncomfortably low(5–7) despite knowledge of the fact that vaccination not only protects individuals but also limits the spread of disease in the general population(2). Efforts to improve quality vaccination coverage and timeliness are very much needed in low income countries where within a the countries, vaccination coverage differs between rural and urban, with the rural areas having the tendency to produce low vaccination coverage rate(2).

Availability of vaccines and vaccine products are some of the very important factors that influence vaccination coverage and this is critical in low income countries (LIC) (8,9). With the relatively high frequency of the introduction of new vaccines in recent years, importance is laid on vaccine management since new vaccines are more expensive (8,10,11). Effective and efficient management and utilization enhances regular supply of the vaccines and this is essential to ensure vaccine security while simultaneously keeping a check on program costs(12). To increase vaccination coverage, there is a strong recommendation to reduce missed opportunity to vaccinate (MOV)(13). Though vaccination coverage is never to be compromised by considering the cost of the vaccine, the recommendations to reduce MOV may sometimes conflict with recommendations to reduce vaccine wastage(8) especially if the policy is not clearly transmitted to the health personnel involved in vaccination.

WHO points to a worldwide statistic of more than 50% vaccine wastage(9,14,15). In 1997, WHO officially stated that 43% of vaccines delivered to developing countries don't end up being administer to children caused mainly by poor infrastructure(16). National statistics being it immunization coverage or wastage usually cover rural-urban differences(17) which is inextricably linked to difference in field realities (infrastructure). While urban areas face its own difficulties in vaccination activities which are mostly linked to low quality of monitoring and tracking(18), factors such as parent's objection or disagreement, concerns about safety of vaccines, walking distances to health facilities and waiting time in the health facilities, health worker density and logistics availability are usually more prevalent in rural than urban settings(19,20) and plays some role in vaccine wastage. Also, the dispersed nature of the population and the long distances to travel by a health worker on an outreach vaccination session coupled with poor road network may compromise the cold chain leading to vaccine wastage. In small facilities; typically in rural

areas, vaccine wastage rate may be high compared to large hospitals typically in urban areas(21). Therefore vaccine wastage is related to vaccine handling and utilization(22) which differs between urban and rural areas due to differences in field realities. With generally low immunization coverage in rural areas(23), it can be suspected that there is link with high vaccine wastage or it can lead to high vaccine wastage.

In Cameroon, the Expanded Program on Immunization (EPI) began in 1976 as a coordinated pilot project of the Organization for the Coordination of Endemic Disease Control in Central Africa (OCEAC). This pilot project became an operational program throughout the country in 1982(4). The EPI aims to prevent, control, eliminate or eradicate VPDs. Following the Declaration of the Reorientation of Primary Health Care in 1993, EPI activities were integrated into the Minimum Package of Activities (MPA) of health facilities nationwide(4) and are given to children free of charge, where vaccination is seen as a fundamental right of every child.

Cameroon's health system is made up of 10 regions and 189 health districts(24) and among the 10 regions is the Littoral Region which is one of the most densely populated with 24 health districts. This region significantly influences the national immunization statistics. Out of the 24 health Districts, 3 are urban, 9 are semi-urban and 12 are rural health districts, with the semi-rural districts lacking the typical criteria of the rural districts.

There are two seasons in Cameroon; the rainy and the dry season. The former usually beginning from June and ending in November(25) has more consequential effects on immunization activities and vaccine supply chain especially in rural areas as road networks are usually despicably poor couple with rampant power failure. These can lead to both open and unopened vial vaccine wastage.

Though there has been improvements over the years, immunization coverage in Cameroon still falls short of target (Table 1a) with many eligible children going unvaccinated or incompletely vaccinated even in central cities(26) and these may be due to programmatic

errors in terms of vaccine logistics(27). Not only is the government aiming at high vaccination coverage, it is also aiming to keep vaccine wastage in check. For instance, Table 1b shows the vaccination coverages and vaccine wastage rates (VWR) targeted in 2017 in Cameroon(28) compared with WHO projected acceptable wastage rates(29).

**Table 1.** Targets for vaccination coverage and VWR in 2017 and Vaccination coverage in Cameroon for some Vaccines

Antigen	Vaccination coverage (%)			Vaccine	Targeted	Targeted	WHO
	2015	2016	2017		Coverage (%)	wastage rate (%)	acceptable WR (%)
BGC	74	70	91	BCG	89	25	50
PENTA 1	92	92	93	VPO	89	10	10
PENTA 3	84	85	86	VPI	79	10	15
OPV3	83	83	84	Penta	89	6	15
Yellow Fever	77	78	78	PCV	89	3	5
				ROTA	82	5	5
				MM	89	25	25
				VAA	89	25	25

1a

1b

## 1.2. Statement of the problem

Immunization coverage is unquestionably related to vaccine wastage because wastage translate to less vaccines available for use especially in areas of poor accessibility to vaccine storage facility(8,9). However, vaccine wastage cannot be completely avoided and so must be incorporated in calculating the vaccine need of a population. Cameroon government views vaccination as a fundamental right of every child and to this regard, has consistently been seeking to improving vaccination coverage over the years but they still fall below target. Seeking to improve immunization coverage goes with seeking to reduce vaccine wastage which differ between rural and urban settings, depending on field realities. Such differences

need to be monitored continuously and used in calculating vaccine needs of a population otherwise it may lead to irrational or inappropriate distribution of vaccines, which can further potentiate vaccine wastage. Very few studies on vaccine wastage has been conducted in Cameroon and none sort to estimate vaccine wastage variations between different environmental and climatic conditions.

### **1.3. Significance of the study**

High immunization coverage unquestionably depends on adequate supply of vaccines which is calculated taking into account vaccine wastage. Because vaccines are costly, wastage should therefore be reduced as much as possible (without compromising vaccination coverage) since it cannot be completely avoided. Various factors influence vaccine wastage some of which are much more prevalent in certain localities than others necessitating continuous monitoring of vaccine wastage and its use in the estimation of the vaccine needs of such localities.

The Littoral region of Cameroon just like many other regions in the country has been having challenges to meeting immunization targets over the years and to meet these targets, adequate supply of vaccines is a prerequisite. Vaccines are distributed from the central level to the peripheral level based on estimated administrative target population, wastage norms, coverage objective and some security margin. This top-down distribution of vaccines may lead to inappropriate distribution of vaccines hence worsening vaccine wastage and its effect on coverage and efficiency of the program. In the littoral region where population mobility is high, mastery of the target population by the central level is difficult and slight increase in wastage rate above national norms may increase the risk of vaccine stock out. This calls for the need for local vaccine rates to be mastered and continuously monitored.

### **1.4. Research questions**

Vaccine wastage cannot be completely avoided and therefore must be incorporated in vaccine needs of the population. Also, vaccines especially newer vaccines are costly and

wastage increases the cost of the program and should be reduced as much as possible. To better understand whether vaccine wastage is high enough, it should be analyzed together with vaccination coverage rate and pattern of vaccine wastage should be compared with that of vaccination coverage. This study seeks therefore to answer the question: ‘what is the relationship between immunization coverage and vaccine wastage?’

The health system in the rural areas are different from those in that urban areas in terms of infrastructure and personnel among others. Also, the characteristics of the population structure in the rural area is different from that in the urban area. For example, rural population are likely to be made up of less educated person compared to the urban population and vaccine take up in a less educated population is low(30) Again, the nature of the terrain in urban areas is made more accessible than the terrain in rural areas facilitating the transportation of vaccines and vaccine products. With these differences, it is important to know if vaccine wastage differ between rural areas and in urban areas.

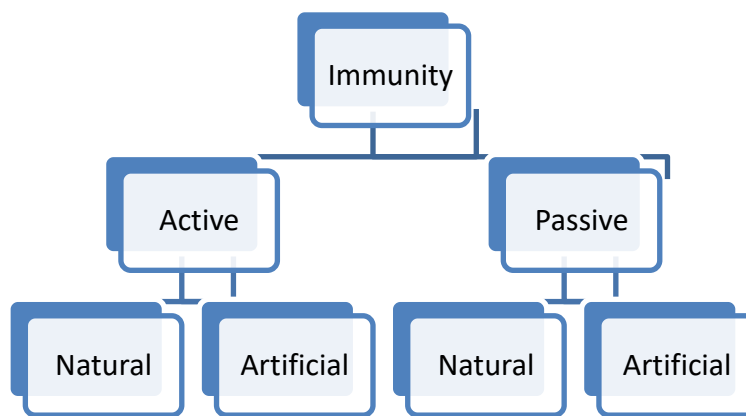
There are two main seasons in the Littoral region of Cameroon; the rainy and the dry season. The rainy season beginning from June and ending in November has more devastating effects as the road networks become very poor, electricity failure is almost constant and the rains may render some vaccination seasons impossible to be attended the population. These challenging circumstances may have an effect on vaccine wastage. Therefore, this study seeks also to find out if there are any differences in vaccine wastage between the rainy and the dry season.

## II. Literature Review

### 2.1. Vaccination

Vaccination is the artificial introduction of a pathogen-based product into the body of a healthy individual or a patient. This product must be able to induce in the recipient specific antibodies against the development of the pathogen. As one of the best efficient preventive measures, vaccination is in line with Primary Health Care (PHC) activities whose aim is the promotion of the health of individuals and communities.

While vaccination is sometimes used interchangeably with immunization, immunity is actually an organism's ability to defend itself when attacked by a pathogenic agent. Immunization therefore refers to all humoral and cellular factors that protect the body against any form of attack. It confers immunity either by antigen being introduced in to the body (active) or by the introduction of specific antibodies (passive). There are two types of immunity; natural and artificial immunities as shown in the Figure 1(4).



**Figure 1.** Diagrammatic presentation of the various types of immunity

## **2.2. History of the Expanded Program of Immunization**

EPI is a World Health Organization's initiative with the goal of making vaccines available to all children throughout the world(31). It was initiated in May 1974 with the objective of vaccinating all the children of the world. Ten years later, a standardized scheduled was provided for some vaccines as: diphtheria-tetanus-pertussis (DPT), BCG, measles and oral polio vaccine (OPV)(31). As knowledge on immunologic factors of disease increase, some other vaccines were included into the list of EPI targeted diseases. These vaccines include : Hepatitis B (HepB), yellow fever for endemic countries for the disease, and Haemophilus influenzae meningitis (Hib) conjugate vaccine in high disease-burden countries.

The Global Alliance for Vaccines and Immunization (GAVI) was created in 1999 with the sole objective of improving child health in very poor countries by extending the activities of EPI. GAVI brought together United Nations (UN) agencies and institutions (WHO, UNICEF, the World Bank), public health institutes, donors, like the Bill and Melinda Gates Foundation and, the vaccine industry, non-governmental organizations (NGOs) and many others. GAVI has assisted in renewing interest and maintaining the importance of immunizations in fighting the world's exorbitant burden of infectious diseases(32).

## **2.3. History of the Expanded Program of Immunization in Cameroon**

In Cameroon, EPI started two years after the initiation by WHO, that is in 1976. It started as a pilot project that was coordinated by the Organization for the Coordination of the Control of Endemic Diseases in Central Africa (OCEAC). This pilot became operational in all the regions of the country in 1982(4).

## 2.4. EPI targeted diseases in Cameroon

EPI programs differ from country to country with respect to the diseases they target. Countries especially those of the developing world do not purchase all the vaccines as soon as there are licensed(33) because diseases endemicity and burden differ from country to country. The following diseases are targeted by the EPI program(4):

### i. Tuberculosis

TB is a contagious disease caused by *Mycobacterium tuberculosis* or Koch Bacillus (KB). It is transmitted through respiratory droplets coughed out by a person whose sputum contains the bacteria. The first contact with the KB (primo infection) may be unnoticed; however, in one out of ten cases, a primo infection may result to a full-blown disease (pulmonary or extra pulmonary disease). Malnutrition, alcoholism, diabetes and especially Acquired Immune Deficiency Syndrome (AIDS) are current risk factors. Vaccination with BCG remains the best means of preventing children from serious forms of TB improved hygiene conditions are also important(4).

### ii. Diphtheria

This disease, caused by *Corynebacterium diphtheria* is an infectious one that is transmitted from one person to another by close personal contact or by inhalation.

With man as the main reservoir, the incubation period is between 3 and 5 days and even more. Unvaccinated Children under 15 years are the most affected. Diphtheria has as symptoms the following: fever, running nose and sore throat. The tonsils are swollen, covered with greyish membrane, which can invade the vocal cords and the trachea; this can easily lead to suffocation. The diphtheria toxin can cause heart and kidney problems. Vaccination of children less than one year is the main preventive action(4).

### iii. Tetanus

This disease is as a result of the actions of neurotoxin secreted by an anaerobic bacterium called *Clostridium tetanii* which develops in soiled necrotic tissues (soiled wound, umbilical cord if delivery took place under poor hygiene conditions). Spores of this bacterium can also enter someone through open wounds as a result of farm work, circumcisions and scarifications.

The incubation period of the bacterium is between 3-10 days and may go up to 3 weeks. Symptoms usually appear before 14 days after contact. In a neonate, the newborn that was normal during the first few days of life becomes unable to suck due to jaw spasms and the spasms become generalized throughout the whole body. Neonatal tetanus is fatal in 100% of the cases and prevention is by immunizing infants, pregnant woman and access to good quality antenatal and delivery services(4,34).

### iv. Pertussis

Pertussis, also called whooping cough is a tracheobronchial infection caused by the bacteria called *Bordetella pertussis*. Transmission is by droplet spread from an infected to and uninfected person. The most vulnerable groups include infants and children living in overcrowded environment. Man is the reservoir of the disease.

The incubation period can go up to 21 days and the characteristic symptom is persistent cough for 4 to 8 weeks with characteristic whooping spasms (coughing fits) that is accompanied usually by cyanosis and vomiting. Apnea and death can result from the coughing fits in infants. Malnutrition, pneumonia, and convulsions can complicate pertussis. Vaccination of children less than one year is the main preventive measure(4).

**v. Poliomyelitis**

Polio is an acute viral infection caused by three types of polio viruses; type 1,2 and 3. In poor countries, the feocal-oral transmission is the route of importance though there exist the oro-pharyngeal transmission(35).

The incubation period varies from 3 to 35 days and diagnosis is by laboratory examination of stool. Most cases are asymptomatic and the most common symptoms are fever, Acute Flaccid Paralysis (AFP) and the most effective means of prevention is through vaccination with the OPV and then environmental and personal hygiene(4,35).

**vi. Measles Mumps and Rubella**

This are acute viral infection that are transmitted by the respiratory route. The only reservoir for the disease is man and closed contact with each other is a favorable environment for the transmission of the disease. The patient is contagious for 2 days before the rash and 4 days after the rash he is still contagious. There are primarily prevented by vaccination with the measles, Mumps and Rubella vaccine at 9 months of age

**vii. Viral hepatitis B**

This is a viral disease caused by the hepatitis B virus. Transmission is through unprotected sexual intercourse with an infected person. Also contact with blood of an infected person is a serious risk factor. Mother to child transmission is possible and during childhood, scratches and wound in infected children predisposes the others to the disease. A dangerous aspect of the disease is that infected persons may remain contagious for a very long time hence exposing those around them(4). The incubation period can be six weeks but can go up to 6 months. Signs and symptoms include: fever, jaundice, fatigue, dark urine and pale stools. Preventive measures include vaccination, practice of safe sex and health

personnel are particularly at risk since they can easily get in contact with patients' blood if universal precautions are not being practiced.

**viii. Yellow fever**

This is a viral hemorrhagic fever that is transmitted from one person to another by the bite of a mosquito called *Aedes Egypti*. This mosquito breeds in stagnant waters around the environment. In bush areas, the monkey is the main host and man is just an accidental host while in urban settings, man become the main host.

**ix. Diseases caused by Hib**

The *Haemophilus influenza* type b bacterium causes many infections affecting mostly children under five years of age. There are about 6 serotype of the bacterium and the type b is responsible for a majority (about 80%) of severe infections in children. This bacterium is transmitted through respiratory droplets. That is through sneezing or coughing and the risk of transmission increases when children spend long times together like in overcrowding situations. Children less than 6 years are the most affected with the peak of vulnerability as from 4-12 months. Also, having a short incubation period, the symptoms of the diseases are as follows: fever, vomiting, lethargy, inflammation of the meninges, epiglottitis and obstructive laryngitis. Coma can result. Effective preventive measure lies in vaccinating the children(4).

**x. Pneumococcal infections**

These infections are caused by the bacterium *Streptococcus pneumoniae* and the most severe diseases are pneumonia, meningitis, and febrile bacteremia. The most common forms of the infections are: otitis, sinusitis and bronchitis. The incubation period is less than 5 days and the symptoms of the diseases are sudden onset of fever, cough, dyspnea, chills and sometimes chest pain. These infections can only be effectively prevented by vaccination.

**xi. Diarrhoea with rotavirus**

This is an acute febrile gastroenteritis caused by a virus of the family rotavirus. Since it is highly contagious, these rotaviruses are associated most of the diarrhea in children. Transmission of the disease is by the faeco-oral route and an infected child is able to transmit the disease to others 4-5 days before becoming symptomatic and then up to 2 weeks after treatment.

**xii. Meningococcal infections**

Meningococcal diseases are diseases caused by the bacterium *Neisseria meningitidis*. Direct contact with the nasopharyngeal secretions of an infected person exposes the healthy individual to these diseases.

This bacterium has a short incubation period that is usually less than four days. Some of the symptoms include: fever, headache, stiff neck, nausea, vomiting, photophobia convulsions, swollen fontanel drowsiness, confusion and sometimes irritability. Prevention is solely by vaccination with the Pneumo vaccine and avoidance of contact with infected individuals.

**2.5. Vaccination implementation strategy in Cameroon**

The Ministry of Public Health (MoPH) of Cameroon stipulates that vaccines for routine vaccination be delivered using the following strategies:

**2.5.1. Routine Immunization**

**2.5.1.1. Fixed post strategy**

These are vaccination sessions held at the health facility according to a pre-established program for the target group (children 0-11 months and pregnant women). This is meant for those persons living near the health facility (one hour's walking distance) or who have easy

access to the health centers. Vaccine wastage in this strategy is usually lower than in the other strategies(36) since there are limited chances of accidents leading to spillage. In the littoral region, this strategy is most effective in urban and semi-urban districts where access to the health facility is easy and within walkable distance to many households.

#### **2.5.1.2. Outreach strategy**

These are vaccination sessions held outside a functional health facility for a portion of the population that is far off (more than 5km radius or beyond an hour walking distance) or whose geographical access to the health facility is difficult. Here the health worker displaces himself and vaccines on an automobile (usually motorbike) to the communities to meet the population. This is what is practiced in the rural districts because the population is highly dispersed.

#### **2.5.1.3. Mobile strategy**

This strategy consists in spending several days in one or more far away communities (usually more than 15km radius from the health facility) to carry out vaccination and other health activities. It is also most often (if not always) practices in rural communities.

#### **2.5.1.4. Vaccination in a temporary fixed post**

Vaccination in a temporary fixed post consists of installing a vaccination post in the community (school, station, market, etc.) for a fixed period of time. It brings the community closer to immunization services and other services in the Minimum Package of Activity (MPA).

## **2.5.2. Additional vaccination strategies**

### **2.5.2.1. Door to door**

Here, vaccinators travel to households to administer vaccines to children of the targeted group. This is done most often during Supplementary Immunization activities (SIAs)

### **2.5.2.2. Special Vaccination Strategies**

Special vaccination strategies are used during SIAs. Among these sessions, the most frequently used are: hit and run, permanent health team, fire walling, vaccination in train stations, toll stations, markets, churches, fields, borders. These sessions aim to ensure access to vaccines for the entire target population. Hit and run, permanent health team and the fire walling are strategies that help to reach people living in insecure areas(4).

## **2.6. The EPI vaccination calendar for infants in Cameroon**

The objective of the vaccination schedule is to administer all the vaccines against EPI targeted diseases in five contacts before the age of one year, while respecting the time intervals between doses. A child is considered to be completely and correctly vaccinated when he or she receives all the antigens while respecting the intervals between doses, the routes of administration and the norms of quality vaccination(4). This is indicated in the vaccination calendar presented in Table 2.

## **2.7. Vaccine wastage**

Since wastage is the action or process of losing or destroying something by using it carelessly or extravagantly(37), vaccine wastage can be defined as the proportion of vaccine that are used but not administer considering that vaccines are designed to be administered to prevent certain diseases(15).

### **2.7.1. Types of vaccine wastage**

A vaccine dose is considered wasted if it not used to vaccinate an eligible person(15,16) and for these reason global guidelines for reducing vaccine wastage stipulate that some vaccines be used for up to 28 days {Multi-dose Vial Policy (MDVP) or Open Vial Policy (OVP)}. For some vaccines like the Bacillus Calmette Guérin (BCG), Measles and Yellow fever vaccines, their utility is limited to 6 hours after reconstitution, after which there must be discarded(15,38,39). This is considered as unavoidable wastage. There are also avoidable vaccine wastage which include expiration, vial breakage, inappropriate vial freezing, theft, exposure to heat and non-respect of the OVP(15). Vaccine wastage can also be classified as opened or unopened vial wastage.

**Table 2.** EPI vaccination calendar of Cameroon from 2015 till date

AGE	VACCINE	ROUTE OF ADMINISTRATI ON	DOSE OF VACCINE	ADMINISTRATION SITE
At birth	BCG	Intrademic	0.05ml	Upper 1/3 of the left forearm
	OPV0	Oral	2 drops	In the mouth
6 weeks	DPT-HepB1+Hib1	Intramuscular	0.5ml	Left thigh
	OPV-1	Oral	2 drops	In the mouth
	PCV13-1	Intramuscular	0.5mls	Right thigh
	Rota 1	Oral	1 ampoule	In the mouth
10 weeks	DPT-HepB1+Hib2	Intramuscular	0.5ml	Left thigh
	OPV-2	Oral	2 drops	In the mouth
	PCV13-2	Intramuscular	0.5mls	Right thigh
	Rota 2	Oral	1 ampoule	In the mouth
14 weeks	DPT-HepB1+Hib3	Intramuscular	0.5ml	Left thigh
	OPV-3	Oral	2 drops	In the mouth
	PCV13-3	Intramuscular	0.5mls	Right thigh
	IPV	Intramuscular	0.5mls	Right thigh
6-11 months	Vitamin A	Oral	100,000 IU	In the mouth
9 months	MMR	Subcutaneous	0.05	Left deltoid
	Yellow fever vaccine	Subcutaneous	0.05	Right deltoid
12 – 59 months	Vitamin A (every 6 months)	Oral	200,000IU	In the mouth

Table legend: Content of the table reconstructed based on the Cameroon MOH guideline, 2018(4)

Unopened vial vaccine wastage is largely linked to supply chain problems(19) where vaccines are wasted in intact vials while opened vial vaccine wastage is linked to both

supply chain and immunization problems(4) and all needs to be monitored to help influence response policies(27,40). Table 3 summarizes the differences between opened and unopened vial wastages.

The reaction of a baby to immunization may also cause the dose administered to be wasted, especially in the case of oral vaccines where crying and agitations can cause some doses to be drop out of the mouth. In this circumstance, more than one dose is required to immunize a child. Vaccine wastage must be calculated at all levels on a routine and regular basis(15) However, in the absence of locality specific wastage rate, WHO provides some indicative wastage rates that can be used to estimate vaccine needs of a population(41). These rates depend on the vaccine type and the number of doses per vial.

**Table 3.** Types of vaccine wastage

Vaccine wastage in unopened vials	Vaccine wastage in opened vials
Expiry	In addition to the types listed in the previous column:
VVM indication	Discarding remaining doses at end of session
Heat exposure	Not being able to draw the number of doses indicated on the label of a vial
Freezing	Poor reconstitution practices
Breakage	Submergence of opened vials in water
Missing inventory	Suspected contamination
Theft	Patient reaction requiring more than one dose
Discarding unused vials returned from an outreach session	

Table legend: Content of the table from WHO and UNICEF, 2005 (15)

Since vaccine wastage cannot be completely avoided, acceptable wastage levels vary between programs in the light of experience and the analysis of local situations. For example, because of sparse population distribution, services in remote areas may have to open more vials than urban services to vaccinate children, and this results to higher wastage rates in rural areas. Similarly, in locations where a great majority of the population can only be reached through outreach services, higher wastage rates are expected(15,42).

The type of vaccine wastage is important to know. A high wastage rate that is attributed to opening a multidose vial for a small session to avoid missed opportunities to vaccinate is better accepted than wastage attributed inappropriate vaccine storage. However, vaccine wastage is expected with lyophilized vaccines as they must be discarded within six hours of opening, compared to liquid vaccines that can be used in next sessions for up to 4 weeks.

### **2.7.2. Wastage factor**

In forecasting vaccine, the vaccine wastage factor is used instead of the vaccine wastage rate. The vaccine wastage factor indicates how much additional vaccine should be ordered in order to allow for a given wastage rate. The vaccine wastage factor (VWF) is a function of a vaccine wastage rate. It used is to estimate the quantity of vaccine needed in the locality considering the quantity that will be wasted. It varies greatly according many characteristics including presentation of vaccine, size of the vaccination session and supply management(41). Therefore, each program is encouraged to monitor its own wastage level in order to better calculate the VWF.

### **2.7.3. Factors affecting vaccine wastage**

According to WHO(15), Many factors contribute to vaccine wastage, ranging from the vaccine to the vaccinator. They are not independent of each other:

### **2.7.3.1. Factors related to vaccines and syringes**

#### **a) Vial size**

More wastage is reported with the larger vial sizes unless they are used in mass immunization activities. Different vial sizes allow immunization managers to choose the best presentation for the purposes of specific programs. Smaller vials cost more than larger ones containing the same vaccine, resulting in a higher cost per child immunized. Also, smaller vials require greater cold chain and vaccine transportation capacity than larger ones(43).

#### **a) Dead space in the syringe**

A dead space in a syringe is the space occupied by a fluid in the syringe that cannot be expelled. Therefore, the higher the dead space of a syringe, the higher the wastage rate since the same quantity of vaccine that cannot be expelled will be drawn into the syringe and not used to vaccinate a target. Related to dead space in the actual number of doses in a vaccine vial. Some vaccines are reported to have fewer doses than is indicated by the manufacturer(44).

### **2.7.3.2. Factors related to national policy**

#### **a) Supply policy**

Inaccurate vaccine forecasting may give rise to increased vaccine wastage. Health districts may receive more vaccines than are needed monthly, leading to the expiry of vaccines before they can be used. Or if their cold chain is not well adapted to keep these vaccines, it may get bad before it can be used.

#### **b) Vaccine vial monitor (VVM) introduction**

VVMs were first used with OPV during 1996. They have now been delivered with more than 1.5 billion doses of OPV to more than 80 countries. As from 2001, VVMs were included as product specifications by UNICEF for all EPI vaccines. Global Alliance for

Vaccines and Immunization (GAVI) also requires the use of VVMs with vaccines. To be able to properly use VVMs, health workers must be trained in good time. A failure to identify health workers who need refresher training on VVM use may also result in the incorrect use of VVMs and some increase in vaccine wastage.

**c) Discarding of doses remaining in opened vials at end of day**

Countries that are still to adopt MDVP have greater wastage rates for liquid vaccines than those that have adopted it already. However, where sterilizable syringes are used or other sources of contamination of opened vials are not under control, countries may have difficulties in adopting MDVP nationwide.

**2.7.3.3. Factors related to logistics**

**a) Stock control**

adequate stock control practices require that vital information on vaccines be recorded when they are received, during storage and when they are leaving the store for distribution. Expiry dates must be recorded properly and properly followed up else, storekeepers may dispatch a batch that expires later than the ones kept at the store.

**b) Alternative cold chain**

An alternative cold chain, may be of value in having excess vaccine for whatever reason. In the case of non-availability, a pushdown distribution approach mostly results in vaccines from the primary vaccine store being sent to the intermediate stores and therefore to immunization points without checking as to whether the cold chain capacity in those areas can really absorb them. This puts the vaccines at risk of expiry or of being exposed to improper temperatures because of a lack of adequate storage capacity.

**c) Quality and management of cold chain**

Cold chain equipment should be compatible with WHO–UNICEF product information sheets (PIS) else it may not be able to ensure the storage temperatures required for different types of vaccines.

**d) Temperature monitoring**

If the temperature in cold chain equipment for storing vaccines is not monitored and controlled regularly, vaccines may be at risk of exposure to unacceptable temperatures, resulting in wastage

**e) Vaccine distribution and transportation practices**

Vaccines are at risk of being damaged by excessive heat or freezing temperatures if correct practices are not followed during transportation. When this happens, there is increased vaccine wastage and supplies may become inadequate.

**f) Reading and/or using VVM status**

Storekeepers should know how to read and interpret VVMs and make informed choices before distributing vaccines. If they do not know, they may put vaccines at risk. For instance, if vials with VVMs showing low heat exposure are sent to the field before vaccine vials with VVMs approaching the discard point, the vaccines kept behind in the store may be at risk of reaching their discard point still in the storage facility.

**g) Communication and supervision**

In cases where global policies to reduce vaccine wastage are adopted at national level, good communication down to sub national and service levels and effective supervision are needed to ensure that the policies are translated into local action. A lack of effective communication and supervision causes policies to remain on paper only.

#### **2.7.3.4. Factors related to immunization practice**

##### **a) Liquid vaccines discarded at end of session (or before four weeks)**

If multidose vials of liquid vaccine presentations are not kept for subsequent sessions (up to four weeks) and are thrown away at the end of a session, vaccine wastage rates are reported to be high

##### **b) Reconstitution practices**

If the whole content of diluent is not used to reconstitute powder vaccine, fewer doses are available in the vaccine vial for vaccination.

##### **c) Cold chain failures**

Cold chain failures may expose vaccines to high temperatures if storekeepers and/or health workers do not know what to do in such cases.

##### **d) Session size**

If larger dose presentations are used during small session size, wastage may increase. The golden rule should be to avoid compromising vaccination coverage. However, tackling the problem with small session size can differ between outreach activities and fixed-site immunization points.

##### **e) Injection practices (contamination)**

Poor injection practices may contaminate vaccine vials. Submerging opened multidose vials in water makes them contaminated by default and must be discarded. If crushed ice or ice cubes are used in vaccine carriers during transportation of vaccines, submerging frequently occurs.

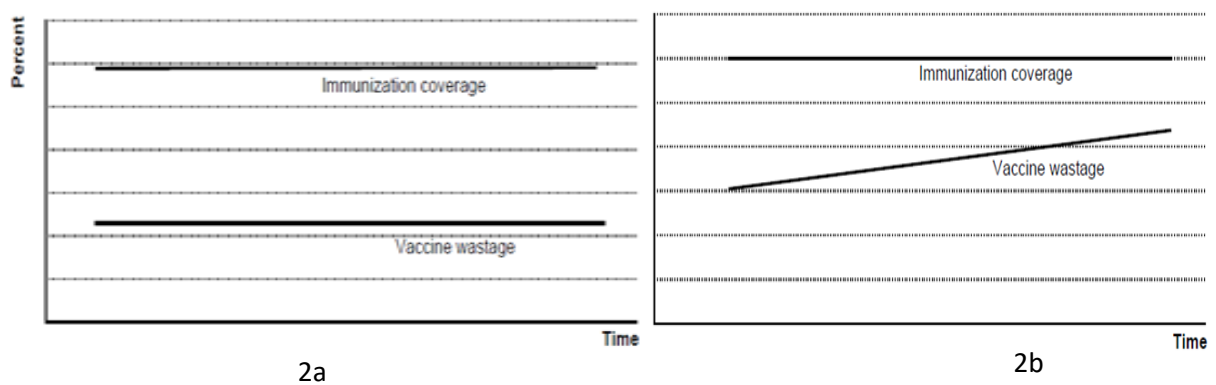
#### **2.8. Relationship between vaccine wastage and immunization coverage**

WHO (15) analyses various relationships between vaccine wastage rate and immunization coverage and says it is key to deciding whether wastage is really high. Both should be analyzed over a period of time rather than at a given point in time in order to reveal

trends. Figure 2 indicate possible reasons for different trends in vaccine wastage and immunization coverage rates.

If immunization coverage and vaccine wastage rates follow the same trend (with little fluctuation) in a given period (as shown in Figure 2a) it is essential to know the reasons for the trend in order to understand whether wastage can be reduced. Reports of the same vaccine wastage without any change in immunization coverage often indicate that wastage is not fully understood and analyzed.

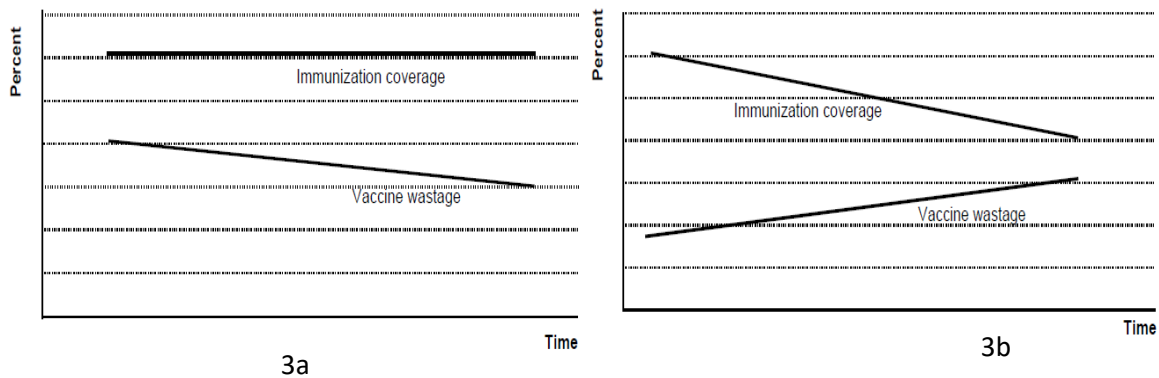
If vaccine wastage increases at a certain point over a period of time while the immunization coverage rate remains the same, potential causes such as expiry or cold chain failure during storage and transportation can be the cause (Fig. 2b). Although most wastage can be expected in unopened vials, discards may involve both opened and unopened vials. The fact that immunization coverage remains level indicates that, despite increased wastage, the program has had enough vaccines to replace these losses. This may indicate a need to review the vaccine forecast. This will determine if more vaccine than necessary is being ordered and received.



**Figure 2.** Relationship between vaccine wastage and immunization coverage

If vaccine coverage remains the same as wastage decreases (Figure 3a), it could be problem with data management. Therefore, validity of data should be investigated and as well as the reasons for the fall in the wastage rate. It could be an improvement in the effectiveness of vaccine management that is responsible for the decrease in vaccine wastage. In this case, it should be documented and attention should then be concentrated on improving coverage rates.

If the immunization coverage rate decreases and the vaccine wastage rate increases (Figure 3b), this indicates vaccine damage in unopened vials, resulting in losses where the system cannot replace the vaccine. Consequently, planned immunizations cannot be achieved. The problem is most likely to be at the storage level and/or during vaccine transportation. Depending on the type of vaccine, freezing or heat exposure of a bulk quantity may be the culprit. The first step therefore is in analyzing the data and ruling out expiry discards.



**Figure 3.** More relationship between vaccine wastage and immunization coverage

If both rates are decreasing the most likely reason is that the number of immunization sessions has been reduced, resulting in refusals to immunize children attending on non-session days and in missed opportunities. Reducing the number of outreach activities may have the same effect. No matter what the reasons, the situation must be studied in detail in order to understand whether the approach to reducing vaccine wastage causes a similar decrease in immunization coverage. If a successful initiative to reduce vaccine wastage result in a reduction in immunization coverage, it should be reviewed. The relationships between immunization coverage and vaccine wastage are summarized in Table 4.

**Table 4.** Problematic time trend relationships between immunization coverage and vaccine wastage

<b>Immunization coverage</b>	<b>Vaccine wastage</b>	<b>Possible solution</b>
Same	<b>Same</b>	Types of vaccine wastage should be analyzed in order to determine whether new tools could be introduced to reduce wastage
Same	<b>Increasing</b>	Focus on the storage and transportation of vaccines, because increasing wastage while coverage remains the same indicates wastage in unopened vials.  If the increase is too high, vaccine forecasts should be reviewed so as to understand whether too much vaccine is being ordered.

<b>Immunization coverage</b>	<b>Vaccine wastage</b>	<b>Possible solution</b>
Same	Decreasing	Validation of the data is the first step. Since wastage is decreasing, special attention should be given to determining how to increase immunization coverage.
Decreasing	Increasing	Vaccine damage occurs in unopened vials. Consequently, losses occur where the system cannot replace the vaccines and therefore planned immunizations cannot be achieved. The problem is likely to be found at the storage level and/or during vaccine transportation (either freezing or heat damage). The first step in analyzing the data should be to rule out expiry discards.
Decreasing	Decreasing	The possibility has to be considered that measures used to reduce wastage contribute to decreased immunization coverage. Likely reasons are a reduced number of immunization sessions and a refusal to give immunization where this would require multidose vials to be opened, in order to prevent high wastage.
Increasing	Increasing	This circumstance may arise because of increased outreach activity. The implementation of the multidose vial policy (MDVP), effective VVM use and the organization of sessions

Immunization coverage	Vaccine wastage	Possible solution
		during outreach activities should be examined in order to determine whether vaccine wastage can be reduced.

Table legend: Content of the table from WHO and UNICEF, 2005 (15)

## 2.9. Reducing vaccine wastage

There is no panacea for reducing vaccine wastage. A method may become more effective in reducing wastage if combined with other appropriate methods. Whatever method is used, there is only one output indicator that should not be affected negatively: vaccination coverage.

### 2.9.1. Changing the vial size

The use of smaller vaccine vials sizes (presentation) naturally results in less vaccine wastage. However, the decision to change the vial size for smaller ones is not easy, as it needs to take into consideration many other factors. Some of these factors include, price and volume of storage facilities(15).

### 2.9.2. Vaccine vial monitor (VVM)

VVMs are time-temperature-sensitive labels attached to vaccine vials(45). Before the development of the VVM, health workers had little or no means of identifying whether vaccine had suffered damage from heat at a point during transportation and/or storage(15). Therefore, health workers depended on appropriate storage and transportation of vaccines and were trained to discard all vaccines after breaks or suspected breakage in the cold chain. In some places, health workers are instructed to discard all vaccine that has been taken to the field twice without being used, regardless of whether there was heat exposure or not. Such

precautions against possible heat damage result in large amounts of usable vaccine being discarded. The VVMs have solved some of these problems.

### **2.9.3. Multidose vial policy**

The multidose vial policy (MDVP), was introduced in 1995 and revised in 2000 on the basis of data collected on the safety and potency of vaccines recommended for use in immunization services by WHO(39). Multidose vials of OPV, PENTA, ATT, hepatitis B, and liquid formulations of Hib vaccines from which one or more doses of vaccine have been removed during an immunization session may be used in subsequent immunization sessions for up to a maximum of 28 days provided that the following conditions are met(39):

- The expiry date has not passed;
- The vaccine is stored under appropriate cold chain conditions;
- The vaccine vial septum has not been submerged in water;
- Aseptic technique has been used to withdraw all doses;
- The VVM, if attached, has not reached its discard point

In Bhutan, the implementation of MDVP gave rise to dramatic decreases in the wastage of liquid vaccines. In comparison with baseline data from the districts, wastage decreased by 49% for OPV, 27% for DTP, 56% for TT and 24% for HepB vaccine(15). This policy does not change the recommendations of handling vaccines and those not concern most lyophilized vaccines. For example, for BCG, Measles and yellow fever vaccines, once they are reconstituted, vaccines vials must be kept at 2-8°C and must be discarded at the end of each immunization session or after six hours, whichever comes first(39).

#### **2.9.4. Earliest-expiry-first-out principle**

In general, when two batches of vaccine are delivered at different times, the second to arrive has a later expiry date than the other especially if the vaccines are derived from the same source. Therefore, the expiry date must always be checked and the vaccine with the shortest shelf-life should be distributed first, even if it arrived last. Therefore, the earliest-expiry-first out principle is better than the first in first out principle that is commonly known.

#### **2.9.5. Improved procurement practices**

Improved procurement practices involves better vaccine forecasting with more realistic wastage rates in order to prevent the arrival of vaccines in excess(15). This may lead to mismanagement of the vaccines and storage in suboptimal conditions. Not only can it increase wastage, in areas where vaccine forecast is poor, with small amount of vaccines supplied relative to needs, vaccination coverage can be compromised.

#### **2.9.6. Optimizing immunization session frequency with session size and vial size**

Wastage can be reduced by increasing the size of a vaccination session (number of children to be vaccinated at a time). However, this may result in compromising coverage as some children vaccination may be postponed to make room for a bigger session some other day. This session size has the greatest potential for negatively affecting vaccination coverage among all the methods of reducing vaccine wastage(15). Consequently, this option should be used with caution and may be more applicable in urban settings where population density is much and children can easily be ‘gathered’.

#### **2.9.7. Prevention of freezing**

With the frequent introduction of new and costly vaccines, that are freeze-sensitive, vaccine freezing has become a topic on which national managers seek advice. Vaccine freezing is preventable and therefore is treated as unacceptable. All possible measures should

be taken to prevent wastage attributable to freezing as exposing vaccines to freezing temperatures during storage and transportation may lead to wastage.

#### **2.9.8. Safe immunization practices**

Safe immunization injection practices should be followed for all vaccines. A new sterile syringe and needle should be used for each new dose given, and the correct route and dosage must also be observed for each type of vaccine. This greatly reduces vaccine wastage therefore, health personnel must be appropriately trained and frequent retrained on safe immunization practices.

#### **2.9.9. Improved vaccine management practices**

There is more and more need for training in vaccine management because of the number of changes in vaccines, presentations and global vaccine handling practices over the past several years, including the introduction of new and underused vaccines through GAVI(15). A need for better vaccine management practices has also been demonstrated by high levels of wastage in many countries, a lack of utilization of policies and equipment that would reduce vaccine wastage such as MDVP and VVMs, and adverse events attributable at least partially to inappropriate vaccine distribution practices(15).

#### **2.9.10. Prevention of submergence of vials in water**

If vaccines are not well protected, opened vials may be submerged in water from melting ice. By definition, these vials are considered contaminated. To prevent this, health workers are advised not to get vaccines in direct contact with ice pack. All opened and unopened vials must be kept in zip-lock bags in order to prevent any direct contact with water. This practice also prevents labels from becoming wet and lost since vials without labels must also be discarded(15,39).

### **III. Methods**

#### **3.1. Study design**

This was a record based analytical study carried out in the Littoral Region of Cameroon using the 2016 and 2017 immunization data for children less than 5 years. Immunization data from all the 24 health districts making up the region and for the two years was included in the study. Health districts in the littoral region are classified as ‘urban’, ‘semi-urban’ and ‘rural’ based on their remoteness. For this study, the health districts were grouped into ‘rural’ and ‘urban’ health districts where the ‘semi-urban’ health districts were combined with the ‘urban’ health districts since they lack the peculiar ‘rural’ characteristics.

#### **3.2. Study setting**

This study was carried out in Cameroon. Cameroon’s health system is divided into ten territories called regions which are further divided into 189 health districts(24). These health districts are further divided into health areas. Littoral is one of the regions with the highest population density of the ten regions and with 24 of the 189 health districts of the entire country. It has 522 health areas.

The region is headed by the Regional Delegate of Public Health (RDPH) with a unit in charge of EPI headed by a public health expert. The health district is headed by a District Medical Officer (DMO) who has direct supervision from the RDPH. Out of the 24 health districts, 3 are urban, 9 are semi-urban and 12 are rural health districts. Figure 4 shows the map of Cameroon with the 10 health regions with the littoral region in red(46).



**Figure 4.** The Littoral region and the other 9 health regions of Cameroon {Source: (45)}

There are two seasons in the littoral regions; the rainy season and the dry season. The Rainy season starts in June and goes through November while the dry season begins in

December and goes through May(25). Road networks during the raining seasons are usually not in good condition especially in the rural districts. Power failure is almost regularly due to the effect of wind current on electric poles. Also, mechanical failures in electrical installations are rampant during this season and these failures are worsen by inaccessible road even for reparation. Vaccines supply chain is particularly difficult in rural districts during this season due to these circumstances(47). Again, with rough roads, chances of accidents are high resulting in unopened vial vaccine wastage when health personnel displace themselves for outreach vaccination sessions.

In 2017 for example, the estimated total population of the littoral region was 3693824 with a total of 95644 live births(48). There are 522 sub districts (or health areas) in the region as shown in Table 5.

**Table 5.** EPI 2017 estimated population for the littoral region, Cameroon

Districts	Total population	Total live birth	Children 0-11 months	Number of Health Areas	Setting
BANGUE	313,369	7,739	7,449	38	Urban
BOKO	345,039	8,521	8,201	40	Semi urban
BONASSAMA	417,084	10,300	9,914	35	Semi urban
CITE DES PALMIERS	313,991	7,754	7,463	36	Semi urban
DEIDO	587,682	14,513	13,969	51	Urban
JAPOMA	140,651	3,473	3,343	27	Semi urban
LOGBABA	225,431	5,567	5,358	26	Urban
NEW BELL	294,419	7,271	6,998	23	Semi urban
NYLON	403,474	9,964	9,590	36	Semi urban
ABO	29,741	936	877	16	Rural
DIBOMBARI	21,550	678	635	5	Rural
EDEA	127,898	4,026	3,770	40	Semi urban
LOUM	52,966	1,667	1,561	11	Rural
MANJO	37,043	1,166	1,092	13	Rural
MANOKA	19,572	616	577	5	Rural
MBANGA	64,636	2,034	1,905	14	Rural
MELONG	77,058	2,425	2,272	32	Rural
NDOM	25,715	809	758	15	Rural
NGAMBE	10,446	329	308	7	Rural
NJOMBE PENJA	49,133	1,546	1,448	7	Semi urban
NKONDJOCK	21,353	672	629	8	Rural
NKONGSAMBA	87,996	2,770	2,594	18	Semi urban
POUMA	13,045	411	385	10	Rural
YABASSI	14,532	457	428	9	Rural
<b>Total</b>	<b>3,693,824</b>	<b>95,644</b>	<b>91,524</b>	<b>522</b>	<b>NA</b>

Table legend: Content from the District Vaccination Data management Tool (DVDMT) for Littoral region(48)

### **3.3. Study Participants**

Study participants were children less than 5 years in the Littoral Region of Cameroon. However, the children were not directly involved in the study. All vaccination records from 1st January 2016 to the 31st December 2017 of children less than 5 years was retrieved and analyzed. The vaccines under consideration in this study were Bacille Calmette Guerin (BCG), Oral Polio Vaccine (OPV), Inactivated Polio Vaccine (IPV), Diphtheria, Pertussis, Tetanus Hepatitis B and Hemophilus influenza type b (PENTA), Pneumococcal Conjugate Vaccine (PCV), ROTA, Measles and Rubella (MR), and Yellow fever.

#### **3.3.1. Inclusion criteria**

Any vaccination record in the Littoral Region of Cameroon between January 1st 2016 and December 31st 2017 in BCG, OPV, IPV, PENTA, PCV, ROTA, MR and Yellow fever was included in the study.

#### **3.3.2. Exclusion criteria**

Records of other vaccines like Ante Tetanus Toxoids (ATT) and Human Papiloma Virus (HPV) were excluded from being used in this study since they are not given to children less than 5 years.

### **3.4. Data source and data collecting process**

Information regarding number of children vaccinated and number of doses of vaccines used was gotten from the immunization data of the Littoral Region of Cameroon. This data was obtained with authorization from the ministry of public health of Cameroon.

To obtain the data, a letter was address to the Central Technical Group (CTG) of Expanded Program of Immunization (EPI) requesting the use of the data. upon approval, the

data was granted access to, then it was proceeded by cleaning to remove data on other vaccines like the HPV and ATT since there were not to be included in the study.

### 3.5. **Variables and the sources of data**

The variables to be used in this study and method of calculation are presented in the Table 6

**Table 6.** Variables in the study

Variables		Specifications	Remark
Children vaccinated	Number of children vaccinated each month		
Vaccine doses	Doses Received	Doses received by the health district during the month	Used to calculate Vaccine Wastage Rate (VWR)
	Doses in stock	Doses in the health district at the beginning of each month (Left over doses from the previous month)	
	Doses remaining (and usable)	Doses left in the health district at the end of the month	
	Doses used	Calculated from Doses received and doses remaining	
	Doses wasted	Calculated as difference between number of children vaccinated and doses used	
Months	Month in which child was vaccinated		
Seasons	Dry season (1)	From December to May	Quite Favorable conditions
	Rainy season (1)	From June to November	Unfavorable conditions
Health Districts			
Setting	Rural Areas (12 HD)	Poor road and electricity supply	Unfavorable
	Urban Areas (12 HD)	9 ‘semi urban’ and 3 ‘urban’	More favourable
Vaccines	Liquid	Oral Polio Vaccine	Wastage relatively easily managed through the OPV
		DTP-HepB Hib (PENTA)	MDVP used
		Pneumococcal	
		IPV	
		Rota virus	

Variables	Specifications	Remark
Lyophilized	BCG	Potential for conflict between reduction in vaccine wastage and MOV
	Measles and Mumps	
	Yellow fever	
Oral vaccines	OPV	Easily administered
	Rota	
Injectable vaccines	DTP-HepB Hib (Penta)	Not very easily administered (liable to dose estimation and reconstitution errors)
	Pneumococcal	
	IPV	
	BCG	
	Measles and Mumps	
	Yellow fever	

### 3.6. Calculation of wastage rate and data analysis

#### 3.6.1. Calculation of Vaccine coverage and vaccine wastage rate

The following formulae were used for the following calculations (15):

- i. Vaccination coverage rate

$$\text{Vaccination coverage rate} = \frac{\text{Number of children vaccinated}}{\text{Number of eligible children}} \times 100$$

- ii. Number of doses used

$$\text{Doses used} = \text{Doses received} + \text{Doses in stock} - \text{usable doses remaining}$$

- iii. Number of doses wasted

$$\text{Dose wasted} = \text{Doses used} - \text{Children vaccinated}$$

- iv. Vaccine Wastage Rate (VWR)

$$\text{Vaccine Wastage rate} = 100 - \text{Vaccine usage rate} = \frac{\text{Doses wasted}}{\text{Doses used}} \times 100$$

- v. Vaccine Wastage Factor (VWF)

$$\text{Vaccine wastage factor} = \frac{100}{100 - \text{Vaccine wastage rate}}$$

#### 3.6.2. Data analysis

The immunization data was entered into a spread sheet. Groupings into seasons, urbanization and liquid or lyophilized vaccines was done. Data was analyzed using r version 3.6.0, where the chi square ( $\chi^2$ ) test was applied for finding difference across rural and urban health districts and between the dry and the rainy seasons. Graphs of vaccine coverage was drawn and compared with that of vaccine wastage to evaluate the relationship between

vaccination coverage and vaccine wastage. Vaccine wastage rate was calculated for the individual vaccines, liquid and lyophilized vaccines, and oral and injectable vaccines. Level of significance will be set at 5% and the 95% confidence interval will be used.

### **3.7. Ethical considerations**

Data (vaccination records of the Littoral Region of Cameroon) was provided to the researcher with permission from the Ministry of Public Health, Cameroon and all of the data was processed with anonymity, and only to be used on researcher's personal computer and only for the purposes of this study

No personal information was involved in this study. Even names of health district were not used. Instead, they will be classified as 'rural' and 'urban'

Ethical clearance was sorted from Yonsei University Health System Institutional Review Board and administrative clearance from the Yonsei University, Graduate School of Public Health, South Korea.

### **3.8. Limitations of the study**

Like most scientific studies, this study has some limitations:

The study uses secondary data where the researcher was not directly involved in collecting the data. Inherent to secondary data, the accuracy of the result of the study depends on the accuracy with which the data was collected in the first place.

With the MDVP, an opened vial can still be used for up 28 days. This means that the doses inside an opened vial may still be usable. However, at the end of the month, only unopened vials are reported as doses remaining. Because data does not account for doses in opened vials remaining at the end of the month, there are considered as used. This involved

only liquid vaccines. These doses are however used and accounted for in the following month. Using data for the entire year reduces the effects of these ‘left over open vial doses’ on calculations of vaccine wastage.

Wastage rates and wastage factors calculated from this data may not reflect rates at service delivery level which are usually higher than reported(49)

## IV. Results

The data shows that there was a reduction in population from in 2017 compared to 2016. For example, in 2016, 133,389 children were targeted for BCG in the urban districts but only 83,444 were targeted in the urban districts in 2017 as presented in Table 7. In both years, more children were vaccinated in BCG, MR and Yellow in the dry season compared to the rainy season. For example, in 2016, 46528 children were vaccinated in BCG but only 41,513 were vaccinated in the rainy season. On the contrary, Lesser number of children were vaccinated in the dry season with the liquid vaccines in both 2016 and 2017. For instance, only 75,031 children were vaccinated with Rota vaccine during the dry season but 86,599 children were vaccinated with the same vaccine in 2017 in the rainy season (Table 7).

A total of 2851527 doses of vaccines were used in 2016 and 2017 in the Littoral Region of Cameroon to vaccinate 2640077 children with BCG, OPV, IPV, PENTA, PCV, ROTA, MR and Yellow fever. Out of these, 1,472,156 doses where used in 2016 to vaccinate 1,369,676 children and 1,379,371 doses where used to vaccinate 1,270,401 children in 2017. The vaccine wastage rate (VWR) for both years combined was highest in BCG and stood at 32.19% seconded by Measle and Rubella (MR) vaccine (19.05%) and then Yellow fever and IPV having 18.34% and 17.87% respectively. There were negative wastage rates in PCV and ROTA throughout 2016 and 2017. Like the wastage rate, vaccine wastage factor (VWF) was also highest in BCG followed by MR, then IPV and their values stood at 1.0031, 1.0018, 1.0018 and 1.0018 respectively as shown in Table 8.

Comparing vaccine wastage between 2016 and 2017, the trend is exactly the same across vaccines in both years; BCG has the highest vaccine wastage rate, followed by MR vaccine, yellow fever vaccine and inactivate polio vaccine (IPV). Also, for both years,

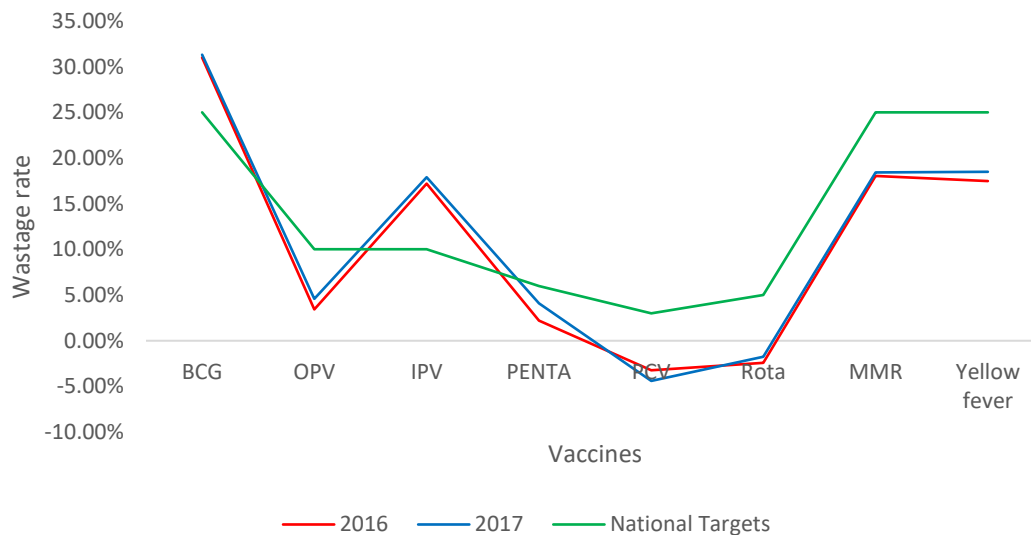
Pneumococcal Conjugate Vaccine (PCV) and Rota vaccines had negative wastage rates, however, the VWR for 2017 was slightly greater than that in 2016 for all the vaccines except Pneumococcal Conjugate Vaccine (PCV) as presented in Figure 5

**Table 7.** A comparison of children vaccinated and vaccine used between rural and urban districts as well as between dry and the rainy season

Grouping	Indicators	2016								2017							
		BCG	OPV	IPV	PENTA	PCV	ROTA	MR	Yellow Fever	BCG	OPV	IPV	PENTA	PCV	ROTA	MR	Yellow Fever
Setting	Urban	Target population	133,389	112,638	112,638	112,638	112,638	112,638	112,638	83,444	80,097	80,097	80,097	80,097	80,097	80,097	80,097
		Children vaccinated	76,912	298,562	72,580	221,968	221,762	144,832	70,388	70,287	74,408	285,696	64,471	209,745	211,082	140,414	57,970
		Vaccine used	108,017	307,052	86,051	225,482	214,541	141,803	84,489	83,874	107,754	298,535	77,052	218,045	202,505	138,329	70,639
	Rural	Target population	19,265	16,269	16,269	16,269	16,269	16,269	16,269	12,200	11,427	11,427	11,427	11,427	11,427	11,427	11,427
		Children vaccinated	11,129	48,521	11,616	37,309	37,317	24,003	11,254	11,236	10,548	41,880	8,989	31,417	31,560	21,216	8,563
		Vaccine used	20,216	53,186	16,278	40,065	36,601	23,423	15,563	15,515	19,138	45,698	12,569	35,662	30,543	21,407	12,974
Season	Dry	Target population	76,327	64,454	64,454	64,454	64,454	64,454	64,454	47,822	45,762	45,762	45,762	45,762	45,762	45,762	45,762
		Children vaccinated	46,528	169,175	39,058	123,095	122,782	80,297	42,743	42,836	46,621	157,827	30,332	111,558	111,502	75,031	37,778
		Vaccine used	65,347	177,408	48,331	126,904	119,434	78,437	51,316	51,320	72,830	174,001	40,522	122,948	109,070	74,839	49,033
	Rainy	Target population	76,327	64,454	64,454	64,454	64,454	64,454	64,454	47,822	45,762	45,762	45,762	45,762	45,762	45,762	45,762
		Children vaccinated	41,513	177,908	45,138	136,182	136,297	88,538	38,899	38,687	38,335	169,749	43,128	129,604	131,140	86,599	28,755
		Vaccine used	62,886	182,830	53,998	138,643	131,708	86,789	48,736	48,069	54,062	170,232	49,099	130,759	123,978	84,897	33,957

**Table 8.** Wastage rate and wastage factor for different vaccines in the Littoral region in between 2016 and 2017

Vaccine	2016				2017				Total			
	Children vaccinated	Doses used	Wastage rate	Wastage factor	Children vaccinated	Doses used	Wastage rate	Wastage factor	Children vaccinated	Doses used	Wastage rate	Wastage factor
BCG	88,041	128,233	31.34%	1.0031	84,956	126,892	33.05%	1.0033	172,997	255,125	32.19%	1.0032
OPV	347,083	360,238	3.65%	1.0004	327,576	344,233	4.84%	1.0005	674,659	704,471	4.23%	1.0004
IPV	84,196	102,329	17.72%	1.0018	73,460	89,621	18.03%	1.0018	157,656	191,950	17.87%	1.0018
PENTA	259,277	265,547	2.36%	1.0002	241,162	253,707	4.94%	1.0005	500,439	519,254	3.62%	1.0004
PCV	259,079	251,142	-3.16%	0.9997	242,642	233,048	-4.12%	0.9996	501,721	484,190	-3.62%	0.9996
Rota	168,835	165,226	-2.18%	0.9998	161,630	159,736	-1.19%	0.9999	330,465	324,962	-1.69%	0.9998
MR	81,642	100,052	18.40%	1.0018	66,533	82,990	19.83%	1.0020	148,175	183,042	19.05%	1.0019
Yellow fever	81,523	99,389	17.98%	1.0018	72,442	89,144	18.74%	1.0019	153,965	188,533	18.34%	1.0018
Total	1,369,676	1,472,156	6.96%	1.0007	1,270,401	1,379,371	7.90%	1.0008	2,640,077	2,851,527	7.42%	1.0007

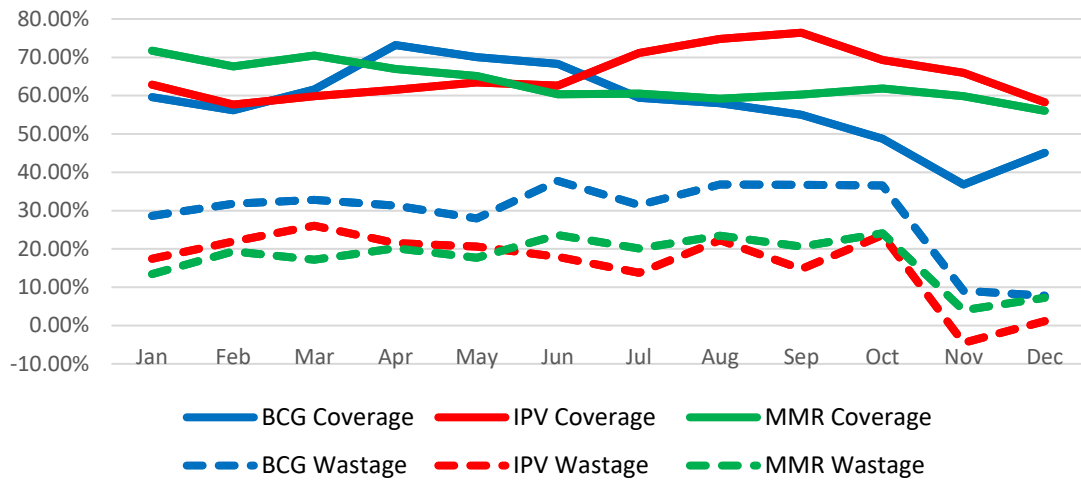


**Figure 5.** Vaccine wastage rates for various vaccines comparing 2016 and 2017

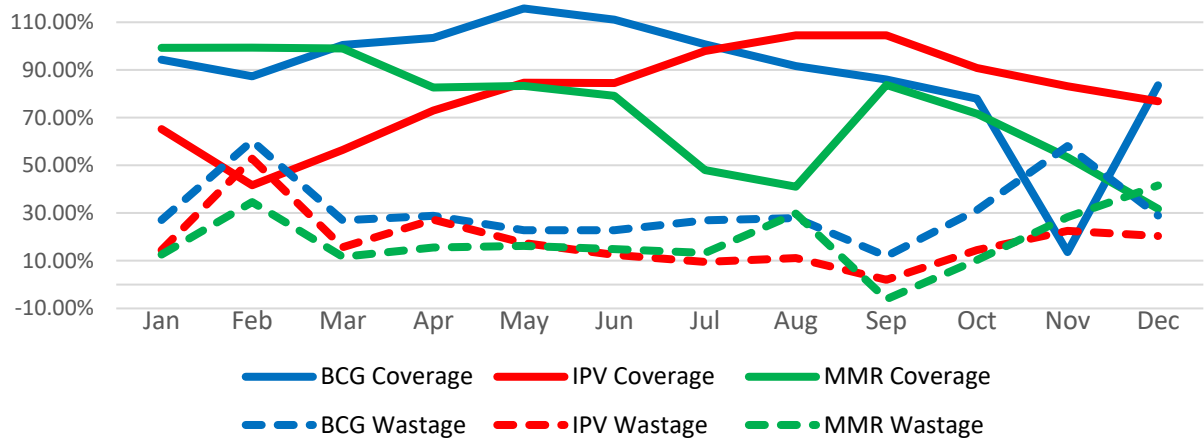
#### 4.1. Relationship between immunization coverage and vaccine wastage

In general terms, in both 2016 and 2017, the vaccination coverages start high in January and remarkably decreases in February before increasing again. From October, vaccine coverage starts a progressive decline trend till December except for BCG that interrupts this trend by increasing in December. However, the most remarkable decline is exhibited by coverage in MR vaccine and BCG as can be seen in Figure 6 and 7.

Like vaccination coverage, VWR for the various vaccines exhibit the same trend but in the reverse order. Vaccine wastage tend to increase at each time vaccine coverage decreases except for 2016 (Figure 6) as from October where both vaccine coverage and vaccine wastage decreased and increased simultaneously.



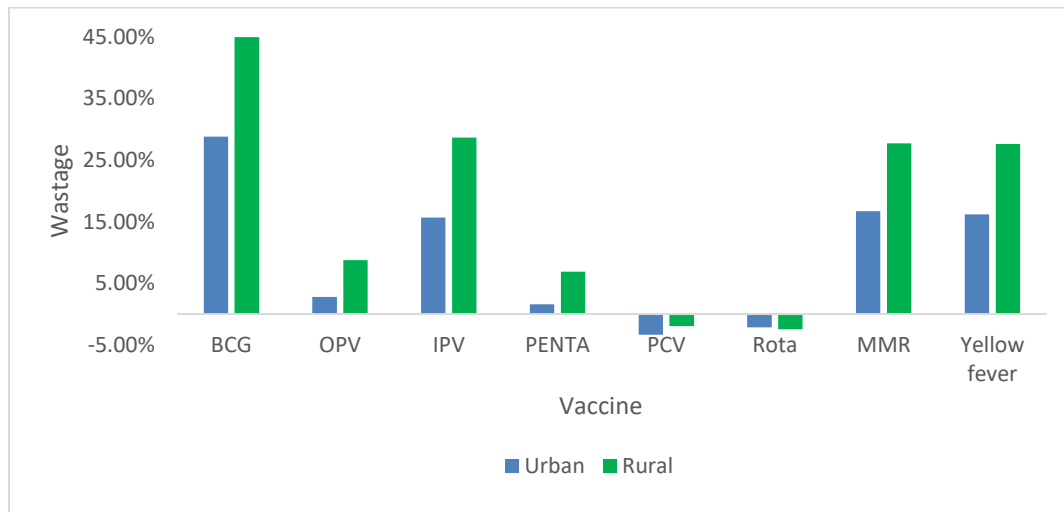
**Figure 6.** Variations between vaccine coverage and vaccine wastage for BCG, IPV and Measles in 2016



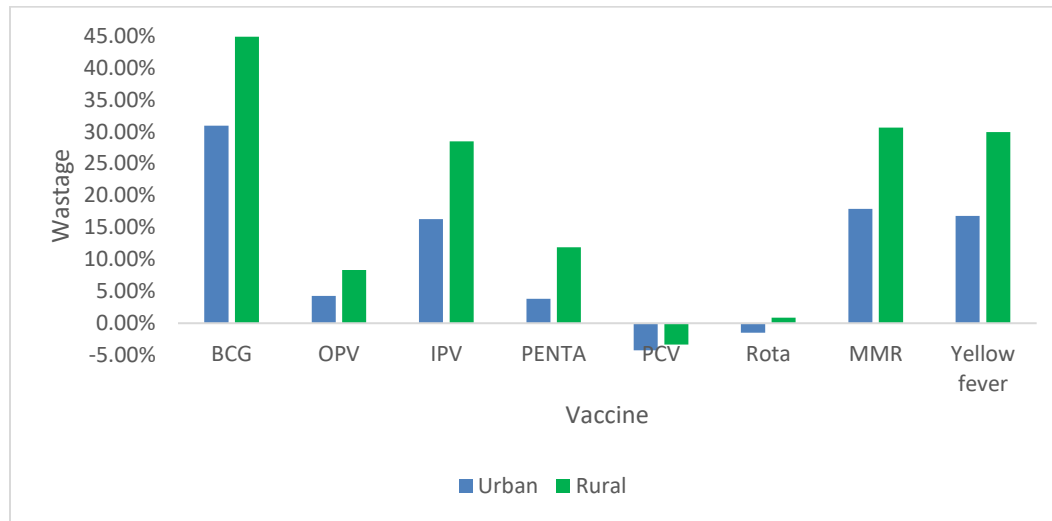
**Figure 7.** Variations between vaccine coverage and vaccine wastage for BCG, IPV and Measles in 2017

#### 4.2. Urbanization and effect on vaccine wastage rate

In both 2016 (Figure 8) and 2017 (Figure 9), vaccine wastage rates were consistently higher in all the vaccines in the rural health districts compared to the urban health districts. And again, vaccine wastage rates were negative for PCV and Rota vaccines in both rural and urban health districts in 2016 and 2017 except the VWR for Rota vaccine that was positive in 2017 and stood at 0.89% compared to -1.51% in the urban districts.



**Figure 8.** Vaccine wastage comparing rural and urban health districts in 2016

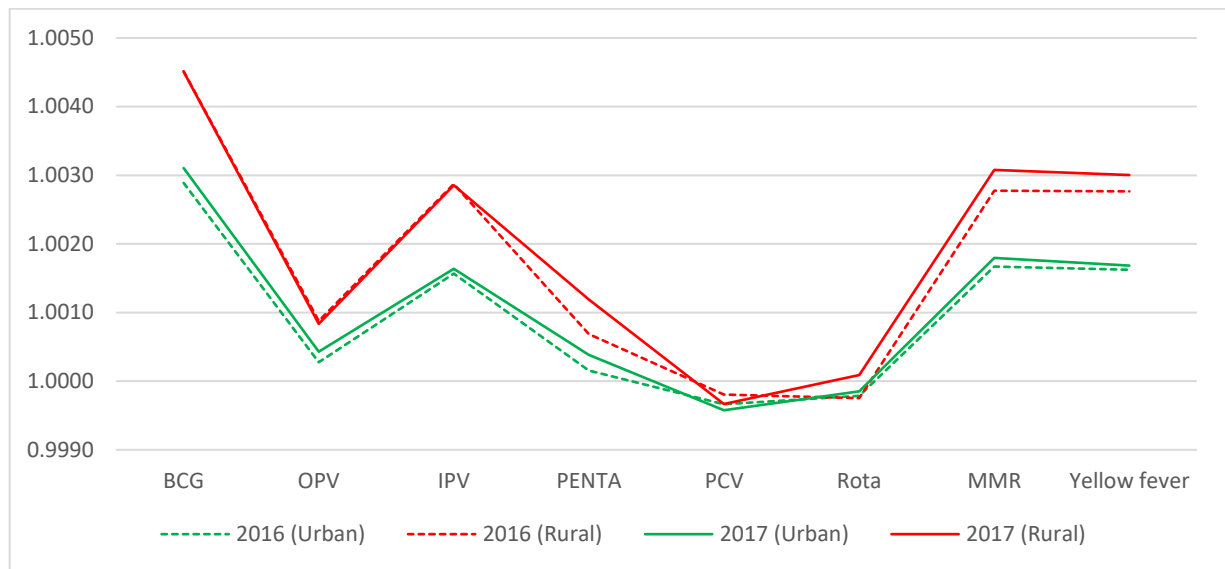


**Figure 9.** Vaccine wastage comparing rural and urban health districts in 2017

As presented in Table 9, wastage rates for all vaccines except PCV and Rota vaccines were statistically significantly different at alpha ( $\alpha$ ) = 5%, between rural and urban health districts in the littoral region in 2016 and 2017 with p-values far less than 0.05. In 2016, VWR for PCV and Rota vaccines were not significantly different, the p-values 0.085i and 0.7411 respectively. In 2017, the VWR for Rota joined the others to be statistically significant, leaving just that of PCV to remain insignificant at  $\alpha$  of 0.005 with a p-value of 0.0215.

#### 4.2.1. Urbanization and Vaccine wastage factor

VWF were distinctively different in BCG, IPV, MR and Yellow fever between urban and rural health districts with the rural district having higher rates. The pattern remained the same 2016 and 2017 as presented in Figure 10.



**Figure 10.** Comparison of vaccine wastage factor between rural and urban health districts

**Table 9.** Vaccine wastage rates for various vaccines comparing rural and urban health districts

Vaccine	2016						2017					
	Urban		Rural		$\chi^2$	<i>p</i> value	Urban		Rural		$\chi^2$	<i>p</i> value
	Children Vaccinated	Vaccine Used	Children Vaccinated	Vaccine Used			Children Vaccinated	Vaccine Used	Children Vaccinated	Vaccine Used		
BCG	76,912	108,017	11,129	20,216	410.93	<0.0001	74,408	107,754	10,548	19,138	300.01	<0.0001
OPV	298,562	307,052	48,521	53,186	88.29	<0.0001	285,696	298,535	41,880	45,698	35.58	<0.0001
IPV	72,580	86,051	11,616	16,278	161.70	<0.0001	64,471	77,052	8,989	12,569	112.35	<0.0001
PENTA	221,968	225,482	37,309	40,065	50.81	<0.0001	209,745	218,045	31,417	35,662	111.64	<0.0001
PCV	221,762	214,541	37,317	36,601	2.97	0.0851*	211,082	202,505	31,560	30,543	1.02	0.3127*
Rota	144,832	141,803	24,003	23,423	0.11	0.7411*	140,414	138,329	21,216	21,407	5.26	0.0215
MR	70,388	84,489	11,254	15,563	111.85	<0.0001	57,970	70,639	8,563	12,351	124.12	<0.0001
Yellow fever	70,287	83,874	11,236	15,515	118.60	<0.0001	63,354	76,170	9,088	12,974	136.62	<0.0001

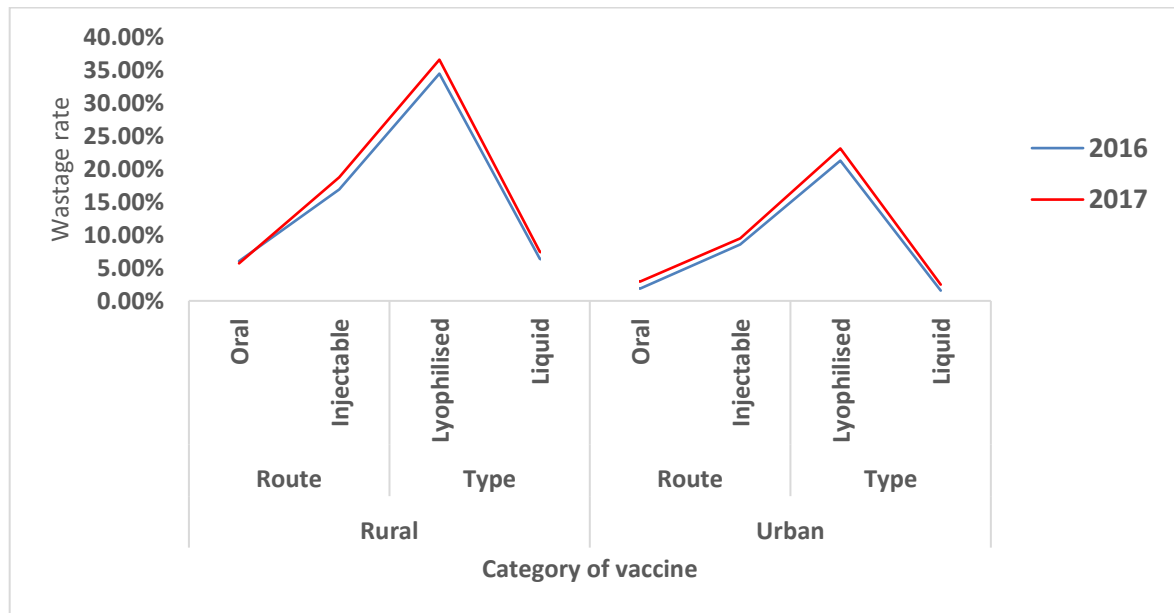
\*Statistically insignificant

**Table 10.** Differences in vaccine rate classified into route of administration and type of vaccine, comparing rural and urban health settings

		2016				2017							
Vaccine		Urban		Rural				Urban		Rural			
		Children	Vaccine	Children	Vaccine	$\chi^2$	<i>p</i> value	Children	Vaccine	Children	Vaccine	$\chi^2$	<i>p</i> value
		Vaccinated	Used	Vaccinated	Used			Vaccinated	Used	Vaccinated	Used		
Route of	Oral	443,394	451,884	72,524	77,189	60.23	<0.0001	426,110	438,949	63,096	66,914	23.82	0.0001
Administration	Injectable	733,897	802,454	119,861	144,238	513.59	<0.0001	681,030	752,165	100,165	123,237	557.84	<0.0001
Type of	Lyophilized	217,587	276,380	33,619	51,294	585.68	<0.0001	195,732	254,563	28,199	44,463	554.49	<0.0001
vaccines	Liquid	959,704	974,929	158,766	169,553	175.20	<0.0001	911,408	934,466	135,062	145,879	164.96	<0.0001

#### 4.2.2. Vaccine categories and wastage

Categorizing vaccines according to their route of administration and their form of preservation, rural settings had clearly higher wastage rates compared to urban districts. VWR for lyophilized vaccines peaked in both the rural and urban health districts. Comparing vaccine wastages for the categories of vaccines between 2016 and 2017, the wastage rates were clearly higher in 2017 than in 2016 as presented in Figure 11.

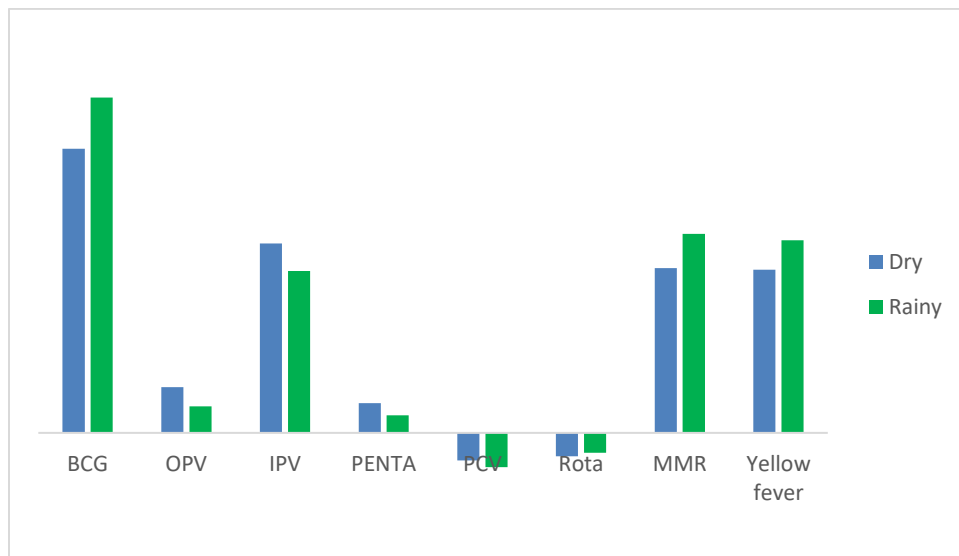


**Figure 11.** Vaccine wastage between rural and urban health districts comparing 2016 and 2017

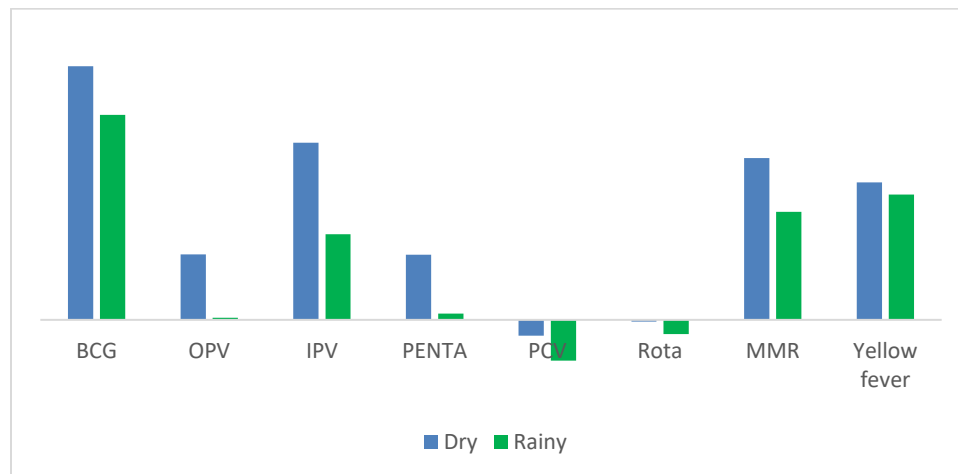
In both years, vaccines administered orally were statistically significantly different between rural and urban health districts as well as vaccines administered parenterally with p-values far  $< 0.0001$  at  $(\alpha) = 5\%$ . Also, the wastage rate of liquid and lyophilized vaccines also statistically significantly differed at the 95% confidence level between urban and rural health districts in both 2016 and 2017 as presented in Table 10.

#### 4.3. Effect of season on vaccine wastage rate

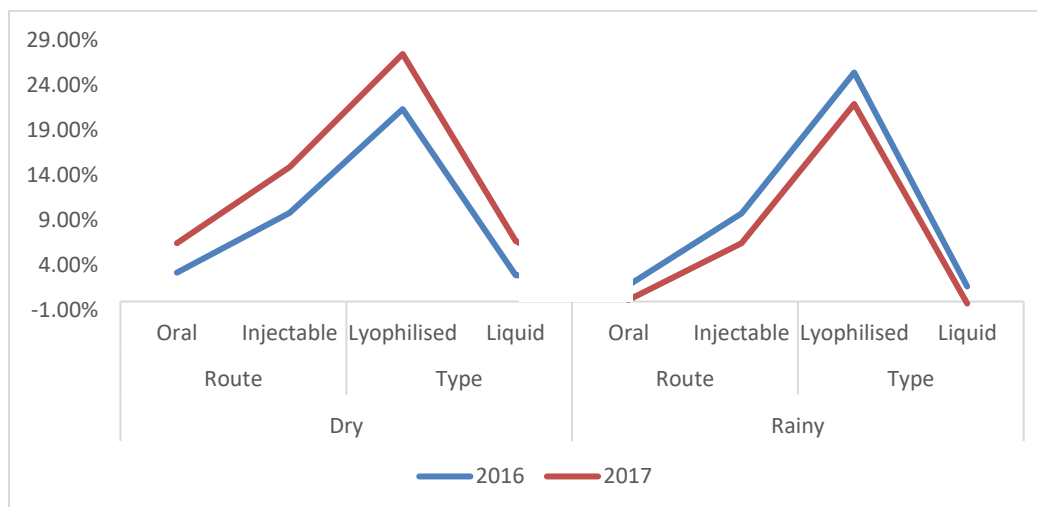
In 2016, more vaccines were wasted during the rainy season in the lyophilized vaccines (BCG, Measles and Yellow fever) whereas the liquid vaccines were more wasted in the dry season than in the rainy season as presented in Figure 12. In 2017 however, the dry season had higher vaccine wastage rates compared to the rainy season in all the vaccines. The greatest difference occurred with IPV where the dry season had more than twice as higher wastage compared to the rainy season which were 25.15% and 12.16% respectively. Interestingly the wastage rate for OPV during the raining season in 2017 was close to zero (0.28%) as shown in Figure 13. Again, PCV and Rota had negative wastage rates in both seasons and in both years.



**Figure 12.** Vaccine wastage comparing the dry and the rainy season in 2016



**Figure 13.** Vaccine wastage comparing the dry and the rainy season in 2017

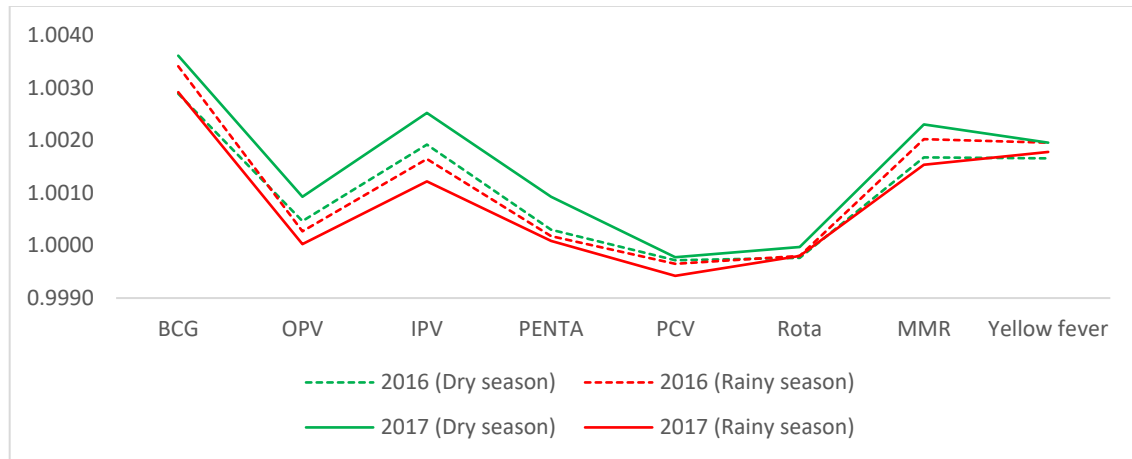


**Figure 14.** Vaccine wastage comparing 2016 and 2017 between the dry and the rainy seasons

Except for the single dose vaccines (Rota and PCV) and only in 2016, the wastage rate of all other vaccines was statistically significantly different between the rainy and the dry season at the 95% confidence level with p value far less than 0.05. As presented in Table 11, wastage rate for the single dose vaccines were not statistically significantly differently between the dry and the rainy season in 2016 at a 5% precision level with a p value of 0.2402 and 0.6175 for PCV and Rota respectively. In 2017 however, even the wastage of these single dose vaccines were statistically significantly different between the dry and the rainy season at  $\alpha$  of 0.05.

#### 4.3.1. Vaccine wastage factor and seasons

Vaccine wastage factor was distinctively different between the dry and the rainy season in 2017 with the dry season having higher wastage factor. In 2016 however, VWF was higher in during the dry season for all of the liquid vaccines (OPV, IPV, PENTA, PCV and Rota). In all the lyophilized vaccines, VWF was higher during the rainy season in 2016 as shown in Figure 15



**Figure 15.** Comparison of vaccine wastage factor between the dry and the rainy seasons

#### **4.3.2. Vaccine categories and wastage**

Classifying vaccines into their form of preservation (liquid and lyophilized form) and also into their route of administration, during the dry season, the wastage rates in 2017 were greater than those of 2016 in all categories of vaccines as presented in Figure 14. However, in the rainy season, wastage rates for all the categories of vaccines were higher in 2016 compared to those in 2017.

Comparing vaccine wastage rate according to the route of administration between the dry and the rainy season, vaccines administered orally were statistically significantly different between the dry and the rainy seasons in 2016 and in 2017. There was a statistically significant difference in vaccine wastage in vaccine administered by injection between the dry and the rainy season in 2017 (p-values far  $<0.0001$ ) but not in 2016 (p-value 0.7633). Also, the wastage rate of liquid and lyophilized vaccines were statistically significantly different at the 95% confidence level between the dry and the rainy season in both 2016 and 2017 as presented in table 12.

**Table 11.** Statistical differences in vaccine wastage comparing the dry and the rainy seasons

Vaccine	2016						2017					
	Dry		Rainy		$\chi^2$	<i>p</i> value	Dry		Rainy		$\chi^2$	<i>p</i> value
	Children Vaccinated	Vaccine Used	Children Vaccinated	Vaccine Used			Children Vaccinated	Vaccine Used	Children Vaccinated	Vaccine Used		
BCG	46,528	65,347	41,513	62,886	74.48	<0.0001	46,621	72,830	38,335	54,062	131.16	<0.0001
OPV	169,175	177,408	177,908	182,830	18.05	<0.0001	157,827	174,001	169,749	170,232	376.18	<0.0001
IPV	39,058	48,331	45,138	53,998	13.11	0.0003	30,332	40,522	43,128	49,099	252.87	<0.0001
PENTA	123,095	126,904	136,182	138,643	5.15	0.0232	111,558	122,948	129,604	130,759	240.39	<0.0001
PCV	122,782	119,434	136,297	131,708	1.38	0.2402*	111,502	109,070	131,140	123,978	34.36	<0.0001
Rota	80,297	78,437	88,538	86,789	0.25	0.6175*	75,031	74,839	86,599	84,897	5.96	0.0147
MMR	42,743	51,316	38,899	48,736	20.37	<0.0001	37,778	49,033	28,755	33,957	80.28	<0.0001
Yellow fever	42,836	51,320	38,687	48,069	14.79	<0.0001	40,115	49,832	32,327	39,312	4.45	0.0349

\*Statistically insignificant

**Table 12.** Differences in vaccine rate classified into route of administration and type of vaccine, comparing the dry and the rainy seasons

		2016				2017							
Vaccine		Dry		Rainy		$\chi^2$	<i>p</i> value	Dry		Rainy		$\chi^2$	<i>p</i> value
		Children	Vaccine	Children	Vaccine			Children	Vaccine	Children	Vaccine		
		Vaccinated	Used	Vaccinated	Used			Vaccinated	Used	Vaccinated	Used		
Route of	Oral	249,472	257,705	266,446	271,368	13.08	0.0003	232,858	249,032	256,348	256,831	264.49	<0.0001
Administration	Injectable	417,042	462,652	436,716	484,040	0.09	0.7633	377,906	444,235	403,289	431,167	928.34	<0.0001
Type of vaccine	Lyophilized	132,107	167,983	119,099	159,691	99.76	<0.0001	124,514	171,695	99,417	127,331	171.55	<0.0001
	Liquid	534,407	550,514	584,063	593,968	23.40	<0.0001	486,250	521,380	560,220	558,965	686.73	<0.0001

## V. Discussion

Vaccination is strongly recommended by the medical community for protection against diseases especially childhood diseases(1). To achieve full effect of vaccination in the population, vaccination coverage must high enough. Vaccine wastage make vaccines less available for use especially in remote areas where access to the central vaccine storage facility is difficult. Because vaccination coverage must not be compromised by actions to reduced vaccine wastage(15), vaccine needs of a population must be calculated taking into account vaccine wastage rate. Therefore, vaccine wastage should to be continuously monitored at all levels. The World Health Organization has also projected vaccine wastage rate in order to help in calculating vaccine needs(29) in cases where actual vaccine wastage is not known. According to WHO projected vaccine wastage rate is expected to be 50% for BCG, 10% for OPV, 25% for 10-20 dose vials lyophilized vaccines 15% for 10-20 dose liquid vaccines and 5% for single dose vaccines. In 2016 and 2017, the targeted wastage rate for the Cameroon's EPI was slightly different from the projected wastage rates by WHO(28).

Vaccine wastage was highest in lyophilized vaccines. That is BCG, 32.19%, MMR, 19.05% and Yellow fever, 18.34%. This goes in line with a study in Gambia(11) that also saw the wastage rates of lyophilized vaccines higher than all the other vaccines. In comparison with a study in Bangladesh(50), the wastage rates here are much more smaller probably because this study uses administrative data since there are always quality issues with administrative data because the purpose for which the data was collected is usually different(51,52). Closely following the wastage rates for lyophilized vaccines is that of IPV which was 17.87%. IPV is a liquid 10 dose vaccine whose wastage rate is expected not to be different from that of PENTA. However, it was very high almost reaching the level of

lyophilized vaccines. IVP was introduced in to EPI in the Littoral region in June 2015(48) and vaccine wastage is expected to increase several fold with the introduction of newer vaccines(53) Its management was probably still new to health workers. Our data also supports existing evidence that wastage rates are low for vaccines that follow the MDVP as in a study in the North West Region of Cameroon(42), and in Bangladesh(50).

### **Relationship between immunization coverage and vaccine wastage**

Vaccine wastage cannot be completely prevented in vaccination it can only be minimized to an acceptable level. It is not very possible to advocate a universally acceptable vaccine wastage level since acceptable wastage levels vary between program in the light of experience and the analysis of local situations(15). The relationship between vaccine wastage rate and immunization coverage is the key to deciding whether wastage is really high or not. If both trends are analyzed over a period of time, vaccine wastage can be assessed to be acceptable or not.

Throughout 2016 and 2017, and except for the period between October and November 2016, vaccine wastage has been having an antagonistic relationship with vaccination coverage. That is, whenever vaccine coverage increases, vaccine wastage decreases and vice versa. If the vaccines are used to vaccinate children, vaccine wastage should decrease with increase in vaccination coverage. This is case with most of the periods between 2016 and 2017. However, there exist other periods where vaccine wastage increases as vaccination coverage decreases. These periods include June 2017 (for BCG and MR), from September to December 2017 for MR and IPV, January and October 2017 for BCG. Also, May 2016 for BCG. The implication is that vaccination coverage didn't decrease because of lack of vaccines but because of its mismanagement or low coverage led to poor vaccine management. This explainable since especially in the rural areas, left over vaccines taken to

the outreach sites may not get back to the cold chain in their optimal conditions(54) for it to be stored again.

Between October and November 2016, the wastage for all the vaccines decreased as the coverage also decreased. This situation can occur when vaccine are not available for vaccination or when strong attachments meant to reduce vaccine wastage also compromises vaccination coverage(8) like refusing to open up a 10 dose vaccine when there is only one target for vaccination. The first case is the most likely cause in this case as there was no BCG even at the central vaccine storage facility in Yaoundé at that time. Lack of a particular vaccine has a demotivating effect on the health care worker in organizing a(n) vaccination (outreach) session as they will need to reorganize such a vaccination again when the other is available. Also, if parents are aware that there is a vaccine that is lacking, they are demotivated to come for a vaccination given that they will have to come again some other time in future to complete the vaccination. The months of February and November are peculiar in that vaccination coverage during these two years always decreased and vaccine wastage increased.

### **Urbanization and effect on vaccine wastage rate**

The MVDP stipulates that a vial may be used for up 28 days after it has been opened provided the storage conditions are favourable(39). Therefore, vaccine wastages are expected to be low in vaccines that follow these OPV(55). Unfortunately, not all vaccines follow this policy. For BCG, MR and Yellow fever, their usage is limited to only six hours after reconstitution after which they must be discarded hence unavoidable vaccine wastage(56). It is therefore not surprising to see that the wastage rates of BCG, MR and yellow fever vaccines were higher than the liquid vaccines in both rural and urban health districts.

In areas where the population sparsely distributed, or small, like in rural areas, not only are children less likely to be fully immunized or go unimmunized(57), vaccine wastage is expected to be high(55) especially for vaccines that don't follow the MDVP. It is the case with the littoral region where over the two years, rural districts had higher vaccine wastage rates compared to urban districts. In rural districts, most of the vaccination strategy employed is outreach strategy and usually vials taken out to this strategy don't go back to the vaccine storage facility of the health facility if the VVMs are not in place. They have to be discarded. The possibility of accidents occurring in the rural areas leading unopened vial breakage is more than urban areas given that outreach strategies are the most practiced. Again, in terms of personnel rural areas are more likely to have less trained personnel than urban areas(55), all these accounting for the elevated wastage rates in rural districts compared to in urban districts. Educational status of persons in rural health districts are relatively low compared to urban dwellers.

The possibility of not fully understanding the importance of vaccination and consequently not respecting vaccination appointment in person with low education level is not rule out(30). This will lead to upon vial vaccine wastage especially in lyophilized vaccines. Cold chain stability is particularly challenging in rural health districts with the possibility of changing vaccines from one cold chain facility to another. This exposes the vaccines to alternating temperatures that may result in damage. This finding does not tie with that of Usuf *et al* in 2018(11) who didn't find any significant difference in vaccine wastage of any kind between rural and urban areas in the Gambia probably because they used few health facilities in both areas. Vial presentation also has an influence on vaccine wastage. Single dose vaccines are less likely to be subjected to vaccine wastage(15) compared to multi-dose vial vaccines, reasons for the statistically insignificant differences between rural and urban health districts in

Rota and PCV. However, because of the peculiarities in rural districts, even single dose vaccine wastage rates are higher than that for urban health districts.

The trend in vaccine wastage remained the same in 2016 and 2017. However, more vaccines were wasted in 2017 than in 2016. There was a revision of the population in the Littoral region in 2017 that lead to a reduction in the overall total population and consequently a reduction in the target population. Vaccine supplies had to follow the reduction; however, this might not have been the case as adapting to the ‘new population’ was a challenge to the health personnel.

#### **Vaccine wastage and type of vaccine**

Oral vaccines are easy to administer and less prone to wastage compared to injectable vaccines (no dead space in the syringe involved), making oral vaccines to have lesser wastage rates compared to injectable vaccines. With Lyophilized vaccines, their wasted rate is higher compared to liquid vaccines because they (lyophilized vaccines) have to be discarded 6 hours after reconstruction or at the end of the vaccination session, whichever comes first(15). This is not the case with most liquid vaccines; they are used according to the MDVP.

BCG, MR and yellow fever make up the list of lyophilized vaccines and among them, BCG has the highest wastage rate because the BCG used in Cameroon is a 20-dose vial vaccine. The possibility of ‘gathering’ many children in one vaccination session so as to reduce vaccine wastage is low and the situation is much worse in rural areas. This makes BCG the vaccine with the highest wastage rate. Nearby health facilities with small vaccination session size usually plan vaccination sessions on the same day so as to share vaccine doses for lyophilized vaccines. This greatly reduces vaccine wastage rate.

### **Effect of season on vaccine wastage rate**

There are two major seasons in Cameroon; the rainy season and the dry season. Though the dry season is dusty especially in rural areas, it is more favourable in terms of weather and road conditions. Electricity is somewhat more stable in the dry season compared to the rainy season. In the rainy season however, the reverse is true. During the rainy season due to poor weather, parents may be constrained to miss their vaccination appointments and this will increase the wastage rate of vaccine that don't follow the open vial policy (BCG, MMR and Yellow fever). Probably why in 2016, vaccine wastage for BCG, MMR and yellow fever (Lyophilized vaccines) were higher during the rainy season. However, the liquid vaccines' wastage rates were higher in the dry season compared to the rainy season which is quite expected. In 2017, the wastage rate for all the vaccines were unexpectedly higher in the dry season where conditions are much more favourable than in the rainy season.

### **Policy implications**

Vaccine wastage is expected in all the program, all localities and at all levels. Though all measures should be taken to reduce vaccine wastage, the one that should not be influenced negatively is vaccination coverage. There should be an acceptable limit of vaccine wastage which might differ from location to location depending on many factors like urban and rural setting, immunization coverage and even seasons of the year.

Since vaccine wastage is not completely avoidable and that vaccination coverage must not be affected by efforts to reduced vaccine wastage policy needs to be enforced to continuously monitor vaccine wastage and used it estimating vaccine needs of the population. In as much as higher wastage rate are acceptable to increased vaccine coverage in a low vaccine coverage setting, efforts to reduce vaccine wastage should not be undermined as it redirects already scarce funds to other needed aspects in health and it is useful as a program

monitoring tool to improve program quality and to increase the efficiency of the program. Vaccine wastage could be reduced by continued training of workers involved in immunization, actual monitoring of the vaccination session, frequent supportive supervision.

### **Innovative approaches to reduce vaccine wastage**

Perhaps, the most innovative approach to vaccine management is the controlled temperature chain (CTC) which allows vaccines to be kept at temperatures outside of the traditional cold chain of +2°C to +8°C for a period of time under monitored and controlled conditions, as appropriate to the stability of the antigen(58). This typically involves a single excursion of the vaccine into ambient temperatures but never exceeding +40°C and for duration of a specific number of days, just before administration.

The following programmatic criteria for a vaccine to be labelled for and used in a CTC has been established by WHO(58):

- a) The vaccine should be used only in a vaccination campaign or special strategy setting. CTC is not currently recommended for immunization through routine delivery.
- b) The vaccine must be able to tolerate ambient temperatures of at least +40°C for a minimum of three days and should be accompanied by:
  - a. a vaccine vial monitor (VVM) on each vial, and
  - b. a peak threshold indicator in each vaccine carrier.
- c) The vaccine must be licensed for use in a CTC by the relevant regulatory authorities, with a label that specifies the conditions.

However, for now, not all vaccines are involved and they can only be used during campaigns and in special settings not in routine immunization(58).

## VI. Conclusion

Vaccine wastage is not completely avoidable and vaccination coverage must not be compromised by actions to reduced vaccine wastage. Therefore, vaccine needs of a population must be calculated taking into account vaccine wastage rate. Analyzing vaccine wastage in relation with immunization coverage is key to deciding whether wastage is really high or not. In the Littoral region of Cameroon, the relationship between immunization coverage and vaccine wastage is mostly inverse; vaccine wastage decreasing as immunization coverage increases and vice versa.

Although urban health areas have their own challenges to vaccination activities which are mostly linked to low quality of monitoring and tracking, factors such as parent's objection or disagreement, concerns about safety of vaccines, walking distances to health facilities and waiting time in the health facilities, health worker density and logistics availability are usually more prevalent in rural than urban settings. With these peculiar characteristics in rural health districts, vaccine wastage tend to be higher than in urban health districts.

The dry season present much more favourable conditions for vaccination activities in especially in rural health districts. However, apart from vaccine wastage rate for lyophilized vaccines that were expectedly higher in the rainy season in 2016 only, vaccine wastage rates are surprisingly higher in the dry season than in the rainy.

The MDVP has come to relieve some vaccines (especially liquid vaccines) of some wastages. However, the problem still remains with lyophilized vaccines which cannot follow the MDVP. Practical efforts to reduce wastage rate includes increasing the vaccination session size but this usually may lead to miss opportunity to vaccinate are so are discouraged. Outreach vaccination strategies help resolve this.

Effective and efficient management and utilization of vaccines enhances regular supply of the vaccines and is essential for vaccine security while simultaneously keeping a check on the program costs. With the diverse settings in the Littoral region of Cameroon, a better vaccine forecasting with more realistic wastage rates in order to prevent the arrival of vaccines in excess or in deficit is indicated.

This study used administrative vaccination data for the littoral region in 2016 and 2017. Though it is official data, it is secondary data that wasn't collected primarily for the purpose of this study so it may not articulately portray the problem as it is in real situation. Therefore, future study should be designed to collect data primarily for the kind of study. Also, differences in vaccine wastage between the dry season and the rainy season should be a subject for future study so as to elucidate reason of increased vaccine wastage in the dry season.

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## VIII. Appendix

### Ethical Authorization

 <p>연세의료원 연구심의위원회 Yonsei University Health System, Institutional Review Board 서울특별시 서대문구 연세로 50-1 (우) 03722 Tel. 02 2228 0454, Fax. 02 2227 7888 Email. irb@yuhs.ac</p>	
심 의 일 자	2019년 10 월 30 일
과제승인번호	Y-2019-0144
연세의료원 연구심의위원회의 심의 결과를 다음과 같이 알려 드립니다.	
Protocol No.	
연구 제 목	카메룬 리토랄 지역의 백신 소모 평가: 시골과 도시 보건지구 간 차이와 정책적 의미
연구 책임자	NkenyiReneNke / 보건대학원 보건대학원
의 회 자	(학)연세대학교
연구예정기간	2019.10.30 ~ 2020.01.29
지속심의 빈도	연제
과제 승인 일	2019.10.30
위험 수준	Level I 최소위험
심의 유형	질의답변
심의 내용	<p>-The data has Health Districts in it and these health districts in the Littoral region of Cameroon are usually classified as "Urban" or "Rural" depending on their remoteness. Therefore, when I get the data, I will classify the health districts into "Urban" health districts and "Rural" health districts and can calculate the differences in vaccine wastage. This presented in the study research proposal on page 9 and 10</p> <p>The data also contains monthly vaccine doses in the following heading 'Doses Received' 'Doses at the beginning' 'Doses remaining', from which 'Doses used' can be calculated as Doses received + doses at the beginning - doses remaining and 'Doses wasted' can be calculated as Calculated as difference between number of children vaccinated and doses of vaccine used.</p> <p>-[변경후]임상 연구계획서(국문) 삭제 -[변경후]증례기록서 삭제 -[변경후]임상 연구계획서(국문) 추가 -[변경후]증례기록서 추가</p>
IRB 회의	연세의료원 IRB
참석 위원	연세의료원 IRB 신속심의자
<p>Ver 1.0 / 누적 출력 횟수 연세의료원 YUHS IRB [2017.04.01] 1/2</p> <div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid black; width: 100px; height: 20px;"></div> <div style="border: 1px solid black; width: 300px; height: 20px;"></div> </div>	



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심 의 결 과      승인, 대상자 동의 면제

심 의 의 견      -

※ 연세의료원 연구심의위원회는 생명윤리 및 안전에 관한 법률을 준수합니다.  
연구책임자 및 연구담당자가 IRB 위원인 경우, 해당 위원은 위 연구의 심의과정에 참여하지 않았습니다.

연세의료원  
 연구심의위원회  
 위원장



**\* 유의사항 \***

**1. 연세의료원 연구심의위원회 규정을 준수하여 주십시오.**

연구책임자께서는 모든 연구 관련자들이 규정을 이행할 수 있도록 협조하여 주시기 바랍니다.

**2. 질의답변**

승인 통보 받지 않은 과제는 연구 진행할 수 없으며, 관련 질의에 대한 답변서와 질의 사항에 따른 변경 및 수정된 자료가 있다면 첨부하여 심의일로 부터 6개월 이내 제출하여야 합니다.

**3. 연구의 승인 유효 기간**

관련법령에 따라 승인된 연구의 유효기간은 최대 1년을 넘을 수 없습니다.  
연구자께서는 승인 만료일 최소 한 달전에 중간보고를 제출하여 승인 유효기간을 갱신하셔야 합니다.  
유효기간이 만료된 연구는 새로운 대상자를 등록하실 수 없습니다.

**4. 계획 변경**

연구 절차, 대상자 수 IRB로부터 승인 받은 내용에 변경 또는 추가 사항이 있을 경우에는 반드시 IRB의 승인을 득한 후에 적용하실 수 있습니다.

**5. 연구자는 심의결과에 이의가 있을 경우 이의신청을 통해 심의관련 의견제시가 가능합니다. 관련 질의에 대한 의견제시와 충분한 근거를 첨부자료로 제출해야 합니다. 자료 미흡 또는 근거가 불충분할 경우 연구자에게 추가자료를 요청할 수 있습니다.**

