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Expanded Programme on Immunization

A GUIDE TO ESTIMATING CAPACITY OF EQUIPMENT REQUIRED FOR STORAGE AND TRANSPORTING EPI VACCINES[1]

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Introduction

When assessing the Cold Chain requirements for a new or Expanded Programme on Immunization, it is often helpful to consider the needs in two distinct steps. First, based on national, regional and district populations, make a broad estimate of the size and type of cold chain. This will give a general idea of costs and equipment. Follow this with a more detailed analysis of needs, identifying specific equipment requirements and drawing up lists of equipment plus a firm budget for the cold chain system.

This paper is intended to be used as a guide for assessing country cold chain needs, following these two steps.

1. FIRST ESTIMATES

Table 1 gives approximate capacities required for a cold chain, assuming routine immunization based on a number of assumptions, using a normal fixed centre strategy combined with out-reach services. This may be used as a first estimate for cold chain system planning, and will give a general indication of cold chain needs at each level.

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[1] This document revises and replaces the original document on this subject, EPI/CCIS/80/10.

Table 1: Approximate Cold Chain System Requirements

Level	Temperature of storage Deg.C	Population served	Type of equipment needed	Gross storage volume needed*
NATIONAL OR REGIONAL STORES (4 months stock)	0 to +8	Up to 8 million	Refrigerators	300 litres/ million
	0 to +8	Over 8 million	Cold room	0.75 m3/ million
	-15 to -20	Up to 30 million	Freezers	164 litres/ million
	-15 to -20	Over 30 million	Cold room	0.41 m3/ million
TRANSPORT TO REGION (Quarterly deliveries to all regions simultaneously)	0 to +8	No limits	Cold boxes	30 litres/ million
TRANSPORT TO LOCAL STORES (Monthly deliveries to all stores simultaneously)	0 to +8	No limits	Cold boxes	12 litres/ hundred thousand
LOCAL STORES INC. HEALTH CENTRES (6 weeks stock)		Up to 15 million	Refrigerator with icepack freezing	1.50 litres/ ten thousand

* Based on the assumptions outlined in Section 2 below. Note that the choices indicated above are only a guide to selection; they do not include local factors which are important in all cases. The choices do not, for example, take account of possible savings through selecting cold rooms built on site because of lower local costs. They also do not reflect the extra difficulty of installing cold rooms, compared to refrigerators or freezers. In all cases where the choice is not clear, the final choice must rest on local factors, such as the relative ease of importing, transporting, installing, operating and maintaining the chosen equipment.

This approximation is not a substitute for detailed country planning of cold chain equipment needs from the health unit to the central level. Before selecting a system or placing orders, the step-by-step analyses outlined in Section 2 must be followed, with actual conditions in the country substituted for the various assumptions used in the examples below. The methods of calculation, however, remain essentially the same.

2. DETAILED ANALYSIS

2.1 Population Growth

When planning for cold chain needs,a five or ten year planning period should always be considered, and the growth of population over that period estimated. The cold chain chosen must be large enough for programme needs at the end of the planning period.

For example, if a country has a population of 8.5 million today and the population growth rate is 2.8% per annum, by next year the population will have increased to:

$$8{,}500{,}000 \times 1.028 = 8{,}738{,}000$$

And, by the end of a five-year planning period, the population will have further increased to:

$$8{,}738{,}000 \times 1.028 = 8{,}983{,}000 \quad \text{(2nd year)}$$
$$8{,}983{,}000 \times 1.028 = 9{,}234{,}000 \quad \text{(3rd year)}$$
$$9{,}234{,}000 \times 1.028 = 9{,}493{,}000 \quad \text{(4th year)}$$
$$9{,}493{,}000 \times 1.028 = 9{,}759{,}000 \quad \text{(5th year)}$$

Or, alternatively,

$$8{,}500{,}000 \times (1.028)^5 = 9{,}759{,}000$$

Therefore, in this case we would need to plan the cold chain for a population of about 9,760,000 persons.

2.2 Net Vaccine Requirements

For each 1 million people in the country, let us assume the following:

- the target of infants to be immunized is 35,000 each year;
- 26,000 children entering school will require DT and BCG boosters;
- 35,000 pregnant women require 2 injections of tetanus toxoid.

We will work on the assumption that 100% of these target numbers of immunizations may be reached. Thus, our targets for the year are:-

- 35,000 infants (3.5% of population)
- 26,000 children entering school (5-6yr age group)
- 35,000 pregnant women (3.5% of population)
- 100% immunization coverage.

Vaccine volumes per dose vary widely from manufacturer to manufacturer. In Table 2 below the volume per dose, including packaging, for each vaccine is the maximum recommended by WHO/EPI. This volume excludes diluent for freeze-dried vaccine.

Table 2. Net Vaccine Requirements per Million Population

Target group	Vaccines (doses/ vial)	Target Imm. this year	No. of doses	cm^3 per dose incl. packing	wastage rate.		convert cm^3 to litres		Net vacc. requ ltrs.	Storage temp. °C
Infants	BCG(20)	35,000	x1	x1.0	x2.0	÷	1000		70	+ 4
	DPT(20)	35,000	x3	x2.5	x1.3	÷	1000		341	+ 4
	Meas(10)	35,000	x1	x3.0	x1.3	÷	1000		137	-20
	Polio(20)	35,000	x4	x1.5	x1.3	÷	1000		273	-20
				Sub-total for Infants				=	411	+ 4
								=	410	-20
School Children	DT(20)	26,000	x1	x2.5	x1.3	÷	1000		85	+ 4
	BCG(20)	26,000	x1	x1.0	x2.0	÷	1000		52	+ 4
				Sub-total for School Children				=	137	+ 4
Pregnant Women	Tetanus Tox.(20)	35,000	x2	x2.5	x1.3	÷	1000		228	+ 4
				Sub-total for Pregnant Women				=	228	+ 4

Total vaccine volume per million pop. at + 4°C = 776 litres
Total vaccine volume per million pop. at -20°C = 410 litres

We may now find the total net vaccine requirements for the whole population. For our sample country, we have estimated that the population by the end of the five-year planning period will be 9.76 million. Thus, the total net vaccine storage needs for the country by that time will be:

at + 4°C: 776 litres x 9.76 = 7574 litres
at -20°C: 410 litres x 9.76 = 4002 litres

Assuming this amount is delivered to the country in 4 consignments at 3-monthly intervals, we therefore need to store the following quantities of vaccine at the national level, including a 25% reserve stock:-

at +4°C: $\frac{7574}{4}$ + 25% reserve = 2367 litres of vaccine including reserve

at -20°C: $\frac{4002}{4}$ + 25% reserve = 1251 litres of vaccine including reserve

2.3 Cold Chain Equipment Options

In addition to the space occupied by the vaccines, we must allow extra space for air movement, loading and unloading clearances and, in the case of cold rooms, walk-around space. This allowance is called a "grossing factor".

There are also practical considerations which affect the choice between different types of equipment. Figure 3 shows the normal limits for the various types of cold chain equipment.

Table 3. Application Ranges for Cold Chain Equipment

Type of Cold Chain Equipment	Total Vaccine Requirement (Inc.reserve) in Litres	Maximum Practical Number of Units per Installation	Grossing Factor	Range of gross Capacities in litres of Available Equipment*
Front loading Refrigerators at +4°C	up to 1400 litres	up to 10	2.0	100 - 280
Top loading refrigerators at +4°C	up to 2000 litres	up to 10	1.2	15 - 250
Front loading Freezers at -20°C	up to 700 litres	up to 10	2.0	140
Top loading Freezers at -20°C	up to 4000 litres	up to 10	1.2	15 - 525
Cold rooms at +4°C	above 2000 litres	no limit	3.0	3000 and above
Cold rooms at -20°C	above 4000 litres	no limit	3.0	3000 and above
Cold boxes	no limit	no limit	1.1**	0.3 - 72***

* Approved equipment as reported in WHO Product Information Sheets SUPDIR 55 Amt5 (1985)
** "Spacing Factor" for Cold Boxes to allow for loading and unloading
*** Net capacity figures in the case of Cold Boxes, with allowances made for the necessary number of ice-packs

For large cold rooms, remember that it may be advantageous to divide the space into two or more separate rooms, or perhaps to have individual rooms for each vaccine, in order to facilitate storekeeping and stock control.

2.4 Equipment Selection

(a) The Central Store

The choice of equipment for the central store may now be made from Table 3. For storage of vaccine at +4°C, we have a requirement for 2367 litres of vaccine including reserve. Thus, we choose a cold room at +4°C, and this will need a gross capacity of:

2367 x 3.0 (grossing factor) = 7101 litres or 7.1m^3 gross storage capacity

At -20°C we require 1251 litres of vaccine including reserve, so the choice is for top loading freezers, which will need a gross capacity of:

1251 x 1.2 (grossing factor) = 1501 litres gross storage capacity

(Note that we have not included any space for icepacks at the moment. The calculation for this will be done later.)

(b) Regional Storage

Assume that the country has 10 regions, and that all regions have equal populations. Thus, each region has:-

$$\frac{9.76 \text{ million}}{10} = 0.976 \text{ million}$$

From Table 2, we will therefore need an annual amount of vaccine storage space for each region as follows:

at + 4°C: 776 x 0.976 = 757 litres, and
at -20°C: 410 x 0.976 = 400 litres

In many countries, vaccine is delivered to regional stores in 4 consignments at 3-monthly intervals and thus, including a 25% reserve stock, we have to store:-

at + 4°C: $\frac{757}{4}$ = 189 litres of vaccine,
+ 25% reserve = 237 litres of vaccine including reserve, and

at -20°C: $\frac{400}{4}$ = 100 litres of vaccine,
+ 25% reserve = 125 litres of vaccine including reserve.

Referring again to Table 3, if we choose top-loading refrigerators at +4°C, we need a gross capacity of:

237 x 1.2 (grossing factor) = 284 litres, gross storage capacity,

and for frozen vaccine, a top loading freezer at -20°C, having a gross capacity of:

125 x 1.2 (grossing factor) = 150 litres, gross storage capacity.

(c) District Storage

If we further assume each region to have 5 districts of equal size, each district will have a population of approximately:

$$\frac{0.976}{5} \text{ million} = 195{,}000 \text{ persons}$$

At the district level, all vaccine will be stored at +4°C so, from Table 2, the annual amount of vaccine storage required per district is:

$$\text{at } +4^{\circ}\text{C: } (776 + 410) \times \frac{195{,}000}{1{,}000{,}000} = 231 \text{ litres}$$

Vaccine will normally be delivered every month, so the quantity to store, including 25% reserve stock, is:

$$\text{at } +4^{\circ}\text{C: } \frac{231}{12} = 19 \text{ litres of vaccine,}$$

+ 25% reserve = 24 litres of vaccine including reserve

From Table 3 we choose a top loading refrigerator at +4°C, which will need a gross capacity of:

24 x 1.2 (grossing factor) = 29 litres, gross storage capacity

(d) Health Centre Storage

If each district is assumed to have 5 health centres of equal size, each will serve a population of:

$$\frac{195{,}000}{5} = 39{,}000 \text{ persons}$$

At this level also, all vaccine is stored at +4°C, so the annual amount to be stored at +4°C per health unit is:

$$(776 + 410) \times \frac{39{,}000}{1{,}000{,}000} = 46 \text{ litres of vaccine}$$

Assuming a monthly delivery of vaccine, and 25% reserve stock, the quantity to store becomes:

$$\text{at } +4^{\circ}\text{C: } \frac{46}{12} = 3.83 + 25\% \text{ reserve} = 4.8 \text{ litres, vaccine inc. reserve}$$

The best choice of equipment would be a top-loading refrigerator having a gross capacity of:

4.8 x 1.2 (grossing factor) = 5.8 litres, gross storage capacity

2.5 Vaccine Transport Requirements

The choice of cold box to be used will depend on the quantity of vaccine to be transported, and the time taken for the longest journey. Table 4 give a guide to the approved cold boxes available, in terms of their carrying capacity and cold life.

Table 4. Vaccine Carrying Capacity and Cold Life of Cold Boxes

Net vaccine storage capacity in litres	Cold Life in Hours at +43°C Ambient Temperature					
	<24	24-48	49-72	73-96	97-168	>168
more than 50	-	E/32	-	-	-	-
30.1 to 50.0	-	E4/33	E4/31	E4/08 E4/39 E4/50	E4/13 E4/38	-
20.1 to 30.0	E4/06	-	E4/09 E4/29	-	E4/37	E4/05 E4/30
10.1 to 20.0	-	-	E4/28	-	-	-
5.1 to 10.0	-	-	E4/10 E4/51	E4/16 E4/26 E4/36 E4/45 E4/49	E4/22	-
2.5 to 5.0	E4/21	E4/40	E4/20	-	-	-
Less that 2.5	E4/44 E4/46	E4/18 E4/19 E4/35 E4/41	E4/34	-	-	-

Note: Code numbers refer to approved equipment, as reported in the WHO Product Information Sheets, SUPDIR 55 Amt 5 (1985).

(a) Transport from Central Stores to Regional Stores

Vaccine deliveries to the 10 regions of the country are assumed to be made every 3 months. Since all vaccines transported by cold box will be carried at +4°C, the net vaccine volume at this temperature becomes:

(from para. 2.4 (b) "The Regional Store" above):
189 + 100 = 289 litres of vaccine per region

Allowing for loading and unloading space, the gross cold box capacity required becomes:

289 x 1.1 (grossing factor) = 318 litres carrying capacity per region

Assuming a cold life of at least 100 hours is considered to be necessary, together with the largest available cold box, Table 4 indicates that type E4/13 or E4/38 would be suitable. If type E4/13 were selected, with a capacity of 31 litres of vaccine and requiring 11.4 litres of ice packs (19 icepacks at 0.6 litres each), each regional delivery would need:

$\frac{318}{31}$ = 11 cold boxes

and 11 x 11.4 = 125 litres of ice-making capacity

At the Central Store, we therefore need a special icepack fast freezer (e.g type E3/26) or a separate chest freezer for freezing this volume of icepacks.

Remember that various types of vaccine delivery strategies may be employed. A single set of cold boxes may be used to deliver to one region at a time, thus necessitating 10 journeys every three months; alternatively, deliveries may be made to several points during a single journey. The strategy chosen will affect the number of cold boxes needed, and also the amount of ice needed at each level.

(b) Transport from Regional Store to District Store

Transport to the district is made every month and each district will need, allowing for loading and unloading space:

(from para. 2.4 (c) "District Storage" above):
19 litres of vaccine x 1.1 = 21 litres carrying capacity

If type E4/05 is used at district level, each district needs 1 box at 22 litres, and 14.4 litres of ice production would have to be provided at the regional store for producing the necessary ice packs. This can, as before, be met by a special icepack fast freezer or a separate chest freezer:

(c) Transport from District to Health Centre

The type of cold box selected above would be too large for deliveries to health centres individually, but since each centre requires 3.83 litres of vaccine per month, (from 2.4 (d) above) and each district has 5 centres:

5 x 3.83 = 19 litres of vaccine have to be delivered per month

One possible solution might therefore be to deliver all vaccines from the same 22 litre capacity cold box on a single delivery journey around the district. A freezer for producing the necessary 14.4 litres of ice-packs would also be required at the district level.

(d) Transport from Health Centres to Outreach Clinics

For those health centres which operate outreach services, the approximate attendance at each outreach site will enable the neccessary capacity of vaccine carriers to be calculated.

Suppose we know the attendance at a certain outreach clinic is usually about 50 mothers. We assume that each mother will bring at least one child to the clinic and, depending on the time of day when the session will be held, she may also bring older, school-age children. Some children who attend will probably be eligible for more immunizations than others, but an estimate of vaccine requirements can be made as follows:-

30 doses BCG = $\frac{30}{20}$ = 2 x 20-dose vials

40 doses DPT = $\frac{40}{20}$ = 2 x 20-dose vials

30 doses measles = $\frac{30}{10}$ = 3 x 10-dose vials

40 doses polio = $\frac{40}{20}$ = 2 x 20-dose vials

30 doses TT = $\frac{30}{20}$ = 2 x 20-dose vials

Obviously, we must allow for at least one vial of every vaccine we expect to use during the session, but it is usually a good policy to carry one or more extra vials in addition, in case attendance is greater than expected or a vial is damaged etc.

Thus, the vaccine carrier needed for this session should have a capacity of:-

VACCINE	NUMBER OF VIALS	NUMBER OF DOSES	VOLUME PER DOSE CM^3	NET VOLUME CM^3
BCG	2+1	60	1.0	60
DPT	2+1	60	2.5	150
Measles	3+1	40	3.0	120
Polio	2+1	60	1.5	90
TT	2+1	60	2.5	150
Approximate total volume :				570 (= 0.6 litres approx.)

Outreach clinics usually vary in size from session to session so, in order to be safe, it might be worthwhile to allow for more volume than the calculated amount. It would also be a good policy to standardise equipment as far as possible, so that choosing a vaccine carrier large enough for the largest outreach attendance in the country would ensure sufficient capacity for all other sessions.

Thus, in our example, we might decide to standardize on a 1 litre vaccine carrier, and decide to supply this model to all health centres in the country where outreach clinics are held. Remember that for each vaccine carrier used, ice-packs must be available, and that each health centre operating outreach services must therefore have a refrigerator capable of freezing the necessary number of ice-packs, usually four per carrier. (Approximately 1.2 litres or kgs. of ice)

3. SUMMARY OF COLD CHAIN REQUIREMENTS FOR SAMPLE COUNTRY

Table 5. National Cold Chain System Requirements

Level	Population Served	Type of Equipment Selected	Gross Cold Chain Capacity Calculated (litres)		
			Vaccine +4°C	Vaccine -20°C	Icepack Freezing
National Store	9.76 million	Cold Room	7101	-	-
		Top Loading Freezers	-	1501	125
Transport to Regions	976,000 each	Cold Boxes	318	-	-
Regional Store	976,000 each	Top Loading Refrigerator	284	-	-
		Top Loading Freezer	-	150	14.4
Transport to Districts	195,000 each	Cold Box	21	-	-
District Store	195,000 each	Top Loading Refrigerator	29	-	14.4
Transport to Health Centre	39,000 each	Cold Box	22 (shared for 5 health units)	-	-
Health Centre	39,000 each	Top Loading Refrigerator	5.8	-	1.2
		Vaccine Carrier	1 (one for each outreach session)	-	-

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