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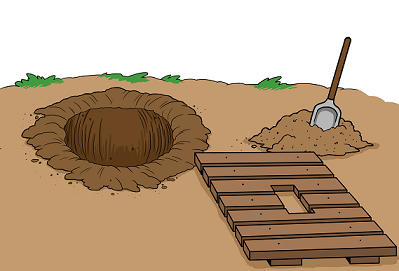
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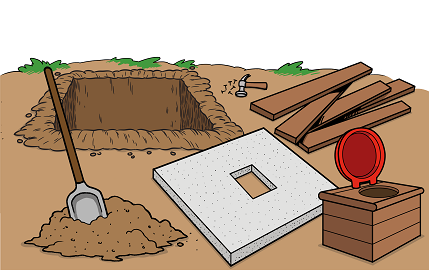
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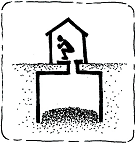
# Introduction

A sanitation system deals with human excreta from the time it is “captured” in a latrine until it is used or disposed of safely. Sanitation systems are built for people, are managed by people, and affect people’s daily lives. The latrine is the part of a sanitation system that people interact with the most. The latrine is made up of the:

* “Front-end” or the user interface: the parts that every user interacts with, including the toilet (seat or pan), slab and superstructure
* “Back-end” or excreta storage: the pit, tank or chamber used to store excreta



The pit latrine is one of the most common low cost sanitation options and used widely around the world. It is a pit dug into the ground, covered with a slab, and usually has some sort of structure (also called a superstructure) around it for privacy and weather protection. Fully or partially lining the pit prevents it from collapsing and provides support to the slab and superstructure. As the pit fills with excreta, liquid infiltrates through the pit walls into the surrounding soil. Microbes help to degrade and reduce the amount of excreta over time, but pits do eventually fill up with sludge.



Pit latrine

(Credit: AKVO, n.d.)

The ventilated improved pit (VIP) latrine (VIP) is a modification of the pit latrine. In a VIP latrine, there is a ventilation pipe and open drop hole (no lid) to help air flow through the structure. This reduces smells in the latrine. A mesh screen at the top of the vent pipe reduces flies in the latrine – the flies are attracted to the light at the top of the pipe, but can’t escape, and die there.



VIP latrine

(Credit: AKVO, n.d.)

For more information about pit and VIP latrines, see CAWST’s Sanitation Fact Sheets and Technical Brief: Sanitation System – Excreta Storage.

This Technical Brief is to help project implementers determine the size of pit and VIP latrines. It describes how to size pits using the following two methods, and provides practice questions for both methods:

1. Choosing a pit size from design tables that have already calculated the values for you.
2. Calculating the pit size yourself using a formula.

For more information on latrine projects, CAWST’s Technical Briefs and Fact Sheets provide details on:

* How to select, site and construct latrines
* Latrine emptying
* Sludge treatment, use and disposal
* Approaches for sustainable latrine project implementation

Please see the Guide to CAWST Sanitation Resources for a complete glossary, list of abbreviations, unit conversions, and an overview of available resources.

CAWST focuses on the planning, design and implementation of on-site sanitation projects for low-income communities not connected to a sewer. For such communities, household or decentralized sanitation offers a hygienic and affordable solution.

CAWST’s free, open content resources and schedule of international training workshops can be found at: [www.cawst.org/resources](http://www.cawst.org/resources) and [www.cawst.org/training](http://www.cawst.org/training).

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**Note about Units**

This Technical Brief uses metric units (e.g., metres, square metres, cubic metres, litres). For unit conversions to the imperial system or US Customary system, please see below, or refer to the Guide to CAWST Sanitation Resources for more conversions.

**Length Volume**

1 m = 3.28 feet 1 m3 = 35.3 ft3 = 264 gallons (US)

1 cm = 0.39 inches 1 L = 0.26 gallons (US) = 33.8 fluid oz (US)

1 L = 0.22 gallons (imperial) = 25.2 fluid oz (imperial)



**Definitions**

**Anal cleansing material:** Solid materials used to cleanse oneself after defecating and/or urinating.

**Anal cleansing water:** Water used to cleanse oneself after defecating and/or urinating.

**Dry latrine:** A latrine that operates without flush water. Inputs can include urine, feces, small amounts of anal cleansing water and dry cleansing materials.

**Excreta:** Urine and feces that is not mixed with any flushwater. Excreta contains many nutrients and pathogens.

**Infiltrate:** To pass into or through something. Infiltration is the process by which liquid from a latrine pit enters the surrounding soil.

**Permeable:** Liquids can pass through. Latrine pit walls must be permeable for liquid to infiltrate into the surrounding soil. Impermeable means that liquids cannot pass through (also called watertight).

**Slab:** A latrine slab is a solid base that a person can stand on while using the latrine. It is the barrier between a person defecating and the pit, tank or chamber that safely stores the excreta. It has a drop hole, pour flush pan or seat through which the excreta enters the pit, tank or chamber. The slab may be made of wood, bamboo, plastic, or concrete.

**Sludge:** Also called fecal sludge. Excreta removed from a pit, septic tank, aqua privy or biogas reactor. It may contain flush water, anal cleansing water, and other anal cleansing materials. It may be raw or partially treated.

**Sludge accumulation rate:** The volume of sludge that builds up in a pit per person per year.

**Wet latrine:** A latrine that operates with water for flushing (pour flush or cistern flush).

# Design Basics

The size of a latrine pit and how fast it fills up depends on a number of factors, including how many people use the latrine and how much water goes into the pit. To design a latrine pit, you need to consider the following five pieces of information (also called variables):



**Key Information Needed to Design a Latrine Pit**

1. **Number of users (N):** The number of people that will use the latrine on a regular basis.
2. **Lifetime (Y):** The number of years it takes to fill the pit.
3. **Pit shape and dimensions:**

**- Length (L)** and **Width (W)** for a rectangular or square pit, or

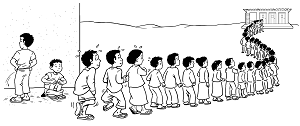
**- Diameter (d)** (the distance from one side of the circle to the opposite side, through the

middle) for a circular pit.

1. **Pit depth (D):** How deep the pit is below the ground surface.
2. **Sludge accumulation rate (R):** The volume of sludge that builds up in the pit per person per year.

## Number of Users

The number of people using the latrine on a regular basis will affect how quickly the pit fills and, therefore, the size required. This is usually the number of people in the household.



## Lifetime

Latrine pits can be divided into the following two categories based on their lifetime:

1. Long-term latrine: Any pit that is designed to take more than two years to fill up.
2. Short-term latrine: Any pit that is designed to take two years or less to fill up.

In rural areas, single pits are usually dug as deep as possible, so that it takes a long time for them to fill up. Pits designed to last 25–30 years are not uncommon, and a lifetime of 15–20 years is reasonable (Franceys et al., 1992). A minimum pit lifetime of 10 years is recommended (Reed, 2014).

In some areas, the conditions make it impractical to build deep pits with a long lifetime. For instance, in urban areas where pit emptying is carried out, or areas where the bottom of the pit is within 2 metres of the groundwater.

If the lifetime of the pit is less than 10 years, you should consider building two pits (also called twin or double pits), and alternate their use (Franceys et al., 1992). Each of the pits should have a minimum two year lifetime, so that the excreta can degrade and the pathogens are reduced over time. The excreta is safer to handle after two years, and then the pit can be emptied and reused. If the pits are to be reused, then local sludge emptying, treatment and/or disposal services are needed, and the pit must be lined to prevent collapse when emptied.

For more information on pit lining, see CAWST’s Latrine Construction Manual.



**Design Tip**

As a general rule, latrine pits should be designed to last as long as possible.

## Pit Shape and Dimensions

You need to decide on the shape of the pit before starting any calculations or using the design tables. The common pit shapes are square, rectangular or circular. The pit design often follows local traditions. You may find that most households in the same community use similar pit shapes and dimensions.

The pit shape is often selected based on the depth of the pit. Deep pits (deeper than about

1.5 metres) are usually circular, whereas shallow pits are commonly square or rectangular. People often find that square or rectangular pits are easier to dig and similar to the construction process used to build their homes (Franceys et al., 1992; Reed, 2014).

When choosing your pit shape, consider the following:

* Circular pits are less likely to collapse at greater depths (more than 1.5 metres) because the pressure from the surrounding soil is evenly spread.
* Square or rectangular pits tend to collapse more often at greater depths because pressure is placed on the four walls. This leaves the corners to absorb the stress.

Pressure from surrounding ground

Pressure from surrounding ground

(Credit: Lifewater International, 2009)



**Design Tip**

Pits are commonly 1.0–1.5 metres wide, since this is a convenient size for a person to work inside while digging. If the pit is wider than 1.5 metres, there is an increased risk of the walls collapsing. As well, latrines with wider pits can be more expensive to build since you will need a bigger slab and may need more pit lining materials.

(Tilley et al., 2014 and Franceys et al., 1992)

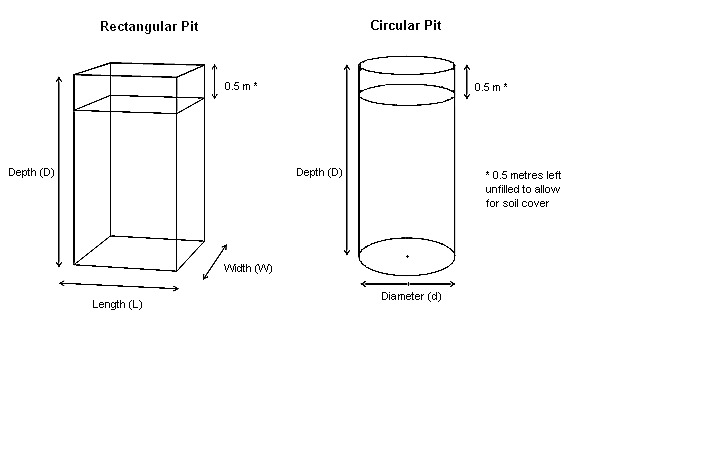
## Pit Depth

It is usually good to dig the pit as deep as possible, but this depends on soil conditions, cost of lining, pit emptying method, and the level of the groundwater (Franceys et al., 1992).

The total pit depth below the ground surface should include:

* The depth or volume of the pit that will be filled with sludge
* At least 0.5 metres at the top of the pit that is left unfilled – the pit is considered full when the excreta is within 0.5 metres from the slab or the top of the pit

If the pit is being closed and covered instead of emptied, the 0.5 metre space at the top of the pit allows for a safe thickness of soil cover. The 0.5 metres of soil on top of the excreta will make the area safe so anyone walking over the old pit will not sink into it. It will also help stop animals from burrowing into the pit, looking for food. As well, the extra 0.5 metre space prevents excreta from splashing the user as the pit gets full, hides the unpleasant sight of excreta in the pit, and reduces problems with smells and flies (Franceys et al., 1992; Reed 2014).



(Credit: Lifewater International, 2009)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Square and Rectangular Pit Variables** | |  | **Circular Pit Variables** | |
| **D =** | Depth (metres) |  | **D =** | Depth (metres) |
| **L =** | Length (metres) | **d =** | Diameter (metres) |
| **W =** | Width (metres) |  |  |
| **N =** | Number of Users (people) | **N =** | Number of Users (people) |
| **R =** | Sludge Accumulation Rate (litres/person/year) | **R =** | Sludge Accumulation Rate (litres/person/year) |
| **Y =** | Lifetime (years) | **Y =** | Lifetime (years) |



**Design Tips**

* Typically, single pits are at least 3 metres deep (Franceys et al., 1992).
* The bottom of the pit must be at least 2 metres above the highest annual groundwater level (Franceys et al., 1992). See CAWST’s Technical Brief: Siting Latrines for more information.
* Manually emptying sludge (with shovels and buckets) from pits deeper than 1.5 metres is impossible, unless the emptier climbs inside the pit, which is a serious health and safety risk. Vacuum tankers can usually only suck down to a depth of 2 to 3 metres, and the truck must be able to park within 30 metres of the pit (depending on the strength of the pump). A compromise must be made between the pit depth and the frequency and difficulty of emptying. Shallow pits (less than 1.5 metres deep) are easier to empty and have less health risks to emptiers than do deeper pits, but they need to be emptied more often (Buckley et al., 2008; Still and Foxon, 2012; Tilley et al., 2014).

## Sludge Accumulation Rate

The sludge accumulation rate (R) is the volume of sludge that builds up in the pit over time. The units are litres/person/year. The diagram below illustrates how a pit fill up over time.

**Degradation**

**(Biological processes)**

**Infiltration (if pit is permeable)**

**Feces**

**Urine**

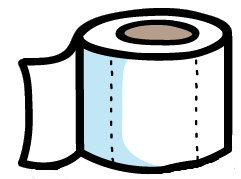
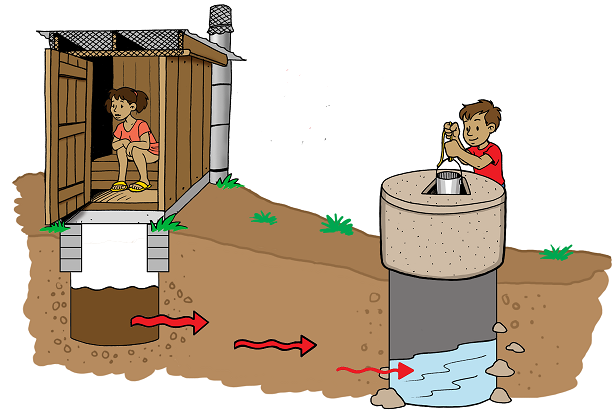
**Water**

**Anal cleansing material**

**Solid waste**

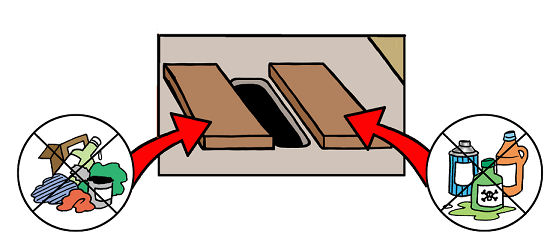
Sludge accumulation in a latrine pit

There are several social, technical and environmental factors which affect the sludge accumulation rate, including the following:

* Amount of feces and urine excreted daily by individuals: This amount varies considerably depending on water consumption, climate, diet and occupation.
* Type of anal cleansing material used: Degradable anal cleansing materials (like paper and leaves) decompose over time inside the pit, reducing the volume. Latrines with degradable materials have a lower sludge accumulation rate than those with non-degradable cleansing materials (like stones and plastic).
* Amount of water that enters the pit: Latrines that use water to flush and have more water in the pit have lower sludge accumulation rates than dry latrines. Biological degradation is more complete in water, where conditions are anaerobic or where there is no oxygen (Still and Foxon, 2012). Water also carries soluble components from the sludge, such as pathogens, organic material, grease and nutrients, out of the pit into the surrounding soil (Buckley et al., 2008).
* Infiltration capacity of the pit: Pits are usually designed with permeable walls that allow infiltration, so liquid can pass out of the pit into the surrounding soil. How much liquid can infiltrate into the soil is affected by the pit lining and soil conditions.

If the pit has no lining or a permeable lining, and the soil is permeable, then the liquids in the pit will infiltrate into the surrounding soil. If large amounts of water are used, it may not all be able to infiltrate into the soil, and some will remain in the pit. Soil pores will also become clogged with time, reducing or even stopping infiltration. For this reason, a higher or more conservative sludge accumulation rate should be used, especially where soil infiltration rates are relatively low to start with (Harvey, 2007; Still and Foxon, 2012).

If the soil has low permeability (such as clay), or if the pit has an impermeable lining, liquid will not infiltrate into the soil. In these cases, the pit will fill much more quickly, especially if flush water is added to the pit.

* Other materials added to the pit: In reality, people often dispose of garbage into pit latrines in the absence of a proper solid waste management system. Adding other materials, especially those that do not easily decompose, will increase the sludge accumulation rate (Buckley et al., 2008; Still and Foxon, 2012). Solid waste may include sanitary products used for menstrual hygiene, condoms, health care waste (such as used needles), paper, metal, glass and organic material (such as kitchen and garden waste). These materials will also make the pit difficult, and unsafe, to empty.
* Biological activity in the pit: Microbes help to degrade and reduce the amount of sludge in the pit over time. The temperature, pH, ammonia level and water content in the pit affect the microbial activity and the sludge accumulation rate (Still and Foxon, 2012). Wet latrines that have water in the pit decompose excreta faster, contributing to lower sludge accumulation rate for wet latrines than for dry latrines with no water or very little water in the pit (Bester et al., 2000 cited in Buckley et al., 2008).

Measuring the local sludge accumulation rate based on these factors can be challenging and is often not possible. In the absence of local measurements, the sludge accumulation rates given in the following table can be used as a guideline.

**Table 1: Sludge Accumulation Rates**

|  |  |  |
| --- | --- | --- |
| **Pit Conditions** | **Sludge Accumulation Rate (R) (litres/person/year)** | |
| Degradable anal cleansing materials (e.g., paper, leaves) and water | Nondegradable anal cleansing materials (e.g., stones, plastic) |
| Water in pit (e.g., pour flush latrine) | 40 | 60 |
| Dry in pit (e.g., no or small amount of water in pit) | 60 | 90 |

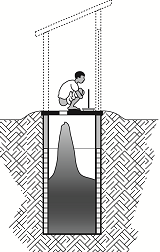
(Adapted from Franceys et al., 1992)

**Note:** The numbers in the above table are long-term sludge accumulation rates. These rates are too low for short-term latrines (pits that are used for about two years) since there is not enough time for the excreta to decompose and reduce its volume. Franceys et al., (1992) suggests that you should increase the rate of accumulation (R) by 50% for short-term latrines (2 years or less). You can do this by multiplying R by 1.5 in the calculations for short-term latrines.

**Case Study: South Africa**

A study of VIP latrines in South Africa found that a sludge accumulation rate of 40 litres/person/year is reasonable. However for latrine design, it was recommended to use a more conservative rate of 60 litres/person/year to ensure that the pits do not fill up before the planned time to empty them comes.

(Still and Foxon, 2012)

**Cold Climates**

Due to the slowing down of biological process, the lack of infiltration,

and the uneven settling or piling up of excreta, pits should be

designed to be larger in cold climates. The sludge accumulation rate

should be increased by as much as 100% (Buttle and Smith, 2004).

Data for septic tanks shows that sludge accumulation may increase

by 50–90% in climates where the air temperature is below 10°C in

winter versus where it is over 20°C all year (Reed, 2014b).

See CAWST’s Technical Brief: Latrines in Challenging

Sludge can freeze in cold weather and create a pyramid

(Credit: Chatterton/WEDC, 2013)

Environments for information on designing latrines for cold climates.

# Calculations Using Design Tables

This section gives tables that have already calculated various pit dimensions and depths. The tables can be used to find the depth of pit required, based on the following variables:

* Number of regular users (4, 6 or 8 people)
* Lifetime (2, 5, 10 or 15 years)
* Shape of pit (square/rectangular or circular)
* Dimensions of pit (length and width or diameter)
* Sludge accumulation rate (40, 60 or 90 litres/person/year)

The tables do not cover all possible options and may not be useful in all circumstances. If none of the options meet your needs, then you will have to design your pit using hand calculations. Section 4 Calculations by Hand explains how to do this.

**Table 2: Pit Dimensions and Depth for 4 Regular Users (N = 4)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pit Dimensions** | **Pit Depth (D) (metres)** | | | | | | | | | | | |
| **2 Year Lifetime1** | | | **5 Year Lifetime** | | | **10 Year Lifetime** | | | **15 Year Lifetime** | | |
| **Square/Rectangular Pit**  **Length (L) x Width (W) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 x 1.0 (square) | 1.0 | 1.2 | 1.6 | 1.3 | 1.7 | 2.3 | 2.1 | 2.9 | 4.1 | 2.9 | 4.1 | 5.9 |
| 1.0 x 1.2 | 0.9 | 1.1 | 1.4 | 1.2 | 1.5 | 2.0 | 1.8 | 2.5 | 3.5 | 2.5 | 3.5 | 5.0 |
| 1.0 x 1.5 | 0.8 | 1.0 | 1.2 | 1.0 | 1.3 | 1.7 | 1.6 | 2.1 | 2.9 | 2.1 | 2.9 | 4.1 |
| 1.2 x 1.2 (square) | 0.8 | 1.0 | 1.3 | 1.1 | 1.3 | 1.8 | 1.6 | 2.2 | 3.0 | 2.2 | 3.0 | 4.3 |
| 1.2 x 1.5 | 0.8 | 0.9 | 1.1 | 0.9 | 1.2 | 1.5 | 1.4 | 1.8 | 2.5 | 1.8 | 2.5 | 3.5 |
| 1.5 x 1.5 (square) | 0.7 | 0.8 | 1.0 | 0.9 | 1.0 | 1.3 | 1.2 | 1.6 | 2.1 | 1.6 | 2.1 | 2.9 |
| **Circular Pit**  **Diameter (d) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 | 1.1 | 1.4 | 1.9 | 1.5 | 2.0 | 2.8 | 2.5 | 3.6 | 5.1 | 3.6 | 5.1 | 7.4 |
| 1.1 | 1.0 | 1.3 | 1.6 | 1.3 | 1.8 | 2.4 | 2.2 | 3.0 | 4.3 | 3.0 | 4.3 | 6.2 |
| 1.2 | 0.9 | 1.1 | 1.5 | 1.2 | 1.6 | 2.1 | 1.9 | 2.6 | 3.7 | 2.6 | 3.7 | 5.3 |
| 1.3 | 0.9 | 1.0 | 1.3 | 1.1 | 1.4 | 1.9 | 1.7 | 2.3 | 3.2 | 2.3 | 3.2 | 4.6 |
| 1.4 | 0.8 | 1.0 | 1.2 | 1.0 | 1.3 | 1.7 | 1.5 | 2.1 | 2.8 | 2.1 | 2.8 | 4.0 |
| 1.5 | 0.8 | 0.9 | 1.1 | 1.0 | 1.2 | 1.5 | 1.4 | 1.9 | 2.5 | 1.9 | 2.5 | 3.6 |

1 The calculations for pits with a 2 year lifetime have taken into account the limited sludge volume reduction that will occur due to decomposition in this short time frame by multiplying the sludge accumulation rates (R) by 1.5.

**Table 3: Pit Dimensions and Depth for 6 Regular Users (N = 6)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pit Dimensions** | **Pit Depth (D) (metres)** | | | | | | | | | | | |
| **2 Year Lifetime1** | | | **5 Year Lifetime** | | | **10 Year Lifetime** | | | **15 Year Lifetime** | | |
| **Square/Rectangular Pit**  **Length (L) x Width (W) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 x 1.0 (square) | 1.2 | 1.6 | 2.1 | 1.7 | 2.3 | 3.2 | 2.9 | 4.1 | 5.9 | 4.1 | 5.9 | 8.6 |
| 1.0 x 1.2 | 1.1 | 1.4 | 1.9 | 1.5 | 2.0 | 2.8 | 2.5 | 3.5 | 5.0 | 3.5 | 5.0 | 7.3 |
| 1.0 x 1.5 | 1.0 | 1.2 | 1.6 | 1.3 | 1.7 | 2.3 | 2.1 | 2.9 | 4.1 | 2.9 | 4.1 | 5.9 |
| 1.2 x 1.2 (square) | 1.0 | 1.3 | 1.6 | 1.3 | 1.8 | 2.4 | 2.2 | 3.0 | 4.3 | 3.0 | 4.3 | 6.1 |
| 1.2 x 1.5 | 0.9 | 1.1 | 1.4 | 1.2 | 1.5 | 2.0 | 1.8 | 2.5 | 3.5 | 2.5 | 3.5 | 5.0 |
| 1.5 x 1.5 (square) | 0.8 | 1.0 | 1.2 | 1.0 | 1.3 | 1.7 | 1.6 | 2.1 | 2.9 | 2.1 | 2.9 | 4.1 |
| **Circular Pit**  **Diameter (d) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 | 1.4 | 1.9 | 2.6 | 2.0 | 2.8 | 3.9 | 3.6 | 5.1 | 7.4 | 5.1 | 7.4 | 10.8 |
| 1.1 | 1.3 | 1.6 | 2.2 | 1.8 | 2.4 | 3.3 | 3.0 | 4.3 | 6.2 | 4.3 | 6.2 | 9.0 |
| 1.2 | 1.1 | 1.5 | 1.9 | 1.6 | 2.1 | 2.9 | 2.6 | 3.7 | 5.3 | 3.7 | 5.3 | 7.7 |
| 1.3 | 1.0 | 1.3 | 1.7 | 1.4 | 1.9 | 2.5 | 2.3 | 3.2 | 4.6 | 3.2 | 4.6 | 6.6 |
| 1.4 | 1.0 | 1.2 | 1.6 | 1.3 | 1.7 | 2.3 | 2.1 | 2.8 | 4.0 | 2.8 | 4.0 | 5.8 |
| 1.5 | 0.9 | 1.1 | 1.4 | 1.2 | 1.5 | 2.0 | 1.9 | 2.5 | 3.6 | 2.5 | 3.6 | 5.1 |

**Table 4: Pit Dimensions and Depth for 8 Regular Users (N = 8)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pit Dimensions** | **Pit Depth (D) (metres)** | | | | | | | | | | | |
| **2 Year Lifetime1** | | | **5 Year Lifetime** | | | **10 Year Lifetime** | | | **15 Year Lifetime** | | |
| **Square/Rectangular Pit**  **Length (L) x Width (W) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 x 1.0 (square) | 1.5 | 1.9 | 2.7 | 2.1 | 2.9 | 4.1 | 3.7 | 5.3 | 7.7 | 5.3 | 7.7 | 11.3 |
| 1.0 x 1.2 | 1.3 | 1.7 | 2.3 | 1.8 | 2.5 | 3.5 | 3.2 | 4.5 | 6.5 | 4.5 | 6.5 | 9.5 |
| 1.0 x 1.5 | 1.1 | 1.5 | 1.9 | 1.6 | 2.1 | 2.9 | 2.6 | 3.7 | 5.3 | 3.7 | 5.3 | 7.7 |
| 1.2 x 1.2 (square) | 1.2 | 1.5 | 2.0 | 1.6 | 2.2 | 3.0 | 2.7 | 3.8 | 5.5 | 3.8 | 5.5 | 8.0 |
| 1.2 x 1.5 | 1.0 | 1.3 | 1.7 | 1.4 | 1.8 | 2.5 | 2.3 | 3.2 | 4.5 | 3.2 | 4.5 | 6.5 |
| 1.5 x 1.5 (square) | 0.9 | 1.1 | 1.5 | 1.2 | 1.6 | 2.1 | 1.9 | 2.6 | 3.7 | 2.6 | 3.7 | 5.3 |
| **Circular Pit**  **Diameter (d) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 | 1.7 | 2.3 | 3.3 | 2.5 | 3.6 | 5.1 | 4.6 | 6.6 | 9.7 | 6.6 | 9.7 | 14.3 |
| 1.1 | 1.5 | 2.0 | 2.8 | 2.2 | 3.0 | 4.3 | 3.9 | 5.6 | 8.1 | 5.6 | 8.1 | 11.9 |
| 1.2 | 1.3 | 1.8 | 2.4 | 1.9 | 2.6 | 3.7 | 3.3 | 4.7 | 6.9 | 4.7 | 6.9 | 10.1 |
| 1.3 | 1.2 | 1.6 | 2.1 | 1.7 | 2.3 | 3.2 | 2.9 | 4.1 | 5.9 | 4.1 | 5.9 | 8.6 |
| 1.4 | 1.1 | 1.4 | 1.9 | 1.5 | 2.1 | 2.8 | 2.6 | 3.6 | 5.2 | 3.6 | 5.2 | 7.5 |
| 1.5 | 1.0 | 1.3 | 1.7 | 1.4 | 1.9 | 2.5 | 2.3 | 3.2 | 4.6 | 3.2 | 4.6 | 6.6 |

1 The calculations for pits with a 2 year lifetime have taken into account the limited sludge volume reduction that will occur due to decomposition in this short time frame by multiplying the sludge accumulation rates (R) by 1.5.

**Table 5: Pit Dimensions and Depth for 10 Regular Users (N = 10)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pit Dimensions** | **Pit Depth (D) (metres)** | | | | | | | | | | | |
| **2 Year Lifetime1** | | | **5 Year Lifetime** | | | **10 Year Lifetime** | | | **15 Year Lifetime** | | |
| **Square/Rectangular Pit**  **Length (L) x Width (W) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 x 1.0 (square) | 1.7 | 2.3 | 3.2 | 3.5 | 5.0 | 7.3 | 6.5 | 9.5 | 14.0 | 9.5 | 14.0 | 20.8 |
| 1.0 x 1.2 | 1.5 | 2.0 | 2.8 | 3.0 | 4.3 | 6.1 | 5.5 | 8.0 | 11.8 | 8.0 | 11.8 | 17.4 |
| 1.0 x 1.5 | 1.3 | 1.7 | 2.3 | 2.5 | 3.5 | 5.0 | 4.5 | 6.5 | 9.5 | 6.5 | 9.5 | 14.0 |
| 1.2 x 1.2 (square) | 1.3 | 1.8 | 2.4 | 2.6 | 3.6 | 5.2 | 4.7 | 6.8 | 9.9 | 6.8 | 9.9 | 14.6 |
| 1.2 x 1.5 | 1.2 | 1.5 | 2.0 | 2.2 | 3.0 | 4.3 | 3.8 | 5.5 | 8.0 | 5.5 | 8.0 | 11.8 |
| 1.5 x 1.5 (square) | 1.0 | 1.3 | 1.7 | 1.8 | 2.5 | 3.5 | 3.2 | 4.5 | 6.5 | 4.5 | 6.5 | 9.5 |
| **Circular Pit**  **Diameter (d) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 | 2.0 | 2.8 | 3.9 | 4.3 | 6.2 | 9.1 | 8.1 | 12.0 | 17.7 | 12.0 | 17.7 | 26.3 |
| 1.1 | 1.8 | 2.4 | 3.3 | 3.7 | 5.2 | 7.6 | 6.8 | 10.0 | 14.7 | 10.0 | 14.7 | 21.8 |
| 1.2 | 1.6 | 2.1 | 2.9 | 3.2 | 4.5 | 6.5 | 5.8 | 8.5 | 12.4 | 8.5 | 12.4 | 18.4 |
| 1.3 | 1.4 | 1.9 | 2.5 | 2.8 | 3.9 | 5.6 | 5.0 | 7.3 | 10.7 | 7.3 | 10.7 | 15.8 |
| 1.4 | 1.3 | 1.7 | 2.3 | 2.4 | 3.4 | 4.9 | 4.4 | 6.3 | 9.3 | 6.3 | 9.3 | 13.7 |
| 1.5 | 1.2 | 1.5 | 2.0 | 2.2 | 3.0 | 4.3 | 3.9 | 5.6 | 8.1 | 5.6 | 8.1 | 12.0 |

**Table 6: Pit Dimensions and Depth for 12 Regular Users (N = 12)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pit Dimensions** | **Pit Depth (D) (metres)** | | | | | | | | | | | |
| **2 Year Lifetime1** | | | **5 Year Lifetime** | | | **10 Year Lifetime** | | | **15 Year Lifetime** | | |
| **Square/Rectangular Pit**  **Length (L) x Width (W) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 x 1.0 (square) | 1.9 | 2.7 | 3.7 | 4.1 | 5.9 | 8.6 | 7.7 | 11.3 | 16.7 | 11.3 | 16.7 | 24.8 |
| 1.0 x 1.2 | 1.7 | 2.3 | 3.2 | 3.5 | 5.0 | 7.3 | 6.5 | 9.5 | 14.0 | 9.5 | 14.0 | 20.8 |
| 1.0 x 1.5 | 1.5 | 1.9 | 2.7 | 2.9 | 4.1 | 5.9 | 5.3 | 7.7 | 11.3 | 7.7 | 11.3 | 16.7 |
| 1.2 x 1.2 (square) | 1.5 | 2.0 | 2.8 | 3.0 | 4.3 | 6.1 | 5.5 | 8.0 | 14.1 | 8.0 | 11.8 | 17.4 |
| 1.2 x 1.5 | 1.3 | 1.7 | 2.3 | 2.5 | 3.5 | 5.0 | 4.5 | 6.5 | 11.4 | 6.5 | 9.5 | 14.0 |
| 1.5 x 1.5 (square) | 1.1 | 1.5 | 1.9 | 2.1 | 2.9 | 4.1 | 3.7 | 5.3 | 11.6 | 5.3 | 7.7 | 11.3 |
| **Circular Pit**  **Diameter (d) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 | 2.3 | 3.3 | 4.6 | 5.1 | 7.4 | 10.8 | 9.7 | 14.3 | 21.1 | 14.3 | 21.1 | 31.5 |
| 1.1 | 2.0 | 2.8 | 3.9 | 4.3 | 6.2 | 9.0 | 8.1 | 11.9 | 17.6 | 11.9 | 17.6 | 26.1 |
| 1.2 | 1.8 | 2.4 | 3.4 | 3.7 | 5.3 | 7.7 | 6.9 | 10.1 | 14.8 | 10.1 | 14.8 | 22.0 |
| 1.3 | 1.6 | 2.1 | 2.9 | 3.2 | 4.6 | 6.6 | 5.9 | 8.6 | 12.7 | 8.6 | 12.7 | 18.8 |
| 1.4 | 1.4 | 1.9 | 2.6 | 2.8 | 4.0 | 5.8 | 5.2 | 7.5 | 11.0 | 7.5 | 11.0 | 16.3 |
| 1.5 | 1.3 | 1.7 | 2.3 | 2.5 | 3.6 | 5.1 | 4.6 | 6.6 | 9.7 | 6.6 | 9.7 | 14.3 |

1 The calculations for pits with a 2 year lifetime have taken into account the limited sludge volume reduction that will occur due to decomposition in this short time frame by multiplying the sludge accumulation rates (R) by 1.5.

**Table 7: Pit Dimensions and Depth for 15 Regular Users (N = 15)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pit Dimensions** | **Pit Depth (D) (metres)** | | | | | | | | | | | |
| **2 Year Lifetime1** | | | **5 Year Lifetime** | | | **10 Year Lifetime** | | | **15 Year Lifetime** | | |
| **Square/Rectangular Pit**  **Length (L) x Width (W) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 x 1.0 (square) | 2.3 | 3.2 | 4.6 | 5.0 | 7.3 | 10.6 | 9.5 | 14.0 | 20.8 | 14.0 | 20.8 | 30.9 |
| 1.0 x 1.2 | 2.0 | 2.8 | 3.9 | 4.3 | 6.1 | 8.9 | 8.0 | 11.8 | 17.4 | 11.8 | 17.4 | 25.8 |
| 1.0 x 1.5 | 1.7 | 2.3 | 3.2 | 3.5 | 5.0 | 7.3 | 6.5 | 9.5 | 14.0 | 9.5 | 14.0 | 20.8 |
| 1.2 x 1.2 (square) | 1.8 | 2.4 | 3.3 | 3.6 | 5.2 | 7.5 | 6.8 | 9.9 | 14.6 | 9.9 | 14.6 | 21.6 |
| 1.2 x 1.5 | 1.5 | 2.0 | 2.8 | 3.0 | 4.3 | 6.1 | 5.5 | 8.0 | 11.8 | 8.0 | 11.8 | 17.4 |
| 1.5 x 1.5 (square) | 1.3 | 1.7 | 2.3 | 2.5 | 3.5 | 5.0 | 4.5 | 6.5 | 9.5 | 6.5 | 9.5 | 14.0 |
| **Circular Pit**  **Diameter (d) (metres)** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** | **R=40** | **R=60** | **R=90** |
| 1.0 | 2.8 | 3.9 | 5.7 | 6.2 | 9.1 | 13.4 | 12.0 | 17.7 | 26.3 | 17.7 | 26.3 | 39.2 |
| 1.1 | 2.4 | 3.3 | 4.8 | 5.2 | 7.6 | 11.2 | 10.0 | 14.7 | 21.8 | 14.7 | 21.8 | 32.5 |
| 1.2 | 2.1 | 2.9 | 4.1 | 4.5 | 6.5 | 9.5 | 8.5 | 12.4 | 18.4 | 12.4 | 18.4 | 27.4 |
| 1.3 | 1.9 | 2.5 | 3.6 | 3.9 | 5.6 | 8.1 | 7.3 | 10.7 | 15.8 | 10.7 | 15.8 | 23.4 |
| 1.4 | 1.7 | 2.3 | 3.1 | 3.4 | 4.9 | 7.1 | 6.3 | 9.3 | 13.7 | 9.3 | 13.7 | 20.2 |
| 1.5 | 1.5 | 2.0 | 2.8 | 3.0 | 4.3 | 6.2 | 5.6 | 8.1 | 12.0 | 8.1 | 12.0 | 17.7 |

1 The calculations for pits with a 2 year lifetime have taken into account the limited sludge volume reduction that will occur due to decomposition in this short time frame by multiplying the sludge accumulation rates (R) by 1.5.

## Practice Questions

Answer the following questions by using Table 1: Sludge Accumulation Rates and the design tables in Section 3. The solutions are found at the end of this section.

**Question 1**

* A family of 4 wants to build a rectangular pit for their dry pit latrine
* They want the pit to have a length and width of 1.0 metre
* They want to be able to use the latrine for 2 years before digging a new pit
* They use grass and leaves for anal cleansing

How deep should their pit be?

**Question 2**

* A family of 6 wants to build a circular pit for their VIP latrine
* They want the pit to have a diameter of 1.0 metres
* They want to be able to use the latrine for 5 years before building a new one
* They use small amounts of water for anal cleansing

How deep should their pit be?

**Question 3**

* A family of 8 wants to build a pour flush latrine
* They want to build a circular pit with a diameter of 1.5 metres
* They want to use the latrine for 15 years and then have the pit emptied by vacuum tanker
* They use water for anal cleansing

How deep should their pit be? What challenges might you find with this pit depth?

**Question 4**

* A family of 15 wants to build a circular pit for their VIP latrine
* They want the pit to have a diameter of 1.5 metres
* They want to use the latrine for 5 years and then have the pit emptied by vacuum tanker
* They use water for anal cleansing

How deep should their pit be? What challenges might you find with this pit depth?

**Question 5 (Challenge Question)**

* A family of 6 wants to build a dry pit latrine
* They want to dig a circular pit of 1.5 metres diameter and 1.5 metres depth
* They use paper for anal cleansing

How long will their pit last?

**Question 6 (Challenge Question)**

* A family of 10 wants to build two circular pits for their pour flush offset latrine
* They want each pit to have a diameter of 1 metre
* They will manually empty each pit after 2 years
* They use paper for anal cleansing

How deep should each pit be? Are there any challenges with this pit depth?

**Question 7 (Challenge Question)**

* A family of 5 wants to build a pour flush latrine
* They want to build a rectangular pit with a length of 1.5 metres and width of 1 metre
* They want to use the latrine for 5 years
* They use with water for anal cleansing

How deep should their pit be?

**Question 8 (Challenge Question)**

* A family of 6 wants to build a pour flush latrine
* They want to build a rectangular with a length of 1.5 metres and width of 1 metre
* They want to use the latrine for 7 years
* They use with water for anal cleansing

How deep should their pit be?

**Question 9 (Challenge Question)**

* A family of 11 wants to build a dry pit latrine
* They want to build a rectangular with a length and width of 1 metres
* They want to use the latrine for 5 years
* They use with water for anal cleansing

How deep should their pit be?

**Question 10 (Challenge Question)**

* A family of 15 wants to build a pour flush latrine. 5 family members go to work every day.
* They want to build a circular pit with a diameter of 1.5 metres
* They want to use the latrine for 5 years
* They use with water for anal cleansing

How deep should their pit be?

**Solutions to Practice Questions:**

1. Using Table 1, sludge accumulation rate = “B” ; Using Table 2, D = 1.2 metres
2. Using Table 1, sludge accumulation rate = “B”, Using Table 3, D = 2.8 metres

Discussion points:

* Emptying sludge from pits deeper than 1.5 metres is impossible using manual methods, unless the emptier climbs inside the pit, which is a serious health and safety risk. The household should contact the local pit emptying service.

1. Using Table 1, sludge accumulation rate = “A”, Using Table 4, D = 3.2 metres

Discussion Points:

* Check that the bottom of the pit is at least 2 metres above the groundwater level.
* Vacuum tankers can usually only suck down to a depth of 2 to 3 metres depending on the strength of the pump. The household should contact the local pit emptying service to ensure that a vacuum tanker will work in this situation or they should resize the pit to be shallower.

1. Using Table 1, sludge accumulation rate = “B”, Using Table 7, D = 4.3 metres
2. Using Table 1, sludge accumulation rate = “B”, Using Table 3, Y = 5 years
3. Using Table 1, sludge accumulation rate = “A”, Using Table 5, D = 2 metres
4. Using Table 1 sludge accumulation rate = “A”

Step 1: Family of 4, Table 3, D=1.0  
 Step 2: Family of 6, Table 4, D=1.3  
 Step 3: Family of 5, Halfway between answers of Step 1 and Step 2, D=1.15 or round up to 1.2 metres

1. Using Table 1, sludge accumulation rate = “A”

Step 1: 5 Years, Using Table 3, R = 40, D = 1.3 metres

Step 2: 10 Years, Using Table 3, R = 40, D = 2.1 metres

Step 3: 7 Years, about halfway between answers of Step 1 and Step 2, D = 1.7 metres

1. Using Table 1, sludge accumulation rate = “B”

Step 1: Family 10, Using Table 5, D = 5 metres

Step 2: Family 12, Using Table 6, D = 5.9 metres

Step 3: Family 11, about halfway between answers of Step 1 and Step 2, D = 5.5 metres

1. Using Table 1, sludge accumulation rate = “A”

Step 1: Family 15, Using Table 7, D = 3.0 metres

Step 2: Family 10, Using Table 5, D = 2.2 metres

Discussion Points:

* The number of users will vary throughout the week. On working days, there will only be 10 users. On non-working days there will be 15 users. It is better to over-estimate and calculate the depth of the pit using 15 users.

# Calculations by Hand

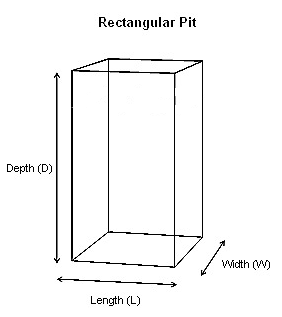
This section will explain the formulas that are used to calculate latrine pit sizes. It will then lead you through example and practice questions for long-term latrine pits (lifetime greater than two years) and short-term latrine pits (lifetime of two years or less).

## Calculating Pit Area and Volume Based on Dimensions

We will start with the pit shapes and the formulas that are needed to figure out the pit area and volume, based on its dimensions.

### Rectangular Pit

Area and volume for a rectangular pit can be calculated from the three pit dimensions:

* **Depth**
* **Length**
* **Width**

A rectangular pit shape is made of 3 sets of rectangles that have different dimensions:

1. **Top and bottom** are the same
2. **Front and back** are the same
3. **Side and side** are the same

***Top and Bottom***

Length (L)

Width (W)

This is the shape that you see when you look at the pit from above.

The length and width of the pit are most likely determined by the size of slab you have or can build.

***Front and Back***

Length (L)

Depth (D)

You create the depth as you dig your pit.

The *front and back* rectangle shares the same length dimension as the *top and bottom* rectangle.

The dimensions of this rectangle are length (L) and depth (D).

Width (W)

Depth (D)

***Side and Side***

The *side and side* rectangle has the same depth (D) as the *front and back* rectangles.

It also has the same width (W) as the *top and bottom* rectangles.

***Area***

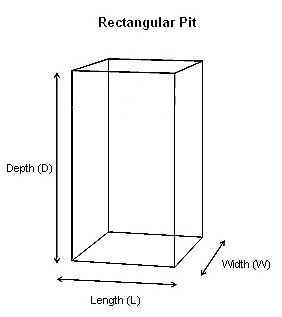
In latrine pit calculations, *area* refers to the area of the *top and bottom* rectangle.

Length (L)

Width (W)



* Length and width are measured in metres (m)
* Area is measured in square metres (m2)

***Volume***

*From the formula above, we know that A = L x W*

****

In pit calculations, the volume formula is often rearranged to solve for depth.



Depth is measured in metres (m)

Area is measured in square metres (m2)

Volume is measured in cubic metres (m3)

### Circular Pit

Area and volume for a circular pit can be calculated from the two pit dimensions: **depth and diameter** (the distance across the middle of the circle).

Depth (D)

Diameter (d)

**Circular Pit**

A circular pit shape is called a cylinder. It is made up of two identical circles that are the top and the bottom, and a rectangle that wraps around them. If you were to unroll a cylinder and lay it flat on the ground it would look like this:

Diameter (d)

Depth (D)

Length (L)

***Area***

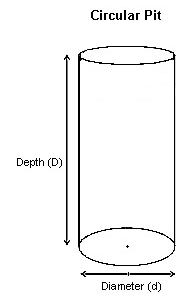


Diameter (d)

* Diameter is measured in metres (m)
* Area is measured in square metres (m2)
* 3.14 is a rounded value for the ratio pi (π)

***Volume***

*From the formula above, we know that* 

****

In pit calculations, the volume formula is often rearranged to solve for depth.



* Depth is measured in metres (m)
* Area is measured in square metres (m2)
* Volume is measured in cubic metres (m3)

## Calculating Pit Volume Based on Usage

The volume of a latrine pit is calculated based on its usage and dimensions. The following formula tells us how much volume the pit needs:

**Space Needed for Soil Cover**

* This part of the formula accounts for the extra volume at the top of the pit needed for the soil cover. Excreta will not fill this space.
* This is the formula for volume, where 0.5 metres is the depth of the cover.

**Amount of Material Entering the Pit**

* This part of the formula tells us how much material (e.g., excreta, anal cleansing material) will be entering the pit.
* The 1000 is a conversion value to change the units from litres (found in the sludge accumulation rate) to cubic metres.







This formula can be rearranged to solve for the number of years that the latrine pit can be used. You may need to use this formula when the pit dimensions are constrained by the depth of the groundwater level. The bottom of your pit must be at least two metres above the groundwater.



## Long-term and Short-term Latrine Pits

The formulas for long-term and short-term latrines are almost identical. The only difference is found in the usage volume formula. The following table explains the changes to the usage volume formula based on the latrine lifetime.

**Table 5: Volume Formulas Based on Latrine Lifetime**

|  |  |  |
| --- | --- | --- |
| **Lifetime** | **Formula** | **Explanation** |
| Long-term latrines |  | This is the basic volume formula for any latrine pit that is meant to fill up in more than 2 years. |
| Short-term latrines |  | This natural process of excreta decomposition and volume reduction is taken into account in the sludge accumulation rates (R) found in Table 1. However, these rates are too low for short-term latrines since there is not enough time for the excreta to decompose and reduce its volume. These rates must be increased by 50% for short-term latrines (Franceys et al., 1992). You can do this by multiplying R by 1.5. |

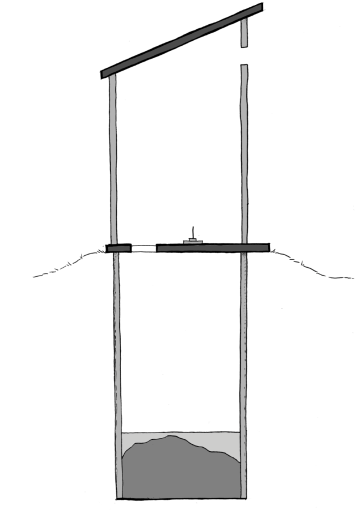
## Summary of Formulas

Use the information in this section as a reference and to help work through the example and practice questions.

**Table 6: Summary of Formulas**

| **What Are You Calculating?** | **Formula to Use** | **Variables to Find** |
| --- | --- | --- |
| **Area: Rectangular** |  | A: Area (m2)  L: Length (m)  W: Width (m) |
| **Area: Circular** |  | A: Area (m2)  d: Diameter (m) |
| **Depth: Rectangular** |  | D: Depth (m)  V: Volume (m3)  A: Area (m2) |
| **Depth: Circular** |  | D: Depth (m)  V: Volume (m3)  A: Area (m2) |
| **Volume: Rectangular** |  | V: Volume (m3)  D: Depth (m)  A: Area (m2) |
| **Volume: Circular** |  | V: Volume (m3)  d: Diameter (m)  D: Depth (m) |
| **Usage Volume: Long-term Latrine** |  | V: Volume (m3)  N: Number of users  Y: Years in use  A: Area of pit base (m2)  R: Sludge accumulation rate (litres/person/year) |
| **Usage Volume: Short-term Latrine** |  | V: Volume (m3)  N: Number of users  Y: Years in use  A: Area of pit base (m2)  R: Sludge accumulation rate (litres/person/year) |
| **Lifetime** |  | V: Volume (m3)  N: Number of users  Y: Years in use (year)  A: Area (m2)  R: Sludge accumulation rate (litres/person/year) |

## Example Questions

The following are examples with the solutions shown, to help you understand how to design latrine pits using formulas.

### Long-term Latrine – Rectangular, Finding Depth

* A family of 4 wants to build a rectangular pit for their dry pit latrine
* They want the pit to have a length of 1.2 metres and a width of 1.0 metre
* They want to be able to use it for 6 years
* They use grass and leaves for anal cleansing

How deep should their latrine be?

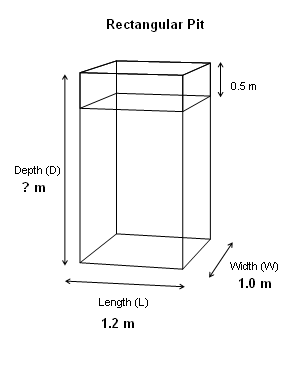
(Credit: Lifewater International, 2009)

**Step 1: Known Information – Write down the variables and their values. Identify the variable that you need to solve.**

*We are using a sludge accumulation rate of 60 litres/person/year because it is mostly dry inside the pit and degradable anal cleansing materials are used (e.g., leaves and grass).*

****

**Step 2: Draw and Label Your Diagram – Draw a diagram of the pit and label all of the dimensions.**



*We are trying to find the depth (D) of the pit.*

**Step 3: Formulas – Write down the formula for the variable you are trying to solve. Check if you have the value for each variable in the formula. If the values are not given, then find another formula to give you the missing value of the variable you want. Be sure that you are using the formula for the right shape and latrine type.**

* *The first formula gives the depth, but we don’t know the value of A (area) or V (volume).*
* *The second formula gives the value for V (volume), but we do not know the value for A (area).*
* *The third formula gives the value of A (area) based on length and width, for which we have values.*

**Step 4: Fill in the formula for which you know the value of all the variables.**

*We are finding the value for A (area) first because we know the values for both L (length) and W (width).*





**Step 5: Fill in the formula for which you know the value of all the variables.**

*From the previous formula we now know the value of A. We can now solve for V.*



* *Fill in all the values for the variables.*
* *Do all the multiplication first.*
* *Divide 1440 by 1000.*
* *Add 1.4 and 0.6.*

**Step 6: Fill in the formula for which you know the value of all the variables.**



*Solve for D (depth) using the values for A and V that were found in the two previous steps.*

**Step 7: Write out the answer.**

The depth must be 1.7 metres for the pit to last 6 years.

### Long-term Latrine – Circular, Finding Depth

* A family of 4 wants to build a circular pit for their dry VIP latrine
* They want the pit to have a diameter of 1.2 metres
* They want to be able to use it for 6 years
* They use grass and leaves for anal cleansing

How deep should their latrine be?

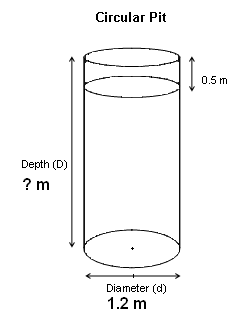
(Credit: Lifewater International, 2009)

**Step 1: Known Information – Write down the variables and their values. Identify the variable that you need to solve.**

*We are using a sludge accumulation rate of 60 litres/person/year because it is mostly dry inside the pit and degradable anal cleaning materials are being used (e.g., leaves and grass).*

****

**Step 2: Draw and Label Your Diagram – Draw a diagram of the pit and label all of the dimensions.**



*We are trying to find the depth (D) of the pit.*

**Step 3: Formulas – Write down the formula for the variable you are trying to solve. Check if you have the value for each variable in the formula. If the values are not given, then find another formula to give you the missing value of the variable you want. Be sure that you are using the formula for the right shape and latrine type.**

* *The first formula gives the depth, but we don’t know the value of A (area) or V (volume).*
* *The second formula gives the value for V (volume), but we do not know the value for A (area).*
* *The third formula gives the value of A (area) based d (diameter), which we know.*

**Step 4: Fill in the formula for which you know the value of all the variables.**

*We are finding the value for A (area) first because we know the value for d (diameter).*



**Step 5: Fill in the formula for which you know the value of all the variables.**

* *From the previous formula we now know the value of A. We can now solve for V.*
* *Fill in all the values for the variables.*
* *Do all the multiplication first.*
* *Divide 1440 by 1000.*
* *Add 1.4 and 0.6.*



**Step 6: Fill in the formula for which you know the value of all the variables.**



*Solve for D (depth) using the values for A and V that were found in the two previous steps.*

**Step 7: Write out the answer.**

The depth must be 1.8 metres for the pit to last 6 years.

### Long-term Latrine – Circular, Finding Lifetime

* A family of 8 wants to build a pour flush latrine
* They want to build a circular pit with a diameter of 1.3 metres
* The groundwater level is 3.1 metres deep
* They use paper for anal cleansing

What is the deepest they can dig their pit? How long will their pit last?

(Credit: Lifewater International, 2009)

**Step 1: Known Information – Write down the variables and their values. Identify the variable that you need to solve.**

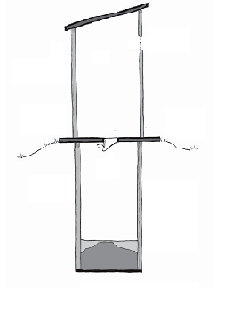
*We need to find the values for lifetime and depth!*

****

*We are using a sludge accumulation rate of 40 litres/person/year because it is wet inside the pit and a degradable material is used for anal cleansing.*

**Step 2: Draw and Label Your Diagram – Draw and label a diagram of the latrine with respect to the groundwater level.**

* *We need to find out how far down we can dig the pit.*
* *We know the bottom of the pit has to be a minimum of 2 metres above the groundwater level.*



Ground water

3.1m

2 m

? m

**Step 3: Formulas – Write down the formula for the variable you are trying to solve.**

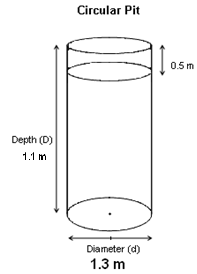
*The full distance to the groundwater level (3.1 metres) minus the 2 metres distance needed between the pit and groundwater level gives the depth that the pit can be dug, which is 1.1 metres.*

****

****

The pit can be 1.1 metres deep.

**Step 4: Draw and Label Your Diagram – Draw a diagram of the pit and label all of the dimensions.**

****

We know all of the dimensions of the pit.

**Step 5: Formulas – Write down the formula for the variable you are trying to solve. Check if you have the value for each variable in the formula. If the values are not given, then find another formula to give you the missing value of the variable you want. Be sure that you are using the formula for the right shape and latrine type.**

** **

* *The first formula calculates the lifetime of the pit (Y), but we don’t know V (volume) or A (area).*
* *The second formula gives the value for V (volume), but we do not know the value for A (area).*
* *The third formula gives the value of A (area) based on d (diameter) of the pit, which we know.*

**Note:** This is the same formula as



but it has been rearranged to solve for Y.

** **

** **

**Step 6: Fill in the formula for which you know the value of all the variables.**

*We are finding the value for A (area) first because we know the value of d (diameter).*



**Step 7: Fill in the formula for which you know the value of all the variables.**

* *From the previous formula we now know the value of A. We also know the value of D from Step 3.*
* *Multiply the area by the depth to find the volume of the pit.*



**Step 8: Fill in the formula for which you know the value of all the variables.**

****

*This formula has been rearranged to isolate Y.*

* *Fill in the values for all the variables.*
* *Do multiplication inside the brackets first.*
* *Subtract the values in the brackets ie.1.4 minus 0.7.*
* *Multiply the values on top and multiply the values on the bottom.*
* *Divide the top value by the bottom value.*

**Step 9: Write out the answer.**

The deepest the pit can be is 1.1 metres below the ground. The pit will last 2.2 years at this depth.

### Short-term Latrine – Circular Twin Pit, Finding Depth

* A family of 6 wants to build circular twin pits for their pour flush offset latrine
* They want each pit to have a diameter of 1 metre
* They use water for anal cleansing
* They will manually empty each pit after 2 years

How deep should each pit be?

(Credit: Lifewater International, 2009)

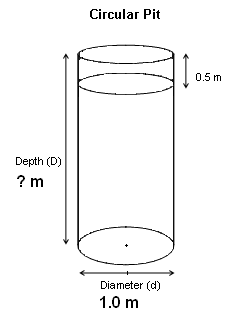
**Step 1: Known Information – Write down the variables and their values. Identify the variable that you need to solve.**

*We are using a sludge accumulation rate of 40 litres/person/year because it is wet inside the pit and water is being used for anal cleansing.*



**Step 2: Draw and Label Your Diagram – Draw a diagram of the pit and label all of the dimensions.**

*We are trying to find the depth (D) of the pit.*



**Step 3: Formulas – Write down the formula for the variable you are trying to solve. Check if you have the value for each variable in the formula. If the values are not given, then find another formula to give you the missing value of the variable you want. Be sure that you are using the formula for the right shape and latrine type.**

* *The first formula gives the depth, but we don’t know the value of A (area) or V (volume).*
* *The second formula gives the value for V (volume), but we do not know the value for A (area).*
* *The third formula gives the value of A (area) based d (diameter), which we know.*

**Note:** A factor of 1.5 is included to increase the sludge

accumulation rate due to the short lifetime

of the pit. There is not enough time for the

volume of sludge to decrease from biological

processes, which is taken into account in the

given sludge accumulation rate.

**Step 4: Fill in the formula for which you know the value of all the variables.**

*We are finding the value for A (area) first because we know the value for d (diameter).*





**Step 5: Fill in the formula for which you know the value of all the variables.**

* *From the previous formula we now know the value of A. We can now solve for V.*
* *Fill in all the values for the variables.*
* *Do all the multiplication first.*
* *Divide 720 by 1000.*
* *Add 0.7 and 0.4*



**Step 6: Fill in the formula for which you know the value of all the variables.**



*Solve for D (depth) using the values for A and V that were found in the two previous steps.*

**Step 7: Write out the answer.**

The pits must be 1.4 metres deep for each of them to last 2 years.

It is important to note that manually emptying sludge from pits deeper than 1.5 metres is impossible, unless the emptier climbs inside the pit, which is a serious health and safety risk. Although 1.4 metres is smaller than 1.5 metres, the difficulty of emptying at that depth remains high. The household should contact the local pit emptying service to ensure that their pit can be emptied either manually or with a vacuum tanker.

## 4.5.5 Long-term Latrine – Rectangular, Finding Depth

* A household of 6 wants to build a dry VIP latrine
* They want to build a rectangular pit with a length of 1.5 metres and width of 1.2 metres
* The want to use the latrine for 10 years
* They use rocks for anal cleaning

How deep should their latrine be?

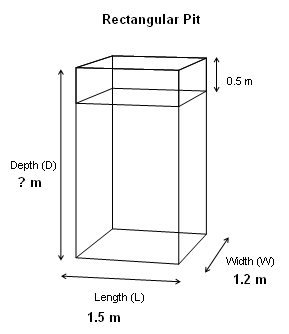
(Credit: Lifewater International, 2009)

**Step 1: Known Information – Write down the variables and their values. Identify the variable that you need to solve.**

****

*We are using a sludge accumulation rate of 90 litres/person/year because it is mostly dry inside the pit and a nondegradable anal cleansing material is being used (rocks).*

**Step 2: Draw and Label Your Diagram – Draw a diagram of the pit and label all of the dimensions.**

****

*We are trying to find the depth (D) of the pit.*

**Step 3: Formulas – Write down the formula for the variable you are trying to solve. Check if you have the value for each variable in the formula. If the values are not given, then find another formula to give you the missing value of the variable you want. Be sure that you are using the formula for the right shape and latrine type.**

* *The first formula calculates the depth, but we don’t know the value of A (area) or V (volume).*
* *The second formula gives the value for V (volume), but we do not know the value for A (area) in this formula.*
* *The third formula gives the value of A (area) based on length and width, for which we have values.*

**Step 4: Fill in the formula for which you know the value of all the variables.**

*We are finding the value for A (area) first because we know the values for both L (length) and W (width).*





**Step 5: Fill in the formula for which you know the value of all the variables.**

* *From the previous formula we now know the value of A. We can now solve for V.*
* *Fill in all the values for the variables.*
* *Do all the multiplication first.*
* *Divide 5400 by 1000.*
* *Add 5.4 and 0.9.*



**Step 6: Fill in the formula for which you know the value of all the variables.**



*Solve for D (depth) using the values for A and V that were found in the two previous steps.*

**Step 7: Write out the answer.**

The pit must be 3.5 metres deep for it to last 10 years.

### 4.5.6 Long-term Latrine – Square, Finding Lifetime

* A household of 5 wants to build a pour flush latrine
* They want to build a square pit with a length of 1.1 metres and width of 1.1 metres
* The groundwater level is 4.2 metres deep and is used for drinking
* They use water for anal cleansing

How long will their pit last?

(Credit: Lifewater International, 2009)

**Step 1: Known Information – Write down the variables and their values. Identify the variable that you need to solve.**

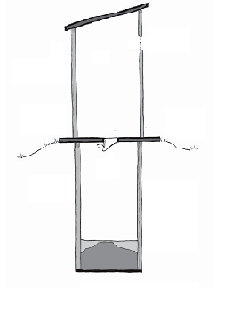
*We need to find the values for lifetime and depth!!!*

****

*We are using a sludge accumulation rate of 40 litres/person/year because it is wet inside the pit and water is used for anal cleansing.*

**Step 2: Draw and Label Your Diagram – Draw and label a diagram of the latrine with respect to the groundwater level.**

* *We need to find out how far down we can dig the pit.*
* *We know the bottom of the pit has to be a minimum of 2 metres above the groundwater level.*



Ground water

4.2 m

2 m

? m

**Step 3: Formulas – Write down the formula for the variable you are trying to solve.**

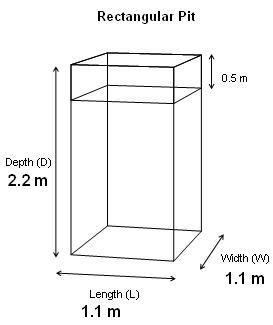
*The full distance to the water table (4.2 metres) minus the 2 metres distance needed between the pit and groundwater table gives the depth that the pit can be dug, which is 2.2 metres.*

****

****

The pit can be 2.2 metres deep.

**Step 4: Draw and Label your Diagram – Draw a diagram of the pit and label all of the dimensions.**

****

We know all of the dimensions of the pit.

**Step 5: Formulas – Write down the formula for the variable you are trying to solve. Check if you have the value for each variable in the formula. If the values are not given, then find another formula to give you the missing value of the variable you want. Be sure that you are using the formula for the right shape and latrine type**

** **

* *The first formula calculates the lifetime of the pit (Y), but we don’t know V (volume) or A (area).*
* *The second formula gives the value for V (volume), but we do not know the value for A (area).*
* *The third formula gives the value of A (area) based on d (diameter) of the pit, which we know.*

**Note:** This is the same formula as



but has been rearranged to solve for Y.

** **

** **

**Step 6: Fill in the formula for which you know the value of all the variables.**

*We are finding the value for A (area) first because we know the values of L (length) and W (width).*



**Step 7: Fill in the formula for which you know the value of all the variables.**



* *From the previous formula we now know the value of A. We also know the value of D from Step 3.*
* *Multiply the area by the depth to find the volume of the pit.*

**Step 8: Fill in the formula for which you know the value of all the variables.**

****

* *Fill in the values for all the variables.*
* *Do multiplication inside the brackets first.*
* *Subtract the values in the brackets (2.6 - 0.6).*
* *Multiply the values on top and multiply the values on the bottom.*
* *Divide the top value by the bottom value.*

*This formula has been rearranged to isolate Y.*

**Step 9: Write out the answer.**

The deepest the pit can be is 2.2 metres below the ground. The pit will last 10 years at a depth of 2.2 metres.

**4.5.7 Short-term Latrine – Circular Twin Pit, Finding Depth**

* A family of 8 wants to build a dry twin pit latrine
* They want each circular pit to have a diameter of 1.4 metres
* They use water for anal cleansing
* They want to manually empty each pit

How deep should each pit be?

**Step 1: Known Information – Write down the variables and their values. Identify the variable that you need to solve.**

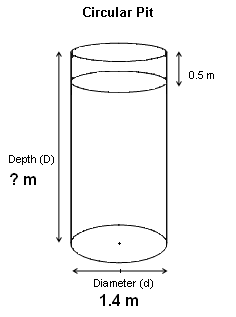
*We know excreta will be safer to empty after 2 years of storage.*



*We are using a sludge accumulation rate of 40 litres/person/year because it is wet inside the pit due to anal cleansing with water and the rest of the pit contents are degradable.*

**Step 2: Draw and Label Your Diagram – Draw a diagram of the pit and label all of the dimensions.**

*We are trying to find the depth (D) of the pit.*



**Step 3: Formulas – Write down the formula for the variable you are trying to solve. Check if you have the value for each variable in the formula. If the values are not given, then find another formula to give you the missing value of the variable you want. Be sure that you are using the formula for the right shape and latrine type.**

* *The first formula gives the depth, but we don’t know the value of A (area) or V (volume).*
* *The second formula gives the value for V (volume), but we do not know the value for A (area).*
* *The third formula gives the value of A (area) based on d (diameter), which we know.*

**Note:** A factor of 1.5 is included to increase the sludge

accumulation rate due to the short lifetime

of the pit. There is not enough time for the

volume of sludge to decrease from biological

processes, which is taken into account in the

given sludge accumulation rate.

**Step 4: Fill in the formula for which you know the value of all the variables.**

*We are finding the value for A (area) first because we know the value for d (diameter).*





**Step 5: Fill in the formula for which you know the value of all the variables.**

* *From the previous formula we now know the value of A. We can now solve for V.*
* *Fill in all the values for the variables.*
* *Do all the multiplication first.*
* *Divide 960 by 1000.*
* *Add 1 and 0.8*
* *Add 1.44 and 0.75*



**Step 6: Fill in the formula for which you know the value of all the variables.**



*Solve for D (depth) using the values for A and V that were found in the two previous steps.*

**Step 7: Write out the answer.**

Each pit must be 1.2 metres deep.

# Additional Resources

**CAWST Sanitation Resources.** Available at: [www.cawst.org/resources](http://www.cawst.org/resources)

* CAWST’s education and training resources are available on a variety of sanitation topics including latrine design, siting and construction; latrine parts and technologies; latrine emptying and transporting sludge; sludge treatment, use and disposal; and latrine project implementation.

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CAWST (Centre for Affordable Water and Sanitation Technology)

Calgary, Alberta, Canada

Website: [www.cawst.org](file:///C:\Users\Schuelert\Desktop\Laura\CAWST\Workshops%20in%20Progress\Latrine%20Design%20and%20Construction\Participant%20Materials\Technical%20Briefs\www.cawst.org) Email: [resources@cawst.org](file:///C:\Users\Schuelert\Desktop\Laura\CAWST\Workshops%20in%20Progress\Latrine%20Design%20and%20Construction\Participant%20Materials\Technical%20Briefs\resources@cawst.org)

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