DEPARTMENT OF WATER AFFAIRS & FORESTRY

CODE OF PRACTICE: VOLUME 1

SEPTIC TANK SYSTEMS

GENERAL GUIDELINES

(July 2008)

CONTENTS

TERMS FREQUENTLY USED

General

Anaerobic: Condition/environment lacking oxygen where only anaerobic microorganisms can grow – no O_2, NO_2^- or NO_3^- is present and the organisms generate their own electron acceptor internally.

Septic Tank: A tank that receives and retains sewage for a period long enough to ensure adequate decomposition.

French drain: A trench filled with suitable material to allow disposal of final effluent from a septic tank or wastewater into the ground.

Drain: Sump with an outlet (e.g. a pipe, channel) that transports sewage from a building to a connecting sewer or disposal site.

DWAF: Department of Water Affairs and Forestry.

Stormwater: Water resulting from natural precipitation or accumulation and includes rainwater, surface water, sub-soil water or spring water.

Water-clogged area: Area that is saturated with water and the water table is shallow, at a depth of 1m or less from the surface.

Seepage pit: A covered pit with open-jointed lining. Septic tank effluent can seep or leach into the surrounding, porous soil.

Effective size: Used to characterise filter sand, with 10% (wt) of grains smaller and 90% (wt) of grains larger than the specified size.

Uniformity coefficient: Also used to characterise filter sand. Ratio of sieve size through which 60% of the sample is passing to 10% of the sample passing.

Manhole: A chamber that allows a person to enter for cleaning purposes or inspection of the sewer lines and/or tanks.

Chemical

BOD: Biodegradable Oxygen Demand - measurement of oxygen utilized by microorganisms during oxidation of organic material contained in wastewater.

BOD_5: Oxygen utilized within 5 days (BOD_5) of microbial activity. This duration was selected to minimize the effect of nitrification.

COD: Chemical Oxygen Demand – measurement of the amount of oxidisable organic matter, *viz* the amount of oxygen required to convert all organic carbon constituents to CO_2 and H_2O.

Flow

ADWF: Average Dry Weather Flow = average total quantity of sewage received per day divided by 24 hours.

AWWF: Average Wet Weather Flow = average flow during the rainy season, which includes rain- and groundwater infiltration into the sewer. Generally assumed (if not specifically measured) as three times ADWF.

PDWF: Peak Dry Weather Flow = maximum flow during peak hours. Generally assumed (if not specifically measured) as twice the ADWF.

1. INTRODUCTION

The construction and use of a septic tank system is subject to a wastewater discharge permit from the Department of Water Affairs and Forestry (DWAF). Only single-households and farms that are not operated as commercial/business entities are exempted from such a permit.

The septic tank provides for partial treatment of sewage only and does not produce a final effluent complying with the currently applicable Namibian standards for effluent discharge, *viz* the General Standards of the Water Resources Management Act, 2004 (Act No. 24 of 2004).

Where a farm becomes a lodge or hunting farm that caters for hunters and/or tourists it becomes a commercial entity. Therefore, such farms need to apply for a wastewater discharge permit and, where a septic tank is employed, need to put in an advanced treatment system (additional to the septic tank) to produce a final effluent conforming to the General Standards of the Water Resources Management Act, 2004 (Act No. 24 of 2004). This applies also to communal farms where latter house a community of more than 100 people within its boundaries. Advanced treatment systems typically consist of pond systems, biofilters or activated sludge plants.

In the Water Resources Management Act, 2004 (Act No. 24 of 2004), there are conditions to facilitate the proper operation of different sewage treatment systems and their methods of disposal. It indicates ways on how to properly use and protect one of our most valuable natural resources, namely water, and to encourage reuse of the treated effluent.

From a health point of view, there is practically no difference between septic tank effluent and raw sewage and septic tank effluent should therefore be regarded as a great potential danger to public health.

All septic tank facilities must be constructed in accordance with these guidelines. [Further information and recommendations can be obtained from the South African Bureau of Standards (SABS/SANS, 1989)]. Local authorities may have additional specifications regarding the proper use, design, operation and maintenance of septic tanks and these must be adhered to at all times.

A septic tank system consists of two major components:

- The septic tank itself. Such a tank must consist of at least two chambers. Where the tank is used to only accumulate sewage and is then emptied from time-to-time by tanker, it is called a conservancy or containment tank.
- The final effluent disposal system. Latter is a subsoil percolation system, typically a French drain, trenches or subsoil filters.

Design information contained in this manual can also be used to provide a septic tank as first treatment step in more advanced treatment systems for lodges, hotels, schools and larger communities. Please note, these guidelines only apply to septic tanks and subsoil percolation systems where no advanced treatment is employed additionally. Where a septic tank forms part of an advanced treatment system, the design parameters thereof may be altered to suit the overall treatment system of the supplier.

Final effluent of a septic tank that has also passed through a percolation system and has been disinfected is suitable for limited reused, e.g. gardening, lawns and certain agricultural produce. Since water is a scarce commodity in Namibia, reuse thereof is strongly encouraged. A reuse permit obtainable from DWAF is required for this purpose.

This manual addresses treatment of wastewater by means of a septic tank system. It includes design information and strives to present information that may be helpful to those performing compliance inspections, sampling and writing or assessing technical reports on which permit conditions are based.

2. DEFINITION AND BACKGROUND INFORMATION

2.1 DEFINITION

A septic tank is a tank that collects and contains sewage only for a specific period. The sewage in the tank is decomposed under anaerobic (lacks oxygen) conditions before being discharged, disposed or subjected to further treatment.

2.2 DOMESTIC SEWAGE CHARACTERISATION

Domestic sewage is a diluted suspension of human discharge into water. The polluting material is mainly of an organic nature (organic carbon) and ammonia nitrogen (main constituent of urine). Organic material consists of a soluble and insoluble portion, each again with a biologically degradable and undegradable fraction. The loading for which a treatment system is laid out (sized) is made up of the volume of sewage/polluted water that will flow into the system and the strength thereof. These two aspects will now be further elucidated.

2.2.1 FLOWRATES

The amount of sewage generated is classified in terms of different flows that can reach a treatment plant and is expressed as:

- AVERAGE DRY WEATHER FLOW (ADWF). The average dry weather flow is the average total quantity of sewage received per day divided by 24 hours and must be averaged over 12 months. For example, average sewage received over the last year was 10 m³ a day:

  ADWF = 10 000 ℓ/d ÷ 24 h = 417 ℓ/h; Design for ADWF = 420 ℓ/h

- PEAK DRY WEATHER FLOW (PDWF). Peak dry weather flows are maximum discharge figures into a plant (or septic tank) during a specific day when it is not raining. It is usually assumed that this figure is double the ADWF. From above example:

  PDWF = 840 ℓ/h

- AVERAGE WET WEATHER FLOW (AWWF). The wet weather flows are maximum flow rates recorded during the rainy season and include infiltrated (rain) water into the sewer. It is usually estimated to be three times the average dry weather flow. From above example:

  AWWF = 1 260 ℓ/h

2.2.2 STRENGTH

The strength of sewage is indirectly obtained by determining chemically the amount of oxygen required to fully oxidize organic and inorganic matter and this is called the chemical oxygen demand (COD). Alternatively, the oxygen required by microorganisms to oxidise organic matter can be determined and this is termed the biodegradable oxygen demand (BOD).

- Chemical Oxygen Demand (COD). The COD test measures the amount of oxygen required to chemically oxidise organic compounds in the wastewater to carbon dioxide and water.
- Five-day Biochemical Oxygen Demand (BOD_5). The BOD test measures the quantity of biologically degradable organic matter in a wastewater in terms of the amount of

oxygen required by microorganisms to oxidise it to carbon dioxide and water. The test is usually conducted over a period of five days and therefore called BOD_5.

In domestic sewages there is a fairly constant COD/BOD_5 ratio of about 2:1. As a general, rough approximation, it may be assumed that the organic load discharged by humans is approximately 100 g COD per person per day.

A wastewater expert should be consulted to determine the make-up, volume and strength of sewage for each particular set-up. COD and BOD tests are complex and should be undertaken by an approved and recognised (in the wastewater treatment field) analytical laboratory only.

2.3 DAILY VOLUME

Septic tank designs for domestic wastewater are based on the volume of sewage generated by a specific establishment per day.

Where a new septic tank is planned or existing discharge figures are not easily measurable, an estimate of the sewage volume and strength that will be generated by a certain establishment can be made. However, every effort should be made to obtain actual discharge figures if possible. The following should serve as an indication only to establish discharge volumes for typical establishments.

Sewage generated in Southern Africa is generally between 60 to 90 litres per person per day for the lower income group, and 130 to 180 litres per person per day for the middle to higher income groups. Large variations in these figures are encountered.

The design of a household septic tank system should not be based on the number of occupants at any particular time because their number may vary. It is suggested that the number of bedrooms should rather be taken as an indication of the flow that may be expected. Table 1 gives such an indication.

Table 1: Sewage flows from various house sizes (CSIR Report 1964)

Number of bedrooms	Sewage flow ℓ/d
2	680
3	900
4	1140
5	1360

For establishments other than households, the sewage flow should preferably be measured, or it may be estimated from readings off the water meter. When flow data are not available, the flows given in Table 2 may be taken as estimates of the expected quantities.

Table 2: Estimates of sewage flows from various establishments (Drews, 1985)

Type of establishment	**Litres per person per day**
Boarding houses	110
(Additional kitchen wastes for non-resident boarders)	25
Hotels without private baths	110
Hotels with private baths	140
Restaurants (toilet & kitchen wastes per patron)	15-25
Tourist camps or caravan parks with central bathhouse	90
Day schools (no shower cubicles, no swimming bath)	37
Day workers at offices/shift	90
Hospitals	340-550
Factories (litres per person per shift, exclusive of industrial wastes)	140
Swimming baths	100
Motels (per bed space)	100
Drive-in theatres (per car space)	9
Airports (per passengers)	9
Service stations (per vehicle served)	9

The next section will explain important parameters and give design figures for building proper septic tank systems.

3. DESIGN

3.1 LOCATION - GENERAL CONSIDERATIONS

Septic tanks rely on anaerobic digestion and release odours that may cause a nuisance, but latter is usually limited to an acceptable level. Septic tanks systems should therefore not be located too close to an establishment or site where they can cause contamination of any well, spring or other water resource. They should be located on firm, stabilised soil. In particular, septic tanks should:

- Not be closer than 2 m and 5 m from buildings and boundaries respectively. In areas where municipal by-laws apply, these must be taken into full consideration.
- Be located near a driveway to facilitate sludge removal by vacuum tanker and provision be made to connect the house sewer to a reticulation system at a later stage.
- Be located downhill from wells or springs.
- Never be closer than 500 to 800 m from any water resource or water supply - larger distances are preferred where possible. If closer, a proper environmental impact assessment (EIA) study to motivate this must be produced by a reputable consultant in this field.
- Not be considered for swampy areas, nor in areas subjected to flooding.
- Be located where there is a large area available with good soil penetration that can serve as disposal field.

In rocky areas, where no subsurface means of dispose of the final effluent is possible, secondary treatment must be provided downstream of the septic tank(s).

3.2 TANK DESIGN AND CONSTRUCTION

In the design and construction of a septic tank system, the following basic design parameters must be adhered to, as a minimum:

- Tank size must allow for a minimum retention time of 72 hours;
- Septic tanks must have at least two true chambers. Whereas three or more chambers will also work well, there is little (process) advantage in providing more than two chambers;
- The ratio between the two chambers (if only two are supplied) must be 2/3 for the first and 1/3 for the second chamber;
- Every septic tanks must have an impenetrable floor;
- Liquid depth is typically 1 to 3 m - the shape of the tank is insignificant. A length to width ratio of 3:1 to 4:1 is most economical;
- A bar screen must be provided at the inlet to catch rags, plastic bags and other large objects that should not enter a septic tank;
- Proper inlets and outlets must be provided (see Sections 3.2.1 & 3.2.2 below);
- Walls should be well built using impenetrable, artificial materials. Latter includes reinforced concrete or cavity walls filled with reinforced concrete, medium density polyetileen (PE) tanks and should be watertight;
- Septic tanks must be covered (not necessarily with concrete) to prevent animals and people falling into them but must be easily accessible for cleaning (emptying the sludge) purposes;

- After construction the tank should be tested for water tightness by filling it with potable water and leaving it overnight. If leaking, the walls must be properly plastered (10 mm thick) or lined to make them water tight;
- Proper access must be provided. If a concrete roof is provided, a manhole to each compartment of the tank must be provided to inspect and clean each compartment individually;
- Where a septic tank is used to collect wastewater containing fat, oil or grease, e.g. from a restaurant, fast-food outlet or kitchen, proper grease traps at the point where the fat/oil/grease is generated, must be provided. Proper maintenance of the grease traps must be provided and they are not allowed to spill over into the septic tank. It is advisable to rather provide a fat trap at the source, e.g. at the restaurant;
- Proper inlet and outlet devices with vents for gases to escape must be provided for the septic tank.

A typical design for a 3 m³ septic tank that would be adequate for a single family (e.g. farmhouse) is shown in Figure 1 below:

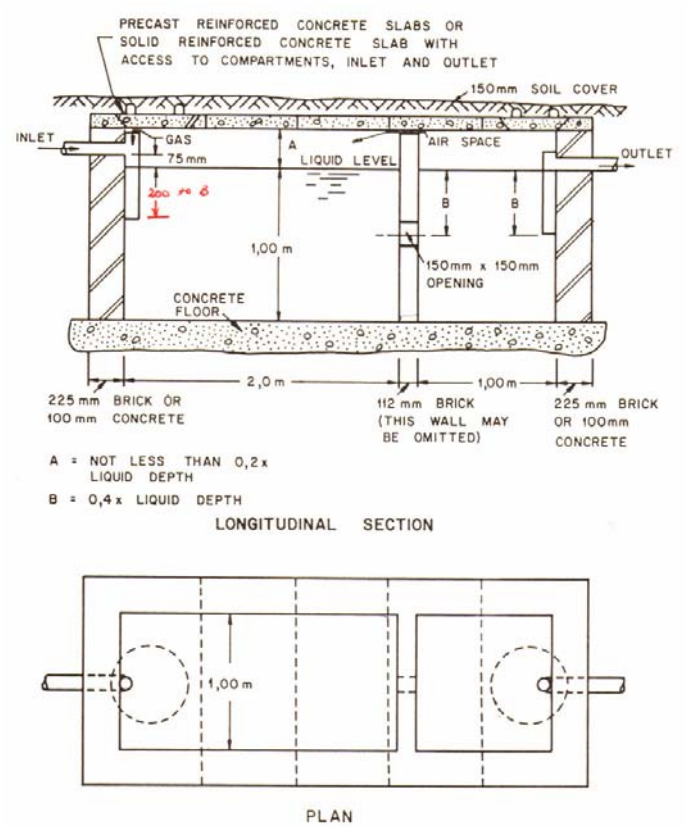

Figure 1 Typical septic tank with 3 m³ capacity (CSIR Technical Guide, K86, 1985)

The design of the in- and outlet devices and importance of grease traps will now be further discussed.

3.2.1 INLET DEVICE

The inlet should enter the tank at least 50 mm above the liquid level in the tank, to allow for peak discharges with momentary rises in liquid levels in the tank. The vertical leg of the inlet pipe, if a T-junction pipe is used, should discharge 200 to 300 mm below the surface to prevent blockage by the scum layer. Exit openings or pipes from the first chamber to the second (and subsequent chambers), should be 500 to 600 mm from the floor to ensure capacity is provided for sludge storage at the bottom of the tank. See also Figure 2 for typical arrangements of an inlet device.

3.2.2 OUTLET DEVICE

It is important that the outlet device penetrates far enough below the liquid level in the last chamber of the septic tank to provide a balance between sludge and scum accumulation. Taking into account the inlet device being 80 mm above the liquid level in the tank, vertical penetration of the outlet pipe should descend to 120 to 220 mm below liquid level.

Gases are given off during decomposition in a septic tank, and suitable vents must be provided for these. Normal plumbing regulations require such vents at the head of the sewer line. The gases will usually be flammable, and can cause explosive mixtures in the presence air. Therefore it is important for the outlet be extended above the liquid line to approximately 25 mm from the top of the tank. The space between the top of the tank and the baffle allows gas to pass through the tank and must be vented off. See also Figure 2 for typical arrangements of an outlet device.

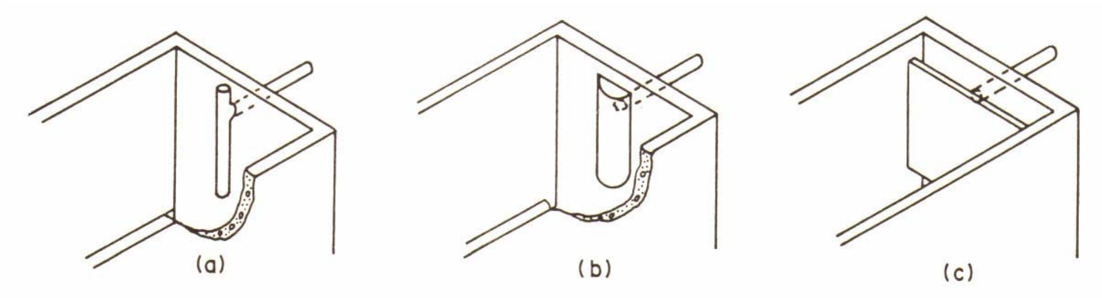

Figure 2 Typical in- and outlet arrangements (CSIR Technical Guide, K86, 1985)

3.2.3 GREASE TRAPS

Grease traps are very important to protect the microbial population inside the septic tank and to ensure the soil retains its ability to absorb final effluent. The aim is to remove as much grease and fat as possible, before it enters the sewer and is discharged into the septic tank. Whereas a single household does not require a grease trap, it must be ensured that no excess oil is discharged into the sewer system (e.g. when cars are serviced).

Restaurants, commercial kitchens (including lodges), fast-food outlets, service stations and other establishments that discharge oil into the sewer, must be provided with a proper grease trap. This trap must also be properly maintained! In order to achieve proper functioning of the grease trap, frequent cleaning is very important. It should be inspected and cleaned once a week, and should be located as close as possible to the point of discharge, e.g. just outside the kitchen.

Its construction and design should provide for quiescent conditions, to allow the fat in suspension to rise and collect at the surface. Small grease traps are prefabricated from salt-glazed earthenware and plastic tanks, but larger ones should be built from concrete, plastered masonry, or steel. The fatty material and solid matter removed from the grease traps of smaller kitchens (eg. lodges) can be disposed of by mixing into a compost heap, buried in a suitable place in garden soil or disposed of on an official disposal site. Oil from service stations should be collected in a drum and returned to the oil company from which the replacement oil is bought (oil companies are under obligation to take back all old oil). See also Figure 3 for typical arrangements of grease traps.

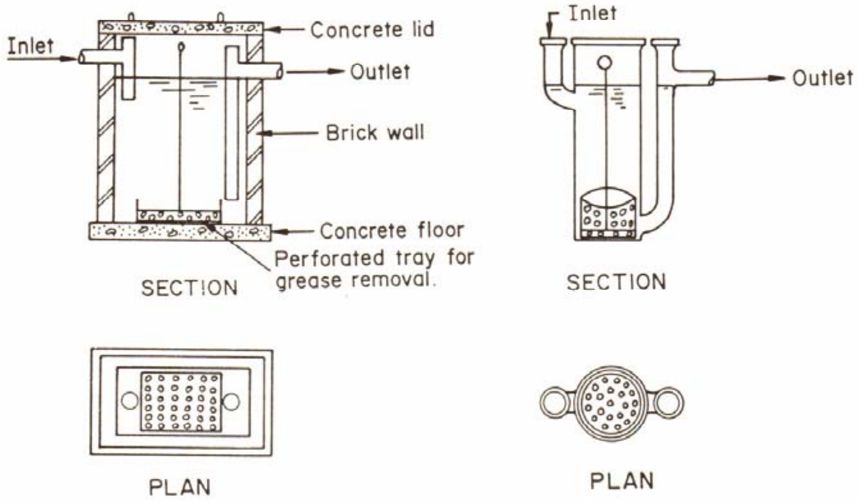

Figure 3 Typical grease traps (CSIR Technical Guide, K86, 1985)

The next section will deal with the functions and proper operation and maintenance of septic tanks.

4. FUNCTIONS OF A SEPTIC TANK

Sewage generation varies throughout the day, resulting in substantial fluctuations in flow and solid material reaching the septic tank. The septic tank allows the small quantity of sludge, contained in the total volume of receiving water, to settle out and decompose anaerobically, i.e. in the absence of oxygen. The tank therefore functions as a sedimentation tank and digester combined. For settling (sedimentation), calm conditions are required while mixing is necessary for efficient digestion. In particular, the tank functions as follows:

4.1 SOLIDS REMOVAL

As sewage enters the septic tank, its rate of flow is reduced so that larger, heavier solids sink to the bottom to form sludge while lighter material rises to the surface to accumulate as scum on the liquid level. Sludge and scum is largely retained in the first compartment of a septic tank, with further settling of smaller particles taking place in the second and consecutive compartments. The final discharge is a liquid, also called “grey water”.

4.2 BIOLOGICAL ACTIVITY

Easily biodegradable carbonaceous material contained in the solids is decomposed anaerobically by microorganisms (mainly bacteria) to produce methane and carbon dioxide gas as final end products. The microorganisms establish themselves over time and proliferate in the absence of free oxygen. It takes approximately three to six months for anaerobic microorganisms to fully establish themselves in a new septic tank. Only thereafter is the tank fully functional. This biochemical process can be accelerated, e.g. by adding commercially available (dry) enzymes or microorganisms. Provision must be made for the gas that forms inside the tank to escape to atmosphere, eg by providing a vent pipe.

Only easily biodegradable carbonaceous material, which serves as food for the microorganisms, is digested / decomposed. Heavy, unbiodegradable carbonaceous material and grit accumulates at the bottom of the tank as sludge and leaves a humus-like residue.

4.3 SLUDGE AND SCUM STORAGE

Sludge is an accumulation of solids at the bottom of the tank, while scum is a partially submerged mat of floating solids that forms at the surface of the liquid in the tank.

Sludge and scum will be digested to reduce the initial volume thereof. However, no matter how efficient the process is, a residual of unreacted solid material will remain. This sludge must be removed periodically as it reduces the working volume of the tank and would ultimately fill the tank.

Fats and oils that do bypass the fat trap (if available) also collect in the tank as scum layer and tend to remain there. The scum layer thickness can be measured with a stick to which a weighted flap has been hinged or with any device that can be used to feel out the bottom of the scum mat. Figure 4 demonstrates this principle.

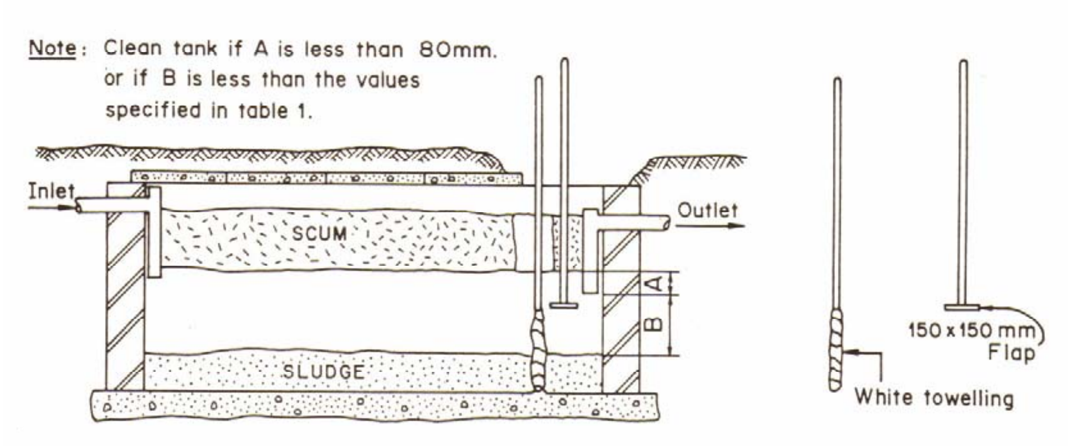

Figure 4 Measuring Sludge and Scum (source: CSIR Technical Guide K86, 1985).

Sludge and scum formation and accumulation varies greatly from community to community and can not be predicted beforehand. Therefore regular inspection (every six months) of the septic tank is the only accurate way in which to determine if the tank requires cleaning.

4.4 SLUDGE DISPOSAL

Sludge removed from a septic tank can be reused for agricultural purposes, but must be completely dried out before being applied to the soil. During handling of the sludge care must be taken to not get in direct contact with the sludge. Reason being, that the wet sludge harbours organisms and eggs (e.g. lintworm) that may be hazardous to human and animal health. Even when dried out, there is a potential danger that eggs or cysts from worms may still remain viable and direct contact with the sludge must be avoided at all times.

Wet sludge that is removed from a septic tank may be buried in uninhabited places or, with permission of the proper authority, emptied into a sanitary sewer system. If buried (land disposal) it must be covered with at least 800 m of soil. The relevant authorities should approve the final site and method of disposal.

In no case should the sludge be disposed of into storm water drains or be discharged directly into a stream or watercourse. The proper disposal of human excreta is the major factor influencing the health of individuals where public sewers are not available. Many diseases, such as typhoid fever, dysentery, and various types of diarrhoea are transmitted from one person to another through faecal contamination of food and water due to improper disposal of human wastes.

For safe disposal of sludge, **the waste sludge shall not**:

- Contaminate any drinking water supply;
- Give rise indirectly to a public-health hazard by being accessible to insects, rodents or other possible animals, which later may come into contact with food or drinking water;
- Give rise directly to a public-health hazard by being accessible to children;
- Violate laws or regulations governing water pollution or sewage disposal;
- Pollute or contaminate the waters of any bathing beach, shellfish-breeding ground or stream used for public or domestic water supply purpose, or for recreational purpose.
- Give rise to nuisance due to odour or unsightly appearance.

5. OPERATION, MAINTENANCE AND CONTROL OF SEPTIC TANKS

5.1 OPERATION AND MAINTENANCE

The following guidelines should be seen as good governance to ensure safe operation of a septic tank and constitute only the very basic points that should be ensured at all times:

- No intractable, industrial or toxic waste shall be allowed to find its way into a septic tank;
- Use only off-the-shelf domestic cleaners for washing purposes in the household;
- Do not add any chemicals into the septic tank (e.g. to get rid of scum or sludge);
- Do regular inspections for sludge and scum accumulation - at least once every six months;
- Responsible sludge emptying and disposal should be conscientiously practiced;
- Septic tanks should not be washed or disinfected after sludge removal;
- Assess annually maximum flows and loadings to ensure system is not overloaded;
- No boreholes shall be allowed within 500 m of the nearest septic tank;
- Abandoned septic tanks should be filled with earth or rock, so as to prevent health and safety risks for humans and animals.
- The use and operation of a septic tank is subject to a wastewater discharge permit from DWAF. Therefore, the Permanent Secretary for DWAF can also cancel the permit, amend, delete or replace any clause in this permit if specified conditions are not complied with;
- Any duly appointed official or representative of the DWA shall have the right of access to the premises concerned for inspection and effluent sampling purpose;

5.2 CONTROL – SAMPLING AND ANALYSES

DWAF will specify the required frequency of sampling in the wastewater discharge permit approval letter. Where no frequency is specified, samples must be taken once every six months and analysed by a registered (by the Ministry of Trade and Industry) analytical laboratory, thus an approved and recognised laboratory for wastewater analyses as required by DWAF.

The wastewater entering a septic tank during a normal day varies significantly, both with regards to volume and organic load, depending on the domestic activities at that time. Therefore a composite sample over 24 hours of the inflow should ideally be taken. This is not a simple process and should rather be left to an expert in the wastewater treatment field. However, grab samples can be used as an indication only. The following procedure describes how to take grab samples and store them for analyses by a suitable laboratory:

- Collect samples at the inlet (as inflow) or outlet (as outflow) to the septic tank;
- Put on surgical gloves, take a sealed, clean 2 ℓ plastic bottle, fill and rinse three times with the wastewater that is to be sampled;
- Fill sampling bottle completely and seal (put on cap) while still under water/while bottle overflows;
- Marc or label each bottle immediately. The labels on the bottles should clearly indicate the name of the plant, owner, exact sampling point/place, date, time and the parameters that should be analysed for;
- Store sample bottles at or below 4°C and deliver them to the laboratory to be analysed within 24 hours. This can be achieved by storing the sample bottles in a refrigerator and transporting them inside a cooler bag/box with ice cubes.

6. FINAL EFFLUENT DISPOSAL

Final disposal of effluent by means of soil percolation systems is not encouraged. The reason being, only partial treatment of the incoming sewage is achieved in a septic tank since no aeration step is included. Especially ammonia nitrogen (major contaminant in urine) is not converted to nitrate and nitrite due to a lack of oxygen and therefore remains in the final effluent. This renders the effluent toxic, even for plants. Also, soil percolation systems often become clogged after a couple of years in use because the micro pores in the soil block up due to fine suspended solids or microorganisms filling these pores over time.

Where soil percolation systems are employed, sand filter trenches (Section 5.4.4) are recommended. Care must be taken that the final effluent does not surface again nor that it infiltrates and contaminates any underground aquifer. Only where a properly designed septic tank is provided, the system is not overloaded and all other criteria for septic tank placement (Section 3.1) and design (Section 3.2) have been adhered to, can a soil percolation system be considered. The suitability of the soil for such a system must then still first be determined.

The following section deals with tests to establish if the soil, that will house the percolation system, is suitable for such purpose. Also, various designs for possible percolation systems will be discussed.

6.1 PERCOLATION TESTS

There are no simple tests by means of which the suitability of a soil to absorb septic tank effluent can be determined accurately. Indications can be obtained by visual inspection of the soil, i.e. whether it has a sandy or clayey nature, or percolation test may be carried out.

The relative proportions of sand, silt and clay determine the texture of the soil and influence its absorptive capacity. The larger and more uniform the soil particles, the larger are the pores and the faster is the percolation rate. Yellow or reddish-brown soils generally indicate good absorptive properties while a dull grey or a mottled colour usually indicates unfavourable conditions for percolation systems. In a geological formation such as limestone or dolomite in which the formation of faults or channels is likely, the disposal of polluted water into the soil is never safe.

A percolation test is more reliable than the visual inspection. The length of time required for the test varies depending on the type of soil, thus enough tests should be made in separate holes to assure that the results are valid. Percolation tests are performed as follows:

- A test hole of 300 mm diameter is excavated at the depth of the proposed trenches’
- Soak the surrounding ground by adding water to the hole for at least four hours;
- Allow the hole to drain and refill with 150 mm of water;
- Note the time taken for the water to seep away;
- Calculate the average time for the water to drop 10 mm – this is called the Percolation Time;
- From the Percolation Time an indication of the sidewall area to be provided in a percolation trench can be obtained from the following table (Table 3):

Table 3: Allowable rate of sewage application to percolation trench to determine sidewall area required (Water Institute of Southern Africa, 1988)

Percolation time (minutes/10 mm)	**Rate of septic tank effluent application to sidewall area of percolation trench (ℓ/m².d)**
1	170
2	110
4	75
10	40
24	25
more than 24	Soil unsuitable for percolation

Note: Trench bottom area should be neglected since it gets clogged very rapidly.

6.2 INFILTRATION AREA

The final effluent from a septic tank system is not allowed to reach a public watercourse, aquifer or accumulate on the surface where it could be accessible to humans, animals or even plants. Where the final effluent is to be used for gardening and/or limited agricultural application additional treatment needs to be provided e.g. in stabilization ponds or advanced treatment systems.

Where only a limited area for percolation is available, the maximum daily discharge from a septic tank system into this area can be determined using percolation test figures as shown in Table 4. The final effluent that can be discharged into a certain area is given by the following formula:

$$Q = 5 \div \sqrt{t}$$

where:

Q = Allowable rate of sewage application in liter per square meter per day

t = Percolation rate

Table 4: Allowable rate of sewage application to determine volume of effluent that can be discharged within a certain infiltration area (CSIR Report, 1964)

Percolation rate (minutes/25 mm fall)	**Maximum rate of effluent application to subsoil infiltration areas (ℓ/m²/d)**
1 or less	170
5	110
10	75
15	50
30	35
60	25
more than 60	soil unsuitable for percolation

6.3 DRAINAGE PIPES FEEDING A SOIL PERCOLATION SYSTEM

Where any drainage pipe is constructed adjacent to, under or through a structural part of any building, adequate measures should be taken to ensure that the trench in which the drain is laid in no ways impairs the stability of any building or interferes with or affects any existing services.

Where any portion of any drain passes under any building, such portion shall be:

- Protected against the transmission of any load onto it;
- Laid without change of direction or gradient;
- Not be provided with any means of access for cleaning from inside such building;
- Supported throughout its length without restricting thermal movement and such support shall be securely attached to the building;
- So placed that any junction, bend or any point of access into it is readily accessible.

Any drain shall be laid:

- In a straight line between any points where changes of direction or gradient occur;
- With approved flexible joints, which will permit joint movement to take place throughout the life of the drainage installation, withstand root penetration and not deteriorate when in contact with sewage or water and will not cause any obstruction in the interior of such drain.

Any drain shall have:

- Soil cover over the outside of the drain of not less 300 mm; or
- Precast or cast-in-situ concrete slabs placed over such drain, isolated from the crown of the pipe by a soil cushion not less than 100 mm thick and such slabs shall be wide enough and strong enough to prevent excessive superimposed loads being transferred directly to the pipes.

Where any drain has a branch drain connected to it, such connection shall:

- Be by means of a junction fitting and shall not be a saddle junction;
- Enable the flow from such branch drain to enter the drain obliquely in the direction of flow so that the included angle between the axes of the two drains does not exceed 45°.

6.4 SOIL PERCOLATION SYSTEMS

Numerous soil percolation systems that serve as receiving bodies for the final effluent from a septic tank have been provided to date and will now be discussed.

6.4.1 PERCOLATION TRENCHES

These are shallow structures that are usually built where sufficient area is available, but limited resources to go deeper into the ground.

- Construction. Trenches should be constructed along the natural contour of the soil. Where two or more trenches are adjacent to each other, the distance between adjacent lines should be twice the depth of the trench.

  Trenches are normally built 1 m to 2 m deep and 600 mm wide. After excavation, the trench is filled with broken stones or gravel and then covered with a layer of straw, hessian, or fine gravel on top of the bed to prevent soil from entering the trench. The gravel fill can be brought to about 100 to 150 mm from the top of the trench.

  The gravel used as filling material should be clean and relatively free from dust and silt. The size of gravel may be in the range of 2 cm to10 cm or larger and it is advisable to have a layer of fine gravel or coarse sand against the infiltration surfaces. The presence of this layer has great merit in protecting the infiltration capacity of the soil.

  The use of corrugated iron sheets or concrete as top layer is not advisable, since it reduces the rate of air exchange, which is needed during the resting periods. The distribution of effluent may be effected, by placing open jointed agricultural pipes in the top of broken stone. It is beneficial for percolation trenches to have a resting period and this is achieved by providing the required area in two or more trenches, which are used in rotation.

- Location. Percolation trenches should be located where dangerous pollution of the ground water is the least likely to occur, even though it is impossible to predict the extent to which pollutants from the source of pollution will travel.

Although no definite measurements can be laid down for the distances between percolation trenches and water supplies, there are some general principles, which should be kept in mind when selecting a suitable site for a percolation trench:

- In saturated soils above the water table, pollutants do not travel far in a lateral direction;
- In a homogenous fine soil above the water table, the distance of the penetration of bacteria from a source of pollution will generally be less than 3 m, because the bacteria are filtered out but this distance is exceeded in coarse soils;
- Viruses generally penetrate further than bacteria, since they are much smaller; however, they are already removed to a large extent in septic tank sludge;
- Coliform bacteria have been reported to survive for 30 days and to travel with the groundwater for 200 m and chemicals have been observed to travel 5 km in 7-8 years;
- In a geological formation such as limestone or dolomite in which the formation of faults or channels is likely, the disposal of polluted water into the soil is never safe;
- If the water table is less than 1 m below the bottom of the percolation system, the system should not be installed;
- Attention should be given to protect the absorption properties of the soil;
- Trenches should not be excavated when the soil is wet enough to smear or compact easily.
- No open trenches should be built.
- All compacted surface should be raked to a depth of 0,3 m and loose materials removed before the gravel is placed in the trench;
- Trenches should not be constructed within 3 m of large trees or dense shrubbery.

Figure 5 shows how a typical trench can be constructed.

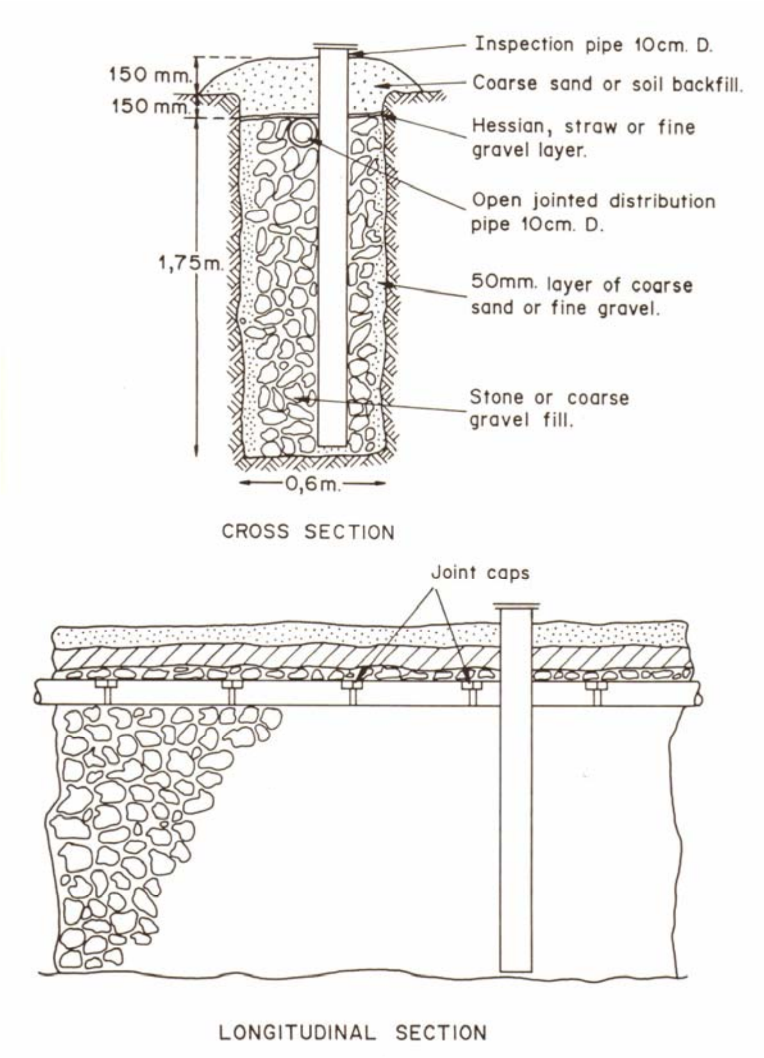

Figure 5 Details of Trench Construction (source: CSIR Technical Guide K86, 1985).

6.4.2 FRENCH DRAINS

A French drain is a receiving body for not heavily polluted effluent or semi-treated effluent. In combined drainage system the sewage first flows into a septic tank, where sedimentation and digestion of mainly solid particles take place. The semi-treated effluent is then discarded into a French drain, from where it infiltrates into the ground.

French drains were often used in the past in separate drainage systems: Kitchen and bathroom wastes bypassed the septic tank and were diverted directly to the French drain. Latter are generally deeper and more compact than trenches and typically are built in the form of a pit or large pipe filled with course material that filters out larger solid particles before the water is released into the receiving soil.

- Construction. French drains are usually built 2 to 4 m below natural ground level. Typical dimensions are 1 to 5 m wide and 2 to 10 m long. The top of the French drain can be covered with clean, coarse aggregate. Typical aggregate size would be 6 to 7,5 mm or bigger, or with boulders with a maximum diameter of 300 mm. In case the drain is a pit, it should first be covered with a zinc plate covered with a layer of earth on top of the plate. They must be constructed strictly in accordance with the allowable soil percolation rate as given in Table 5 (below). This requires a fully witnessed and logged soil percolation test.

Table 5: Rates of percolation and effluent application (SABS 0400-1987)

Percolation rate: Average time for 25 mm fall of test water level in minutes	Rate of application of effluent to subsoil infiltration areas (Q), *ℓ/m²/d*
0-3	108 max
3-5	108-100
6-10	99-80
11-15	79-65
16-20	64-53
21-26	52-40
27-30	39-33
Over 30	Not permitted

- Location. French drains should be constructed in areas where there is no danger to cause pollution of any spring, stream, well or other source of water and shall not be constructed closer than 3 m from any building;

6.4.3 SEEPAGE PITS

A seepage pit is a covered pit with open-jointed lining through which the septic tank effluent may seep or percolate into the surrounding soil. It is considered a less desirable method of disposal compared to an absorption field.

- Construction Seepage pits are usually circular in plan; vertical walls should be lined with open-joined bricks without mortar below the inlet. The brickwork of the seepage pit above the inlet pipe should be constructed with mortar or otherwise strengthened to prevent collapsing of the structure. In some constructions walls were made of precast, reinforced concrete sections with slotted holes.

  Cored units are used to provide necessary structural strength. The cores should be laid in the vertical plane and no openings should be made between the units, whatever the material was used. Materials such as heavyweight concrete blocks, structural clay tile, and fieldstone are also acceptable for strengthen the joints.

  The unevenness of the edges will provide all of the spaces necessary for the effluent to seep into the surroundings soil. Large openings should be avoided - they make the walls structurally less stable and permit easier infiltration of the surrounding soil into the pit. The annular opening between the seepage-pit lining and the surrounding soil should be filled with coarse sand.

  During construction, it is very important that proper precaution is taken to prevent walls from collapsing while workmen are in the excavation pit. Fatal accidents have occurred when this basic safety measure was not observed. Figure 6 shows a typical arrangement of a seepage pit.

- Location. Seepage pits should never be used where there is a likelihood of contaminating ground water. They should not be used in areas where domestic water supplies are obtained from shallow wells, or where there are limestone formations and sinkholes with connection to underground channels through which pollution may travel to water sources. If used:
    - o The pit excavation should be more than 1,2 m above ground-water table;
    - o They should not be located within 6 m of any dwelling or property line;
    - o Adjacent seepage pits should be separated by a distance equal to 3 times the diameter of the largest pit;
    - o For pits over 6 m in depth, the minimum space between pits should not be less than 6 m.

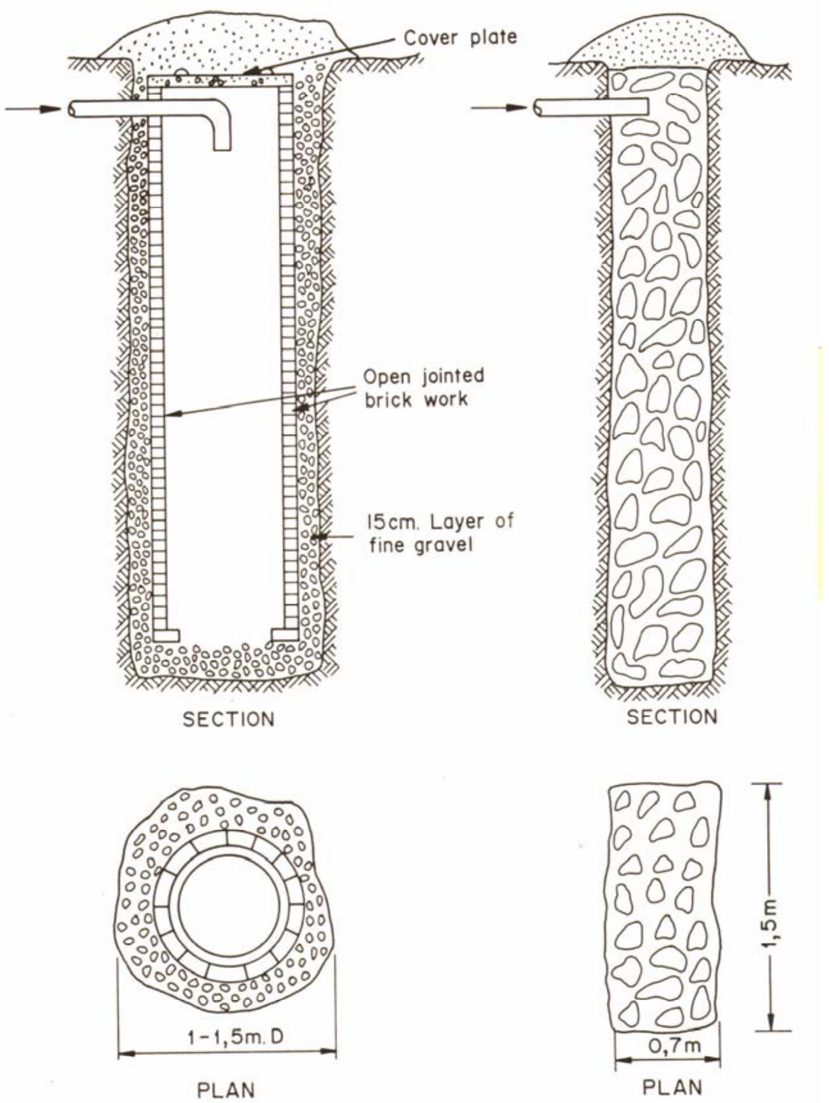

Figure 6 Typical Seepage Pit Construction (source: CSIR Technical Guide K86, 1985).

6.4.4 SAND FILTER TRENCHES

Sand filter trenches must be considered in soils that are relatively impermeable, where absorption trenches and seepage pits can not be used.

Sand filter trenches are somewhat similar to percolation trenches, the major difference is that the filter trenches are deeper, generally somewhat wider, contain an intermediate layer of sand as filtering material and are provided with under-drains for further discharge of filtered sewage. The final effluent is only absorbed by the soil to a limited extent. For this particular reason filter trenches are regarded as means of sewage treatment processes and not strictly for sewage disposal.

- Construction. Filter trenches should be designed for filtration the same percolation rates as given in Table 5. The filtering material should be clean, coarse sand. The sand should have an effective size of 0,4 to 0,6 mm and a uniformity coefficient below 4. Since it is often difficult to obtain sand of this size, an effective size as small as 0.25 mm may be acceptable. Courser sand is preferable, because fine sand will lead to premature clogging and needs frequent replacement. The sand should not be less than 0,60 m deep. Above and below the sand, a layer of coarse-screened gravel or crushed stone should be provided. The gravel and stones should pass a 63 mm screen, but should be retained on a 20 mm screen. Fine gravel, down to 0.3 mm may be used above and around the coarse material, to bed the distribution pipes and under-drain system in. The slope of the distributor pipes should be about 0.5% where dosing tanks are not used, and the slope of the under-drain systems should be about 0.5 to 1.0%. It is essential that the sand be thoroughly settled by flooding before the distribution pipes are placed at the final level. Numerous different underdrain systems are available on the market and suppliers should be consulted.

6.4.5 SUBSURFACE SAND FILTERS/BEDS

Filter trenches are not economical for large installations, thus subsurface sand filters are used instead. They are cheaper, require less area and have a similar design. Both types of installations have distributor pipes and under-drain systems, with filter sand in-between. The essential difference is that filter trenches are narrow and the filter material is laid in trenches with natural soil in-between, whereas a big, single area is used for subsurface filter systems.

- Construction. The sand in a subsurface filter should be of a quality at least equal to that specified for a filter trench, with an effective size preferably between 0,4 and 0,6 mm and with uniformity coefficient less than 4. Again, gravel or crushed stone as previously specified (Section 5.7. 1) should be provided above and below the sand bed.

  Distribution tanks should be installed where the total filter area exceeds 170 m² and where the distributor pipes exceed 90,0 m. The size of the tank should be able to hold 60 to 75 % of the volume of the distributor pipes.

  Under-drains may be of an agricultural tile or bell-and–spigot pipes. Perforated pipes are recommended for the distributor arms. Where distribution tanks are used, the distributor pipes should be laid with a 0,3 % gradient; otherwise, they are laid to a gradient of ca 0,5 %.

Figure 7 shows a complete septic tank system with various possible final effluent discharge systems.

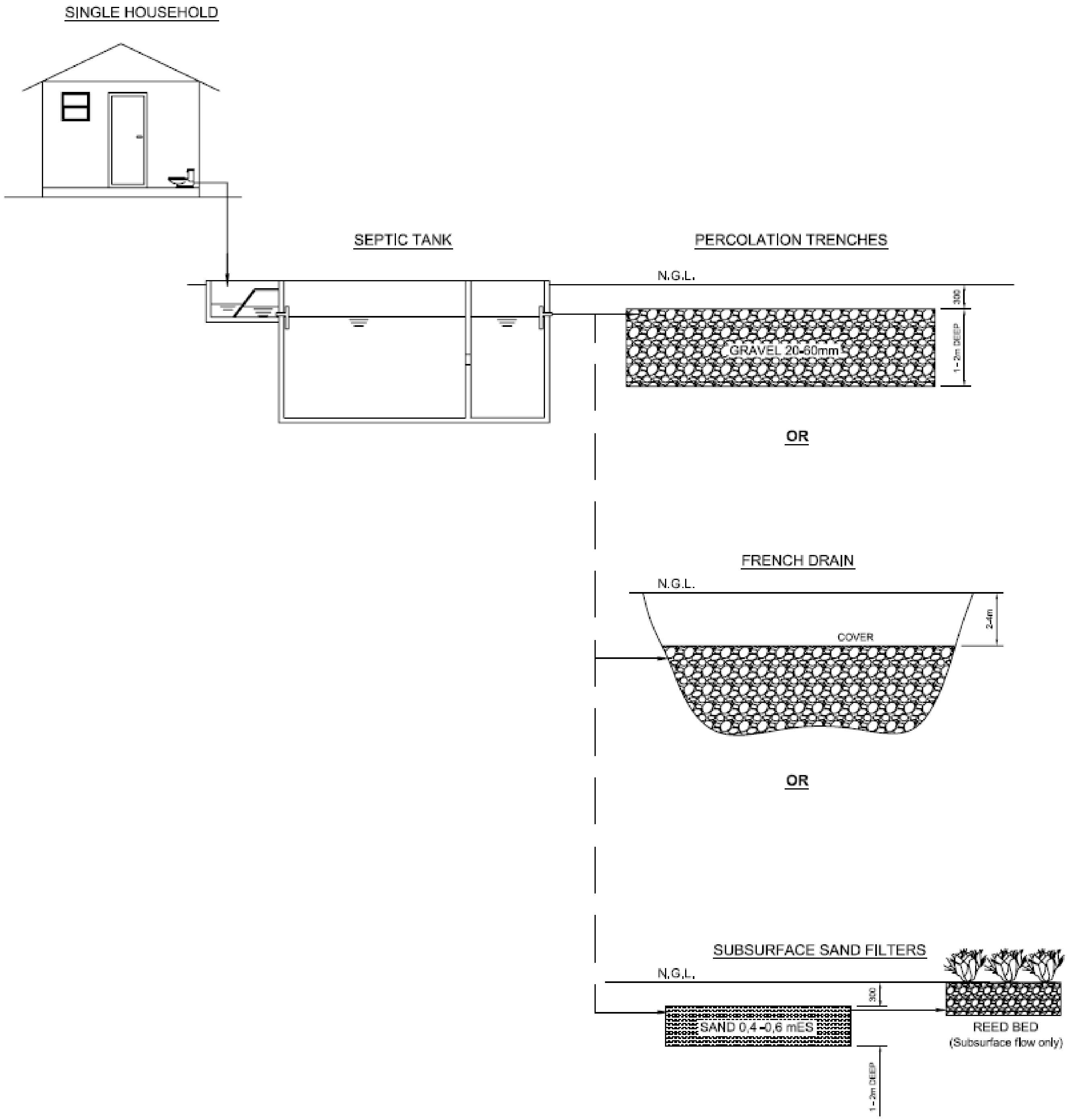

Figure 7 Septic Tank System(s) for Single Households

7. DISINFECTION

Filter trenches and subsurface filters produce a final effluent and, if the system is properly designed and operated, this effluent is clear and sparkling but may not conform to environmental and health standards. The effluent can, however, be used for irrigation of gardens, lawns and for limited use in agriculture (only certain crops allowed). Only if the final effluent conforms to the General Standards as per the Water Resources Management Act, 2004 (Act No. 24 of 2004), is it allowed to be discharged into the environment.

Since water is a scarce commodity in Namibia, reuse thereof is strongly encouraged. A reuse permit obtainable from the Department of Water Affairs is required for this purpose.

Whereas the filtration step will remove a high percentage of bacteria contained in the sewage, the remaining bacteria may still be hazardous and capable of causing diseases. Therefore, the final effluent must be disinfected, even if it does not come in direct contact with humans.

For proper disinfection, chlorine or any other recognised disinfection method may be applied. If chlorine use added, this chemical must be added to the final effluent and be allowed to react for at least 20 minutes to kill potentially harmful microorganisms. This is done in a chlorination tank, properly designed to ensure the chlorine is spread evenly throughout the complete volume of water. Sufficient chlorine must be added to obtain and maintain a free chlorine residual above 0,3 mg Cl_2/ℓ, measured 20 minutes after application and at peak flows. Chlorine comes commercially in various forms:

- As a gas (but liquefied under pressure) in steel cylinders;
- In liquid form (containers) as sodium hypochloride;
- In solid form, commonly distributed as chlorine pills or granules (e.g. HTH).

REFERENCES

Drews, R.J.L.C. 1985. A guide to the use of Septic Tank Systems in South Africa. CSIR. Pretoria, South Africa.

SABS 0400. 1989. The South African Standard Code of Practice for the Application of the National Building Regulations. SABS 0400. 1987, amended 1988 and 1989.

The Water Institute of Southern Africa. 1988. Manual on the design of small sewage works. Pretoria, South Africa.

Water Resources Management Act. 2004. Act No 24 of 2004: Government Gazette of the Republic of Namibia, No 3357 of 23 December 2004.