EWCE 333
Wastewater Engineering and Sanitation

Lecture 3

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Lecture Outlines

Topics	Reference
• On-site sanitation systems for rural & low income urban communities • Simple pit technology – design considerations and design • Two pit latrine systems – design considerations and design	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Low Cost Sanitation Technologies

- **Pit Latrine**

- **Pour-flush Latrines** (where a water seal is maintained with low-volume of flushing)

All forms of pit latrines are not fully sanitary.

With slight modifications in design and with some interventions, conventional pit latrines could be improved to be hygienic.

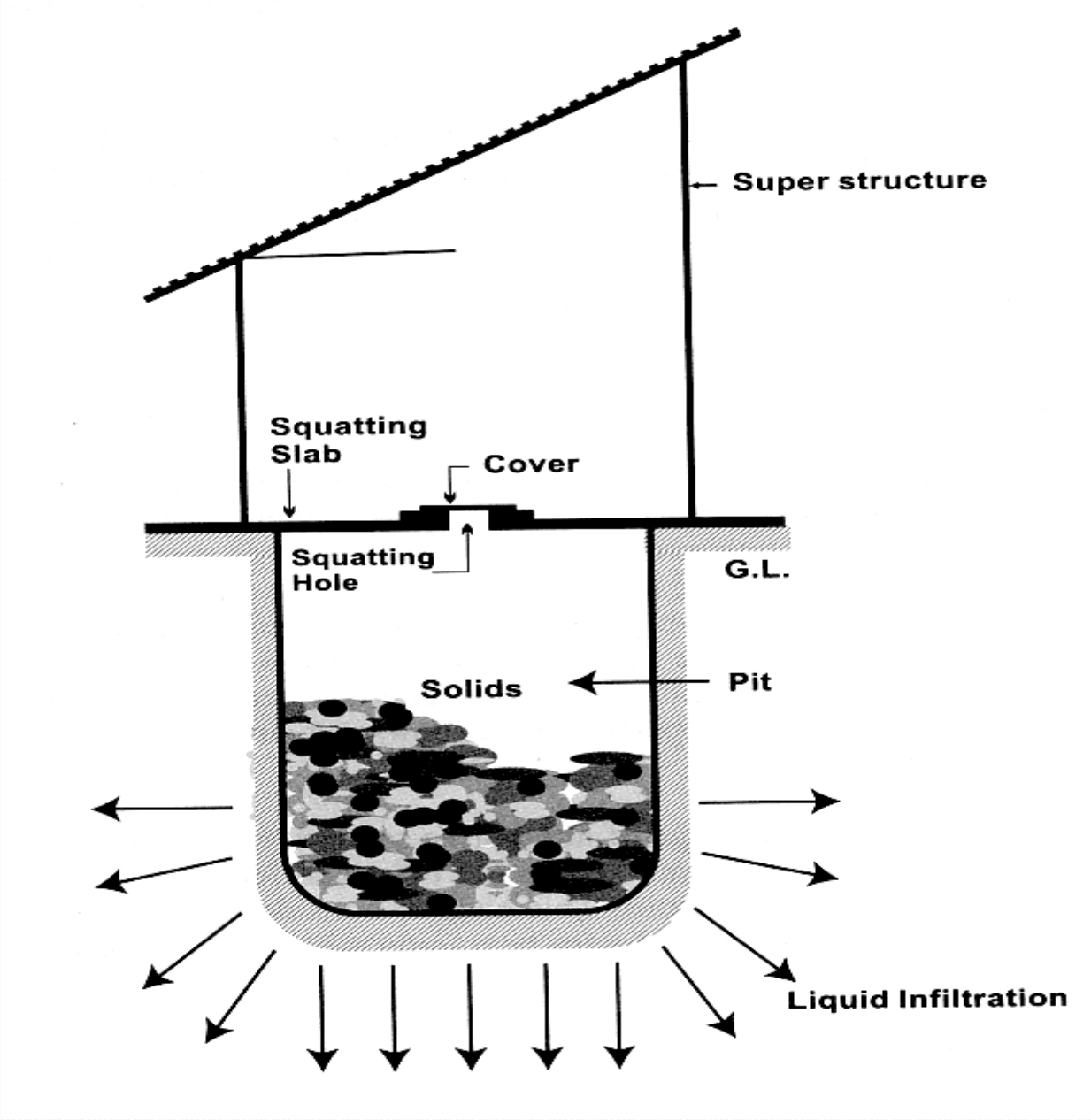
Pit Latrine Technologies

The major types of pit latrines include:

- Simple or Home-made pit latrines
- Ventilated Improved Pit (VIP) Latrines
- Reed Odorless Earth Closet (ROEC)

Pit Latrine Technologies



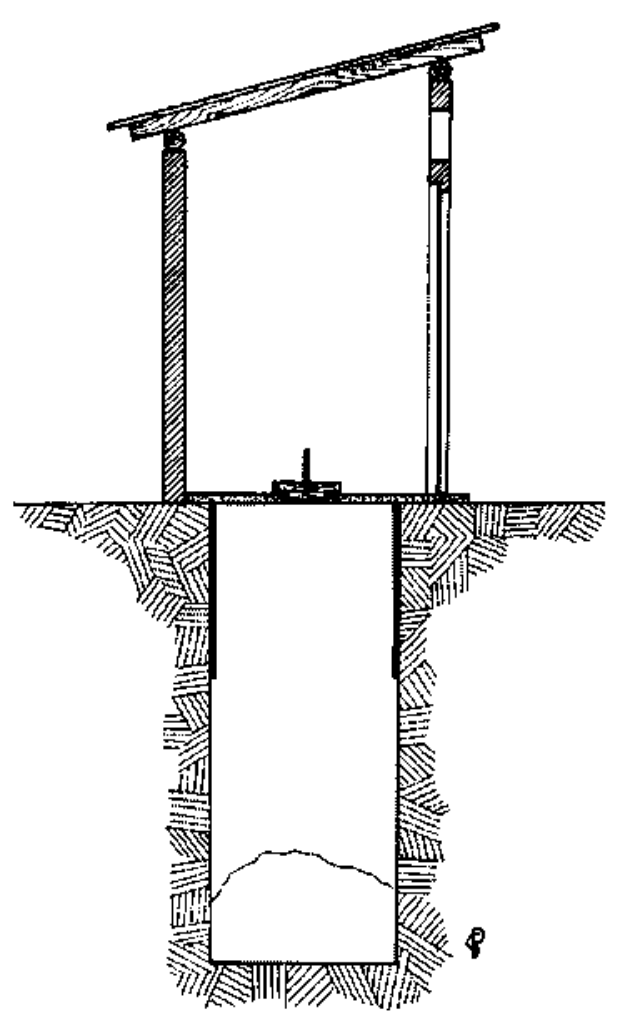


Pit Latrine Technologies

- Most common and simplest form of excreta disposal in developing countries
- Consists of a manually dug or bored hole into the ground, an appropriate seat or squatting slab and a shielding superstructure
- Urine and other liquids soak into the ground and solid materials are retained and decomposed in the pit

Types of Pit Latrines

- **Direct pit latrine**- Excreta falls directly into a pit underneath the user



Types of Pit Latrines

- **Off-set pit latrine**- Excreta pass through a short pipe or a channel to a pit a few meters away

- **Partly off-set pit latrine**- When part of the pit is under the shelter and part is outside

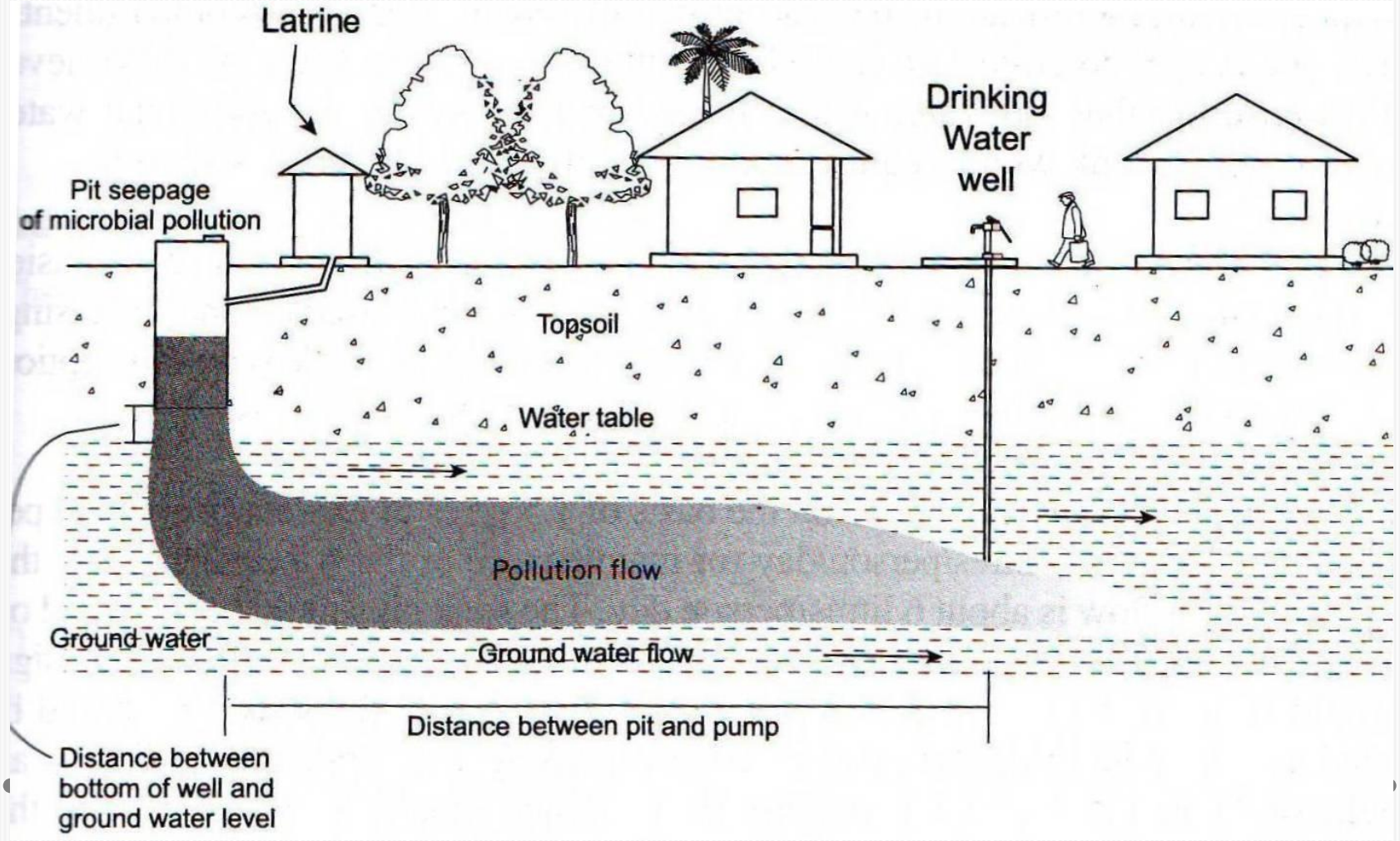
Design Considerations for Pit Latrines

- Pit width - ≤1.5 m (commonly 1.0-1.5 m), to avoid expensive construction of cover slab
- Soils with permeability ≥ 2.5 mm/hour to allow liquid infiltration into soil.
- Pits in unstable soils must be fully lined (otherwise, collapse of superstructure).

Materials used: concrete blocks, bricks, cement-stabilized soil blocks, masonry, perforated oil drums etc.

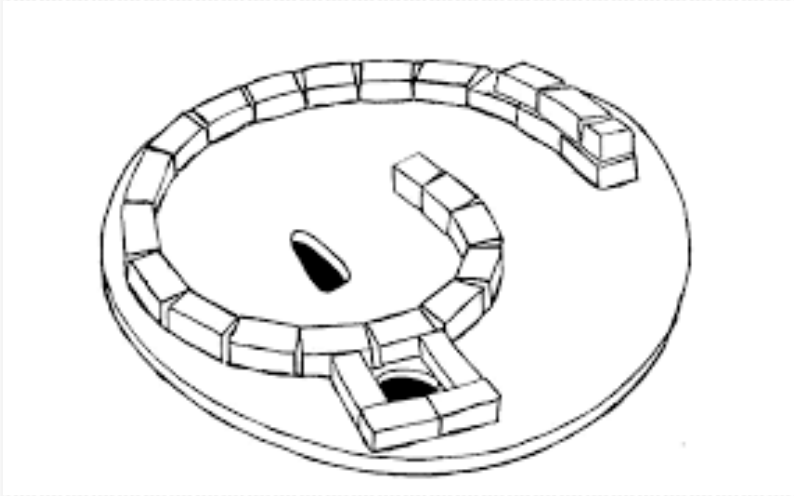
Design Considerations for Pit Latrines

- Distance between pit and a source of drinking water ≥10.0m should be provided (to avoid possible contamination).



Design Considerations for Pit Latrines

- Distance between pit bottom and water table ≥2m.
- Adequate ventilation by leaving openings above and below door or by constructing a spiral wall without door.



Design Considerations for Pit Latrines

- Pit depth: depends on ground water table, soil condition.

- 5-ring pits (@ 1 ft. per ring) are common.

Design of Pit Latrines

Effective Pit Volume:

$$V = C \times P \times N \ldots\ldots (1)$$

where, V = Effective volume of the pit, m^3

C = Solids accumulation rate, m^3/person/year

P = Number of persons, (expected to use the latrine)

N = Design life, years

Design of Pit Latrines

Typical values of C:

- Wet pit: 0.04 m^3/person/year (0.02 - 0.04)

- Dry pit: 0.06 m^3/person/year (0.03 - 0.06)

Note: Accumulation rate is lower for wet pit (i.e., pit below GWT) because biodegradation is faster under wet condition

Design of Pit Latrines

Effective Pit Volume, $V = (\pi d^2/4)\, h$ ..... (2)

where, d = diameter of pit, m

h = effective depth of pit, m

Assuming a suitable d (maximum permissible d is 1.5 m) of pit, h can be obtained.

Usually a free space of 0.5 m is kept at top of the pit.

Total depth of pit, $H = h + 0.5$ ..... (3)

Advantages of Pit Latrines

- Low investment for construction.
- No expert inputs are required during construction.
- Design is readily available; local materials can be used
- Free from the risk of falling a child into it and hence suitable for children.

Advantages of Pit Latrines

- Excrements are better contained than in open defecation.
- Unit can serve one or several households.
- Easy operation and maintenance.
- Pit latrines use no water for flushing.

Disadvantages of Pit Latrines

- Potential odor and flies problem in simple pit latrine.
- Require access to open ground and digging of new pits or emptying of existing ones every few years.
- Emptying of pits can be very difficult (may require manual labor, pits may collapse). Also manual desludging poses health hazard

Disadvantages of Pit Latrines

- Toilets cannot be situated in houses, hence lack of privacy and safety concerns especially during night time.
- Re-location of individual leach-pits difficult in densely populated areas
- They cannot be used at all in crowded areas, on rocky ground, where the groundwater level is high or in areas periodically flooded

Design Problem for Pit Latrines

Problem 1:

Local authority in a village is offering pre-cast concrete rings of 1.0 m diameter and 0.3 m depth of concrete slab to cover it at a subsidized rate.

Design a simple pit latrine for a family of 7.

The soil is unconsolidated/loose and the GWT is 5.0 m below the ground surface.

The family wants the latrine to serve for 4 years.

(Note: Change design parameter as you find appropriate.)

Design Problem for Pit Latrines

Solution:

Effective Pit Volume

$V = C \times P \times N$

$= 0.06 \times 7 \times 4 = 1.68\ m^3$

Cross sectional area of pit = $(\pi d^2/4)$

$= 0.785\ m^2$

Effective Pit depth = 1.68/0.785 = 2.14 m

Design Pit depth = 2.14 + 0.5 = 2.64 m (free board/space =0.5m)

No. of rings required = 2.64/ 0.3 = 8.8 ≈ 9 rings (Height of ring = 0.3m)

But to use more than 5-6 rings is not realistic.

Design Problem for Pit Latrines

Considering N = 3 yrs

$V = 0.06 \times 7 \times 3 = 1.26\ m^3$

Effective Pit depth = 1.26/0.785 = 1.61 m

Design depth = 2.11 m

Rings required = 2.11/ 0.3 = 7 rings

Possible but construction could be difficult.

Actual depth of pit = $7 \times 0.3 = 2.1 + 2 = 4.1m$

Design Problem for Pit Latrines

Considering N = 2 yrs
$V = 0.84\ m^3$

Effective Pit depth = 1.07 m

Design depth = 1.57 m

Rings required = 1.57/ 0.3 = 5.23 ≈ 6 rings

Actual depth of pit = 6 × 0.3 = 1.8 m
1.8 + 2 = 3.8 < 5m (ok)

Design Problem for Pit Latrines

Also recommended:

1) A vent pipe for the pit
(150 mm dia. PVC pipe, top of the vent pipe is 500mm higher than highest point of roof)

2) Use of suitable cover for the squatting hole, when latrine not in use

Design Problem for Pit Latrines

Problem 2:
Repeat the problem 1,
if the latrine has to serve 2 families, each with 7 members.

GWT is high, located 4.0 m below the ground surface.

Design life cannot be less than 2 years and a 2.0 m gap must be provided between the pit bottom and GWT.

Design Problem for Pit Latrines

Problem 3:
A farmer excavated 1.5 m x 2.0 m x 2.5 m (depth) pit for construction of a room which he now wants to convert into a pit latrine.

Requirements/ constraints are:
(i) Water availability is limited
(ii) Excreta cannot be seen through squatting hole.

Design a suitable latrine and find design life for 6 persons. Consider low GWT.

The pit is to be constructed as a permanent one with brick lining.

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Lecture 5

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Lecture Outlines

Topics	Reference
• Pour-Flush Latrine Latrine - design considerations and design	Water Supply and Sanitation - Feroz Ahmed and Mujibur Rahman ITN -BUET

Water Seal (Pour-Flush) Technologies

- A further improvement to the pit latrine can be obtained with a water-seal.
- The pour-flush latrine has three major components parts: (a) the superstructure, (b) The latrine pan with its integral water seal and (c) a single or altering twin leach pits.
- Water-seal is a U-pipe filled with water, attached below the squatting pan that completely prevents passage of flies and odor.

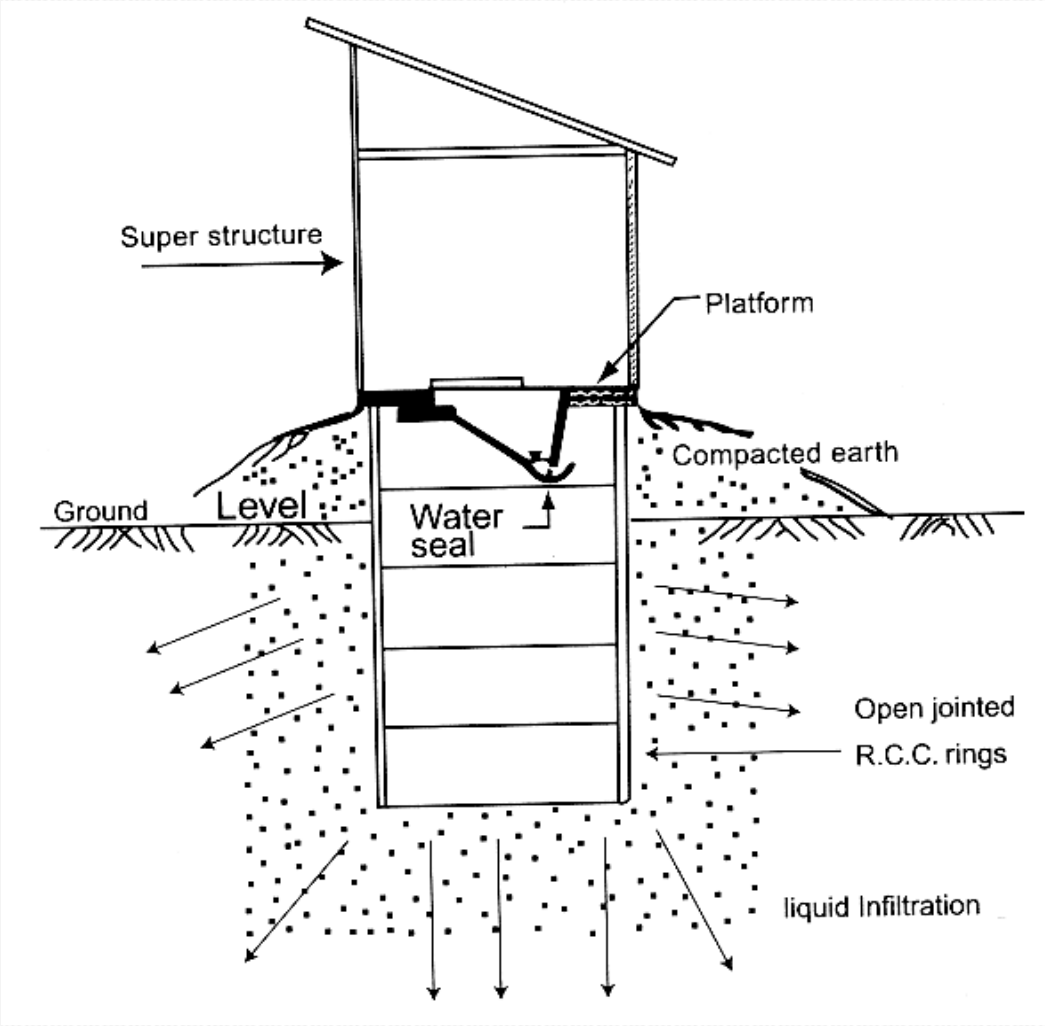
Pour-Flush Technologies

- The water-seal is only 15-25 mm deep and the latrine can be flushed by hand using 1.5 to 2.0 litres of water.
- The latrine can also be located, if desired inside the house with off-set pit.
- Small quantity of water used in a pour flush toilet is sufficient to carry the excreta to a soakage pit up to 80m away.

Types of Pour-Flush Technologies

(1) **Direct Pit Pour-flush Latrine**

- Modification of simple pit latrine where the squatting plate is provided with a 25 mm water seal and is placed directly over the pit.



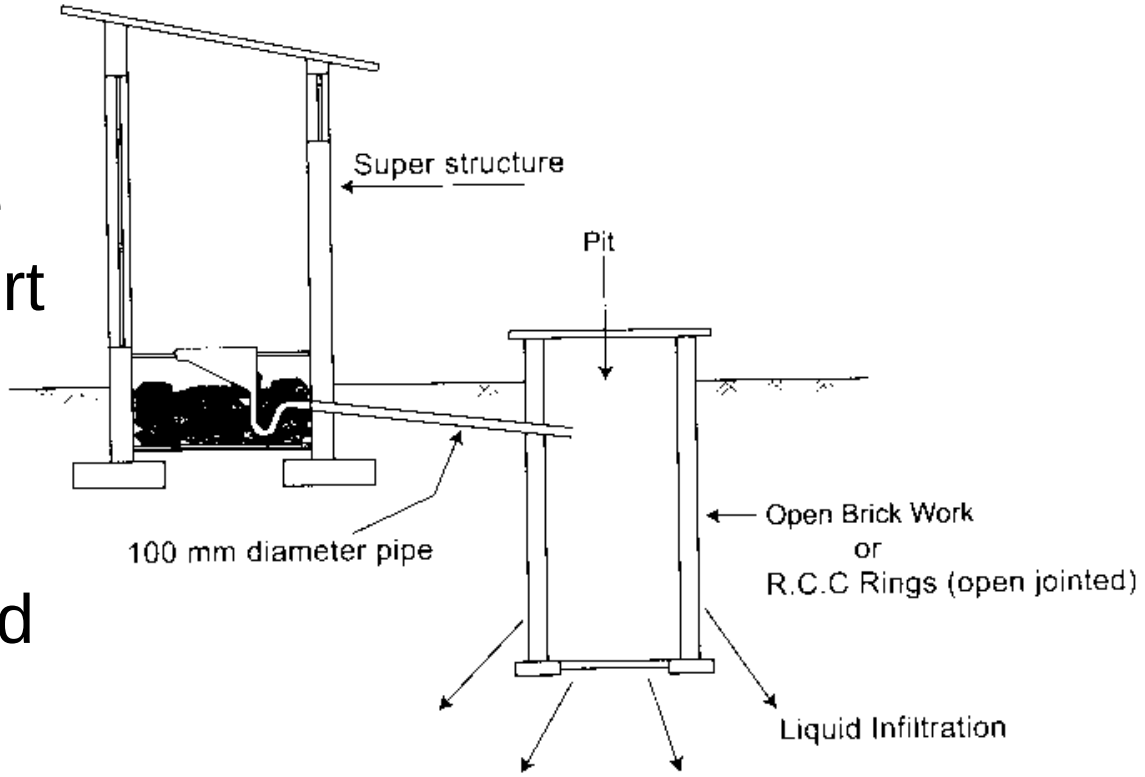
Types of Pour-Flush Technologies

(2) Off-set Pit Pour-flush Latrine

- Completely off-set pit

- Pit is connected to the pour-flush pan by a short length of 100 mm diameter pipe.

- Latrine can be installed inside the house



- Free from fecal odor and insect problems

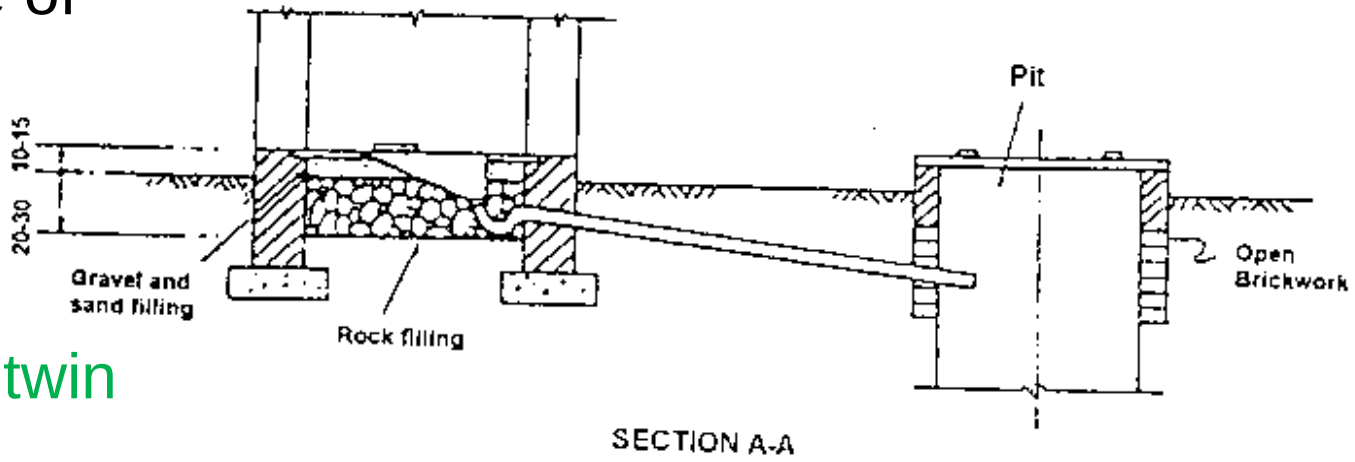
- No need for a separate superstructure.

Types of Pour-Flush Technologies

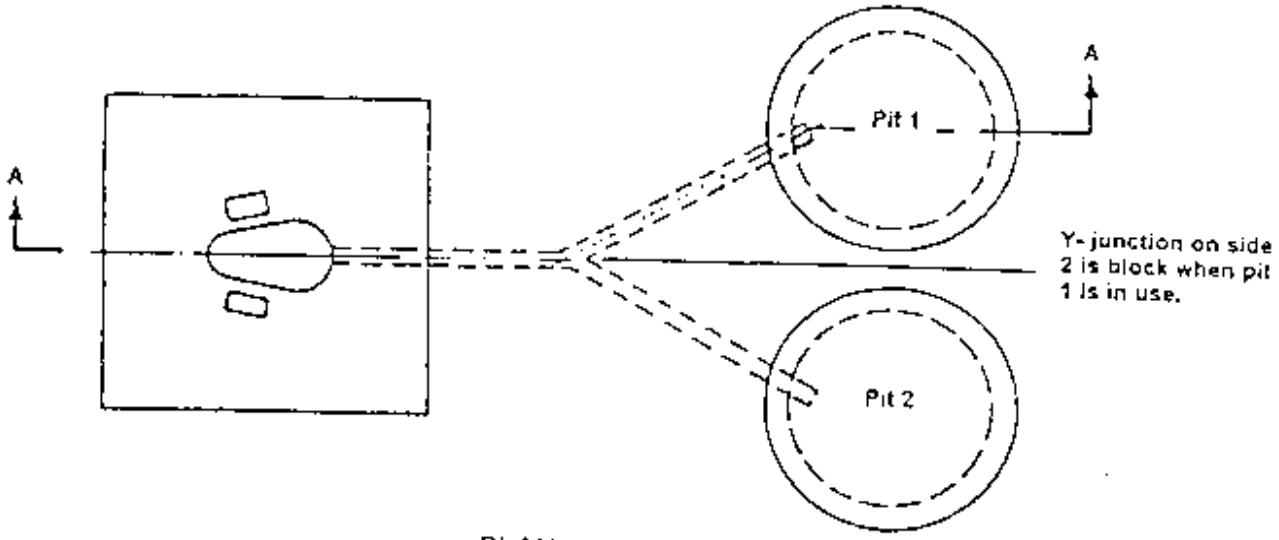
Off-set pit pour-flush latrines can be of two types –

(a) single

(b) alternating twin off-set pit.



SECTION A-A



PLAN

Alternating Twin Off-set Pit Pour-Flush Latrine

- The alternating twin-pit system comprises –
  (i) a squatting pan and
  (ii) a Y-junction for directing excreta from squatting pan to either of the two leach pits.

- The pits are used alternately and at a given time only one pit is in use.

- When the first pit is full, the flow of excreta is directed to the second pit through a Y-junction and contents of the first pit are left to decompose.

Alternating Twin Off-set Pit Pour-Flush Latrine

- The contents of the first pit decompose to safe, pathogen-free humus within 18 to 24 months.

- The contents of the first pit may then be dug out and the pit is kept ready for reuse.

Functions of Pour-Flush Latrine

- After each use, the latrine is manually pour-flushed with about 2-3 liters of water (compared to 10-20 liters used in conventional toilets)

- The water seal provides a barrier against odour and insect.

- From excreta, flush water and wash water around 10-20 liters/capita/day (lpcd) of wastewater enter into the pit.

Functions of Pour-Flush Latrine

- The pit has to provide sufficient volume for solids storage, as well as sufficient area for the wastewater to infiltrate into the soil.

- It requires that the soil has sufficient long term infiltrative capacity.

- If the soil is unsuitable for infiltration, the liquid effluent can be removed by other means e.g., by connection to the sewerage system if available.

Suitability of Pour-Flush Latrine

- Pour-flush latrines may be used in both rural and urban areas provided they are appropriately designed and that they can rely on water availability for flushing, and for maintaining the water seal.

- Single pits may be appropriate in urban areas only if they can be desludged mechanically by a vacuum tanker, since their contents are not pathogen free.

- Twin-pits are recommended if the pits are to be desludged manually, as the resting period ensures that the contents to be removed are substantially free of pathogens.

Design of Pour-Flush Latrine

Table 1: Design Values for Long-term Infiltration Rates for Wastewater into Various Soils

Soil Type	Long term infiltration rate, I (L/m^2-day)
Sand	50
Sandy loam	30
Porous loam, porous silty clay loam	20
Compact silty loam, clay	10

Design of Pour-Flush Latrine

The side wall area required for infiltration, (A_i, m^2) is given by:

$$A_i = Q / I \quad \ldots\ldots\ldots (1)$$

where, **Q** = waste water flow rate (L/day)

I = long-term infiltration rate (L/m^2 - day)

- The wastewater flow (Q) depends on the number of users, frequency of flushing, flush volume, urine volumes and amount of water used for anal cleansing.

- Generally Q varies between 5-20 Lcd.

Design of Pour-Flush Latrine

The pit volume, V_i (m^3) corresponding to the sidewall area can now be calculated. For a circular pit of diameter, D,

$$\mathbf{V_i = \pi D^2 h/4 \ldots\ldots\ldots\ (2)}$$

Now, side wall area for a cylinder, $A_i = \pi Dh$

where h= the height of the sidewall area

$= A_i / \pi D$ …… (3)

Replacing the value of h (from eqn 3) in equation 2

$$V_i = (\pi D^2/4) *(A_i /\pi D)$$
$$= A_i D/4$$
$$= (Q/I) * (D/4) \text{ (from eqn 1)}$$

i.e., $\mathbf{V_i = QD / 4I \ldots\ldots\ldots\ (4)}$

Design of Pour-Flush Latrine

For alternating twin-pits, the effective volume of each pit is calculated –

- ✓ either using **equation 4** (**$V_i = QD / 4l$**)
- ✓ or **$V_s = C \times P \times N$**, whichever is greater.

For single pit pour-flush latrines, the effective volume is given by:

$$V = V_s + V_i \quad \text{..... (5)}$$

Advantages of Pour-Flush Latrine

- Less expensive compared to conventional latrines.
- Offers appropriate and hygienic solution for excreta disposal.
- Requires less volume of water for flushing (1-3 lit/flush only).
- Can be upgraded to connect to a sewerage system or septic tank system.
- Eliminates odor release, insect and fly breeding.

Advantages of Pour-Flush Latrine

- Safe for children.
- Can be located inside the house.
- Potential for resource recovery using the sludge as soil conditioner.
- Easy construction and maintenance.
- Twin pit latrine can serve as a permanent structure because of its pits is used alternatively.

Disadvantages of Pour-Flush Latrine

- Requires separate sullage disposal facilities.
- Water (at least 4 liters / person / day) must be available throughout the year.
- Water seal may be clogged easily if garbage is thrown into it.
- Construction is difficult and expensive in areas with high ground water and shallow soil overlying hard rock.

Disadvantages of Pour-Flush Latrine

- Risk of polluting ground water and/or nearly water sources.
- Construction and maintenance of twin pit pour-flush latrine is difficult.

Design of Pour-Flush Latrine

Problem:

Design leach pits for both – (a) single pit and (b) twin offset pit pour – flush latrine for a family of 7 members for a design period of 2.5 years.

The X-section of the pits has to be square.

The average waste water flow rate is 12 liters per person per day.

The soil is porous silty loam with long – term infiltration rate of 20 L/m^2-day.

In sketch, show the designed latrine and pit arrangement.

Design of Pour-Flush Latrine

Solution:

Given,

Family Members = 7

Design Period, N = 2.5 years

Pit X-section Shape = square

Avg. Wastewater flow rate, q= 12 lpcd

Soil type = Porous silty loam

Long term infiltration rate, I = 20 L/m^2-day

Design of Pour-Flush Latrine

Now,
Total waste water flow, Q = 12×7 = 84 l/d

Area required for infiltration, A_i = Q/I m^2
= 84/20
= 4.2 m^2

Assuming, pit width = 1.2 m

Therefore, Pit Volume, V_i = QD/4I
= (84×1.2)/(4×20)
= 1.26 m^3

Design of Pour-Flush Latrine

Pit volume with respect to solid storage

Let, solid accumulation rate, C = 0.04 m^3/person-yr

N = 2.5 years

Therefore, pit volume, V_s = CPN

=0.04×7×2.5

= 0.7 m^3

Design of Pour-Flush Latrine

Case – 1 : single pit pour – flush system :

The effective volume, $V = V_i + V_s$

$=1.26+0.7$

$=1.96m^3 \approx 2m^3$

Considering, pit width = 1.2m

For square pit, effective depth, $h=V/1.2^2$

$=2/1.2^2=1.39m$

$\approx 1.5m$

Assuming 0.5m clear space, total depth=1.5+0.5

=2m

Design of Pour-Flush Latrine

Case II: alternating twin pit pour flush system

Governing volume of pit $=1.26m^3$

Pit width= 1.2m

Depth of pit= $v/1.2^2$

$=1.26/1.2^2$

$= 0.875m^2$

Let, Clear depth = 0.5m

Therefore, total depth $=0.875+0.5$

$=1.375m \approx 1.5m$