CE 443: Environmental Engineering III
Module 01

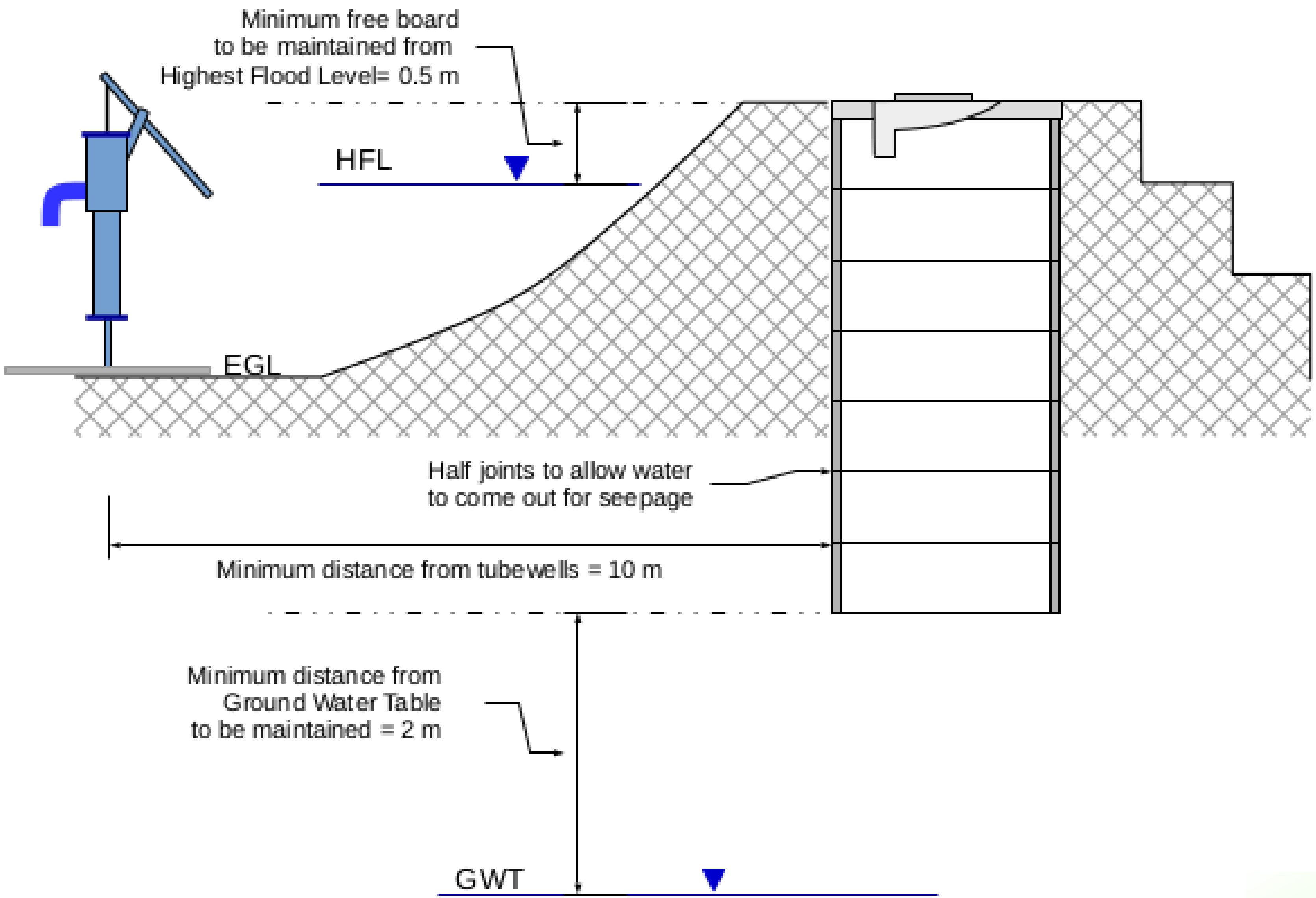
Contents:

Sanitation and health; Low cost sanitation technology - on-site sanitation systems for rural communities;

Mathematical Problem solving
&
Related matters

Dr. Miah M. Hussainuzzaman

Sanitation: Design Considerations



Sanitation: Design Formula (Dry systems)

Effective volume of a pit

$V = CPN$

- N → Design period, years
- P → Population to be served, persons
- C → Contribution / solids accumulation rate, m^3/person/year
- V → Effective volume of the pit, m^3

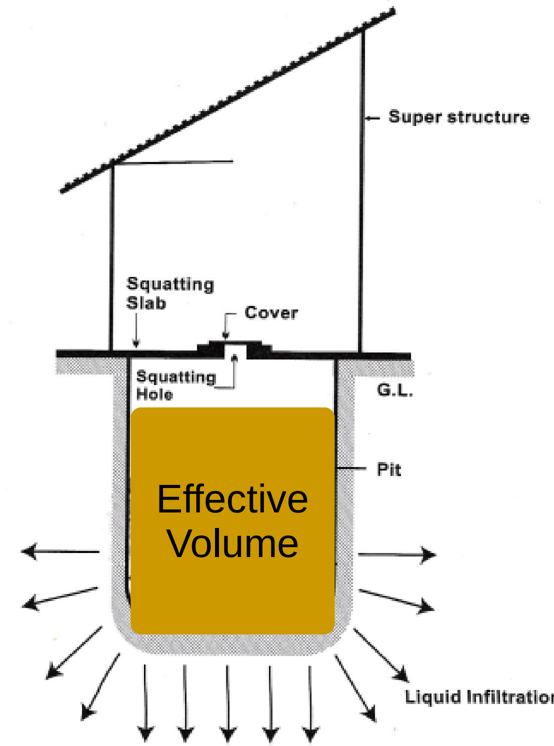
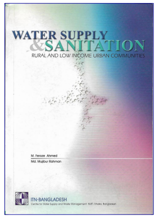


Table 9.1 (Ahmed & Rahman) Values of Solids Accumulation Rates (m^3/person/year)

Wet Pit		Dry Pit	
Anal cleansing: water	Anal cleansing: solids	Anal cleansing: water	Anal cleansing: solids
0.04	0.06	0.06	0.09



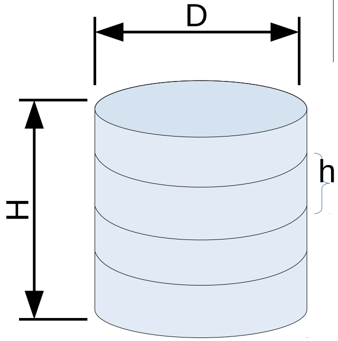
Sanitation: Mathematical examples

Example 1:
Design a pit latrine for a family of 10 persons. The design should last 3 years. Some of the users may use solids for cleansing purpose. Use RCC rings of 1 m diameter and 0.5 m height.

Solution:

Formula

V = CPN



Data Given:

P = 10 Persons
N = 3 years,
C = 0.07 m³/person/year

V = ?

D = 1 m
h = 0.5 m
H = ?

Calculations:

$V = 0.07$ m³/person/yr x 10 person x 3 yr

$= 2.1$ m³

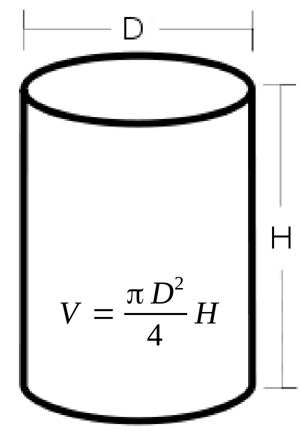
$$V = \frac{\pi D^2}{4} H$$

$$\Rightarrow 2.1 = \frac{\pi \times 1^2}{4} H$$

$$\Rightarrow H = 2.674\ m$$

$$n = \frac{H}{h} = \frac{2.674}{0.5} = 5.35$$

Use 7 rings (Ans.)



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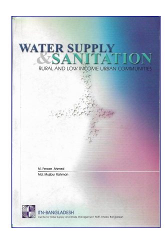


Solids accumulation rate, C: Excreta deposited into the pit have two essential components:

- liquid fraction of excreta (mainly urine), together with small amount of water that enters the pit due to anal cleansing and slab washing which ultimately infiltrates into the surrounding soil;
- the faecal solids in excreta that are digested anaerobically to produce (i) gases such as methane, carbon dioxide and hydrogen sulphide which are exhausted from the pit via the squat hole or the vent pipe; and (ii) soluble compounds which are either further oxidized in the pit or are carried into the surrounding soil by infiltrating of the liquid fraction.

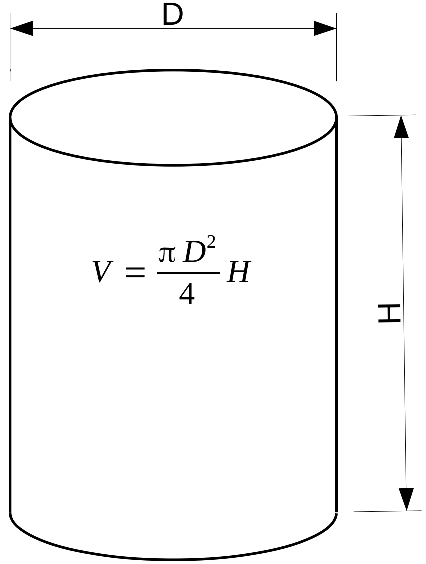
In dry pits (not extended below the groundwater table), solids accumulation rates vary between 0.03 and 0.06 m^3/person/year, and in wet pits between 0.02 and 0.04 m^3/person/year. Accumulation rates are lower in wet pits because biodegradation is faster under wet conditions than under the only just moist conditions in dry pits. For design purposes, solids accumulation rates may be taken as 0.04 and 0.06 m^3/person/year in wet and dry pits respectively. The value of C can also be obtained from Table 9.1.

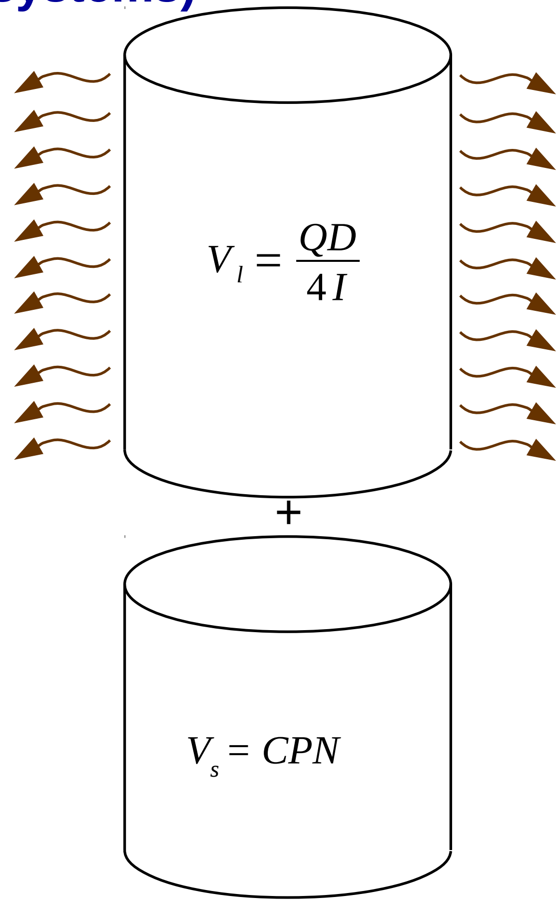
Providing a prefabricated slab with a squatting pan attached to it can be the simplest and cheapest improvement of a conventional pit latrine. For structural stability reinforcement is placed in the slabs. Prefabricated cement slabs in a simple pit latrine prevent transmission of hookworm. A pit lining may be required in loose soils.

Sanitation: Design Formula (Wet systems)

Effective volume of a wet pit

$$\text{Volume of Circular Pit} = CPN + \frac{QD}{4I}$$





$\text{Infiltration Rate} = I \quad liter/m^2/d$

$\text{Out flow rate, } Q = A\,I \quad liter/d$

$$\Rightarrow A = \frac{Q}{I}$$

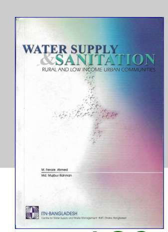
$$\text{Surface Area}, A = \pi D H$$

$$V = \frac{\pi D^2}{4} H = \pi D H \times \frac{D}{4} = A \times \frac{D}{4}$$

$$\Rightarrow V = \frac{Q}{I} \times \frac{D}{4} = \frac{QD}{4I}$$

Table 9.2 (Ahmed & Rahman) Design values for long-term infiltration rates for wastewater into various soils

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



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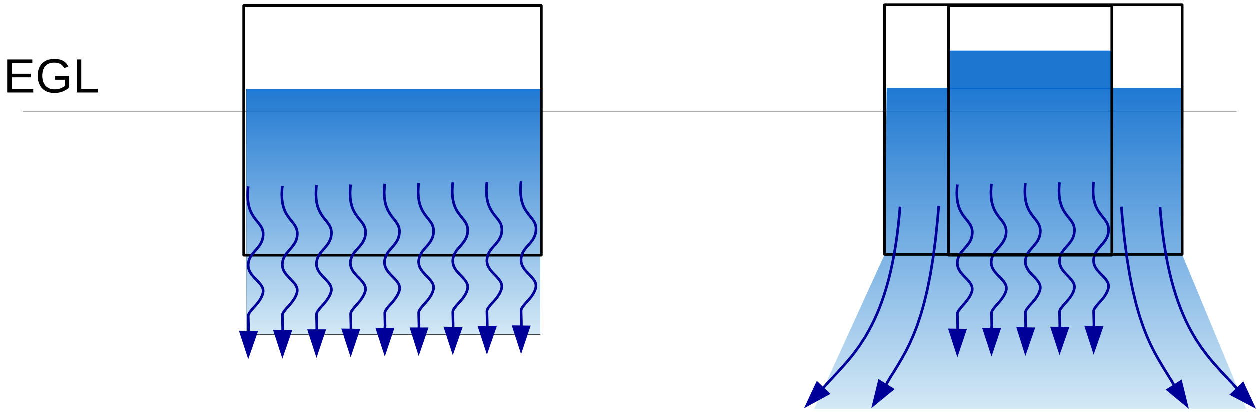
Sanitation: Design Considerations (Infiltration rate: instantaneous vs long term)

Single ring infiltrometer

Double ring infiltrometer

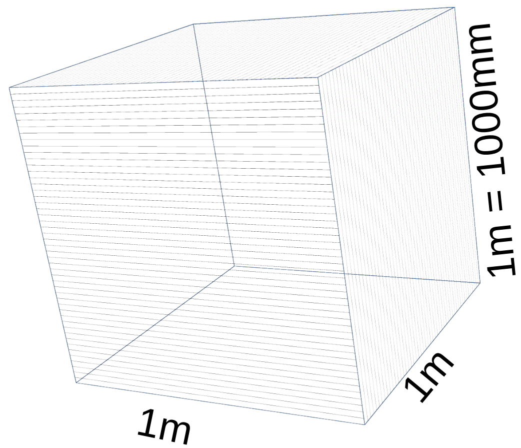


Minimum value for toilet: 2.5 mm/hr = 60 mm/day = 60 liter/m^2/day

Sanitation: Design Considerations (Unit of flow rate or infiltration rate)

Minimum value for toilet: 2.5 mm/hr = 60 mm/day = 60 liter/m^2/day

$$\frac{litre}{m^2} = \frac{1\,litre}{1\,m^2} = \frac{10^{-3}\,m^3}{1\,m^2} = \frac{10^{-3}}{1}\,m = \frac{1}{1000}\,m = 1\,mm$$



1 m^3 = 1000 L

1m x 1m x 1m = 1000 L

1m x 1m x 1000mm = 1000 L

1m x 1m x 1mm = 1 L

1m x 1m x ***X***mm = ***X*** L

X mm/m^2 flow = ***X*** L/m^2 flow

Sanitation: Mathematical examples

Example Problem: Design the pit of a pour flush pit latrine for a family of 7 members. The latrine is to be built with pre-cast concrete rings of 1.2 m in diameter and 0.5 m in depth; the design life of the pit should be at least 4.0 years. Expected type of soil is porous silty loam. Calculate the number of rings to be used for the pit. Each person uses 25 liters of water per day, some of them may use solids during cleaning.

Provide a neat sketch showing the cross section with elevations of the pit.

a) The groundwater table (GWT) is 4.0 m below ground surface.

b) The groundwater table (GWT) is 6.0 m below ground surface & Highest Flood Level (HFL) is 1.0 m.

Solution:

$$Effective\ Volume\ of\ Circular\ Pit,\ V_e = CPN + \frac{QD}{4I}$$

Given Data:

C = 0.05 m^3/person/year

Population, P = 7 persons

Per capita water use, q = 25 lpcd

Water flow rate, Q = Pq = 7 x 25 = 175 l/d

Design life, N = 4 years

Pit Diameter, D = 1.2 m

Ring height, h = 0.5 m

Infiltration rate, I = 20 l/m^2/d
[from p-129 table, for porous silty loam]

$$V_e = 0.05 \times 7 \times 4 + \frac{175 \times 1.2}{4 \times 20} = 1.4 + 2.625 = 4.025\, m^3$$

Let effective height of pit as H meters.
Therefore,

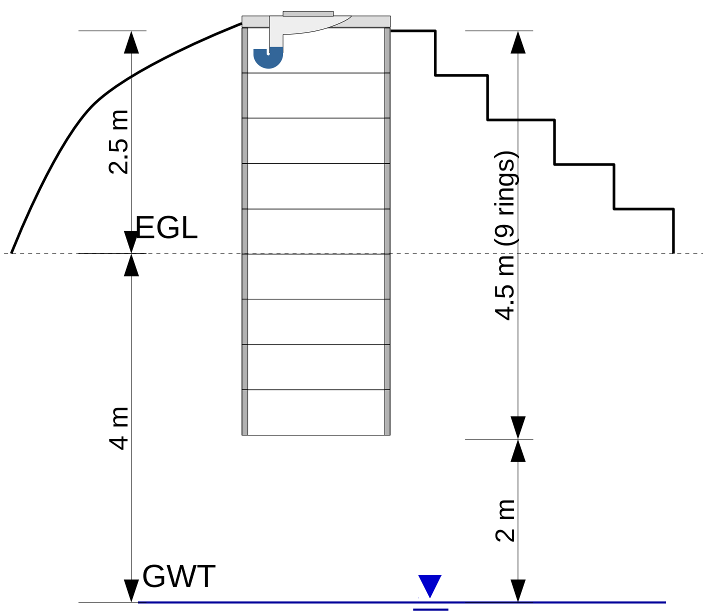
$$V_e = \frac{\pi D^2}{4} H \Rightarrow H = \frac{4\,V_e}{\pi D^2} = \frac{4 \times 4.025}{\pi \times 1.2^2} = 3.559\, m$$

$$\text{Number of rings, n} = \frac{H}{h} = \frac{3.559}{0.5} = 7.11 \approx 8$$

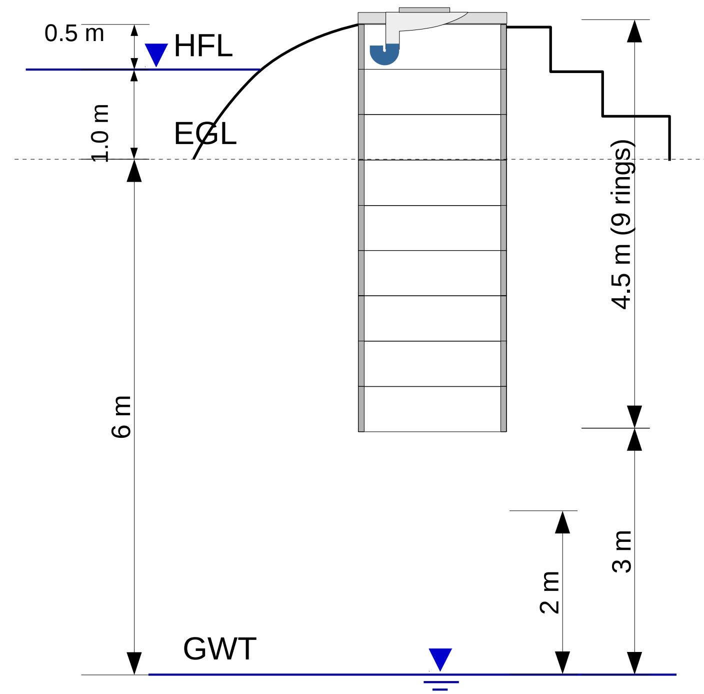
Use 9 rings. (Ans.)

Sanitation: Mathematical examples

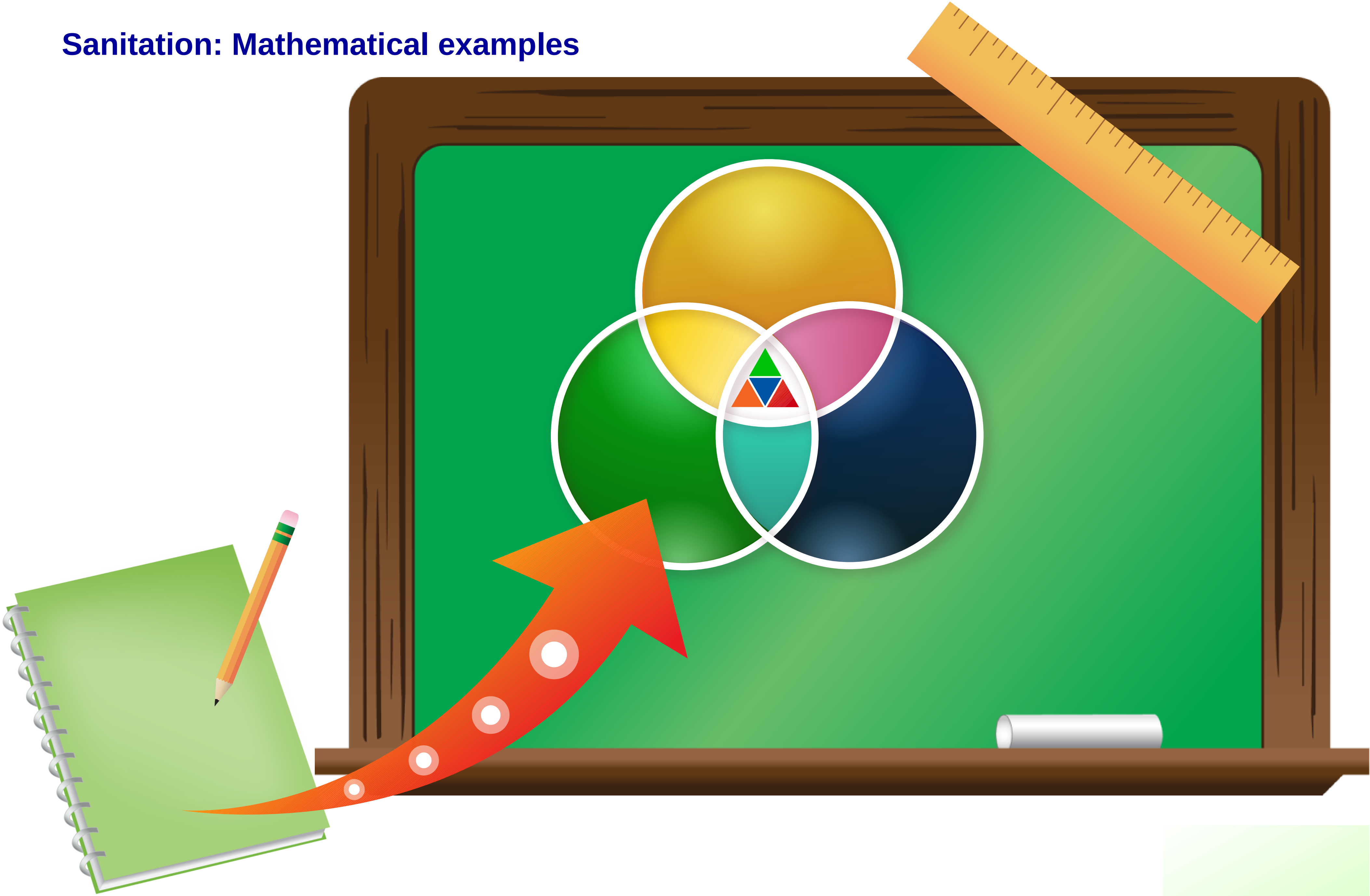
a) Sketch for GWT @ 4m depth



b) Sketch for GWT @ 6m depth with HFL @ 1m



Sanitation: Mathematical examples



Daffodil International University

Dr. Miah M. Hussainuzzaman