How fast do pits and septic tanks fill up? Implications for design and maintenance

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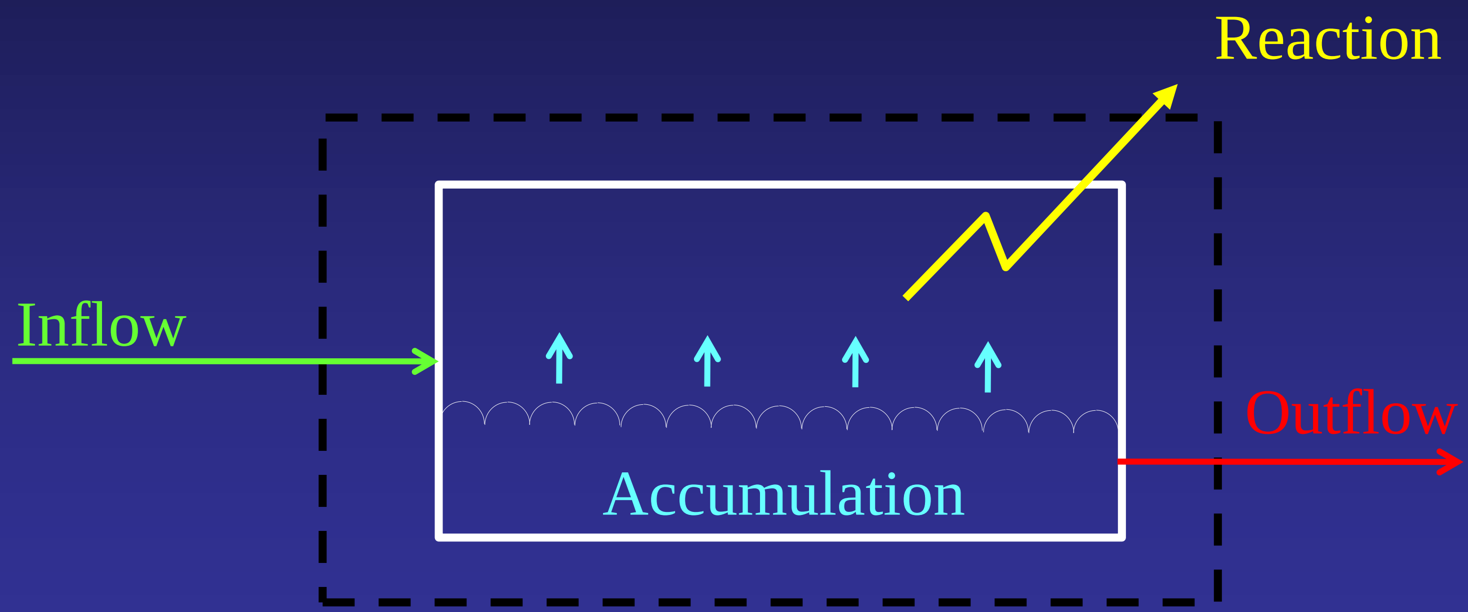
Mass Balances: An introduction to basic Chemical Engineering

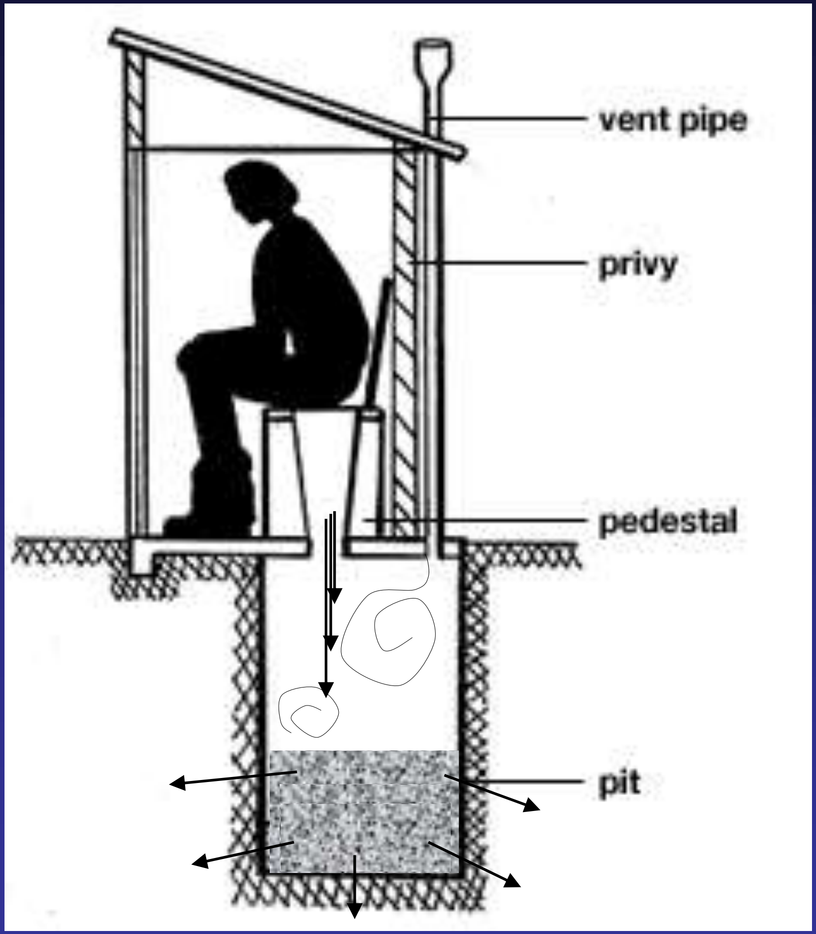
- Matter cannot be created or destroyed



Accumulation = Inflow – Reaction – Outflow

Application to pit latrines

- Inflow:
  - Urine and faeces
  - Anal cleansing material
  - Cleaning water, detergents, disinfectants, rubbish



- Reaction
  - Biodegradable material = Food
  - Food + O_2 → BUGS + CO_2
  - Food (no O_2) → bugs + CH_4 (methane)
- Outflow:
  - Continuous drainage to surroundings
    - Water and dissolved components
- Accumulation = Inflow – reaction – outflow

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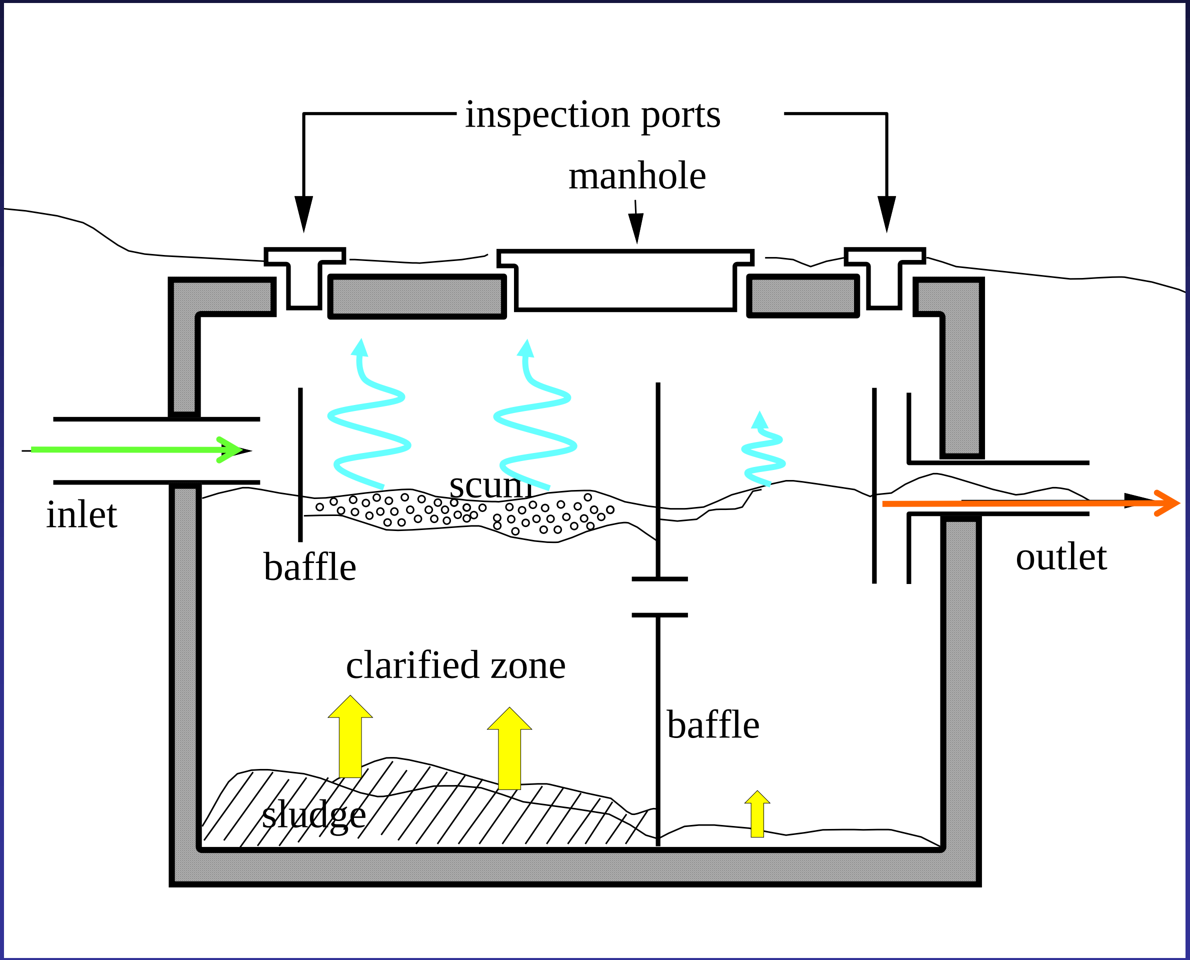
Mass balance in pits cont.

- So accumulation is due to
  - BUGS
  - bugs
  - Salts
  - non-degradable material (including rubbish)
  - Some undegraded, but potentially biodegradable material

Application to septic tanks



Inflow:

- Similar to pit *but*
- More water
- More detergent

Reaction:

- Similar to pit *but*
- Less oxygen
- More anaerobic (usually)
- Less aerobic degradation

Accumulation:

- Scum (degrades slowly)
- Bugs
- Unbiodegradable material
- Some potentially biodegradable material

Outflow:

- Similar to pit *but*
- More water
- Solids can leave too

Accumulation rate calculations:

- Rate at which material is added
  - Average excreta production per person per day
    - Faeces ~0.12 – 0.40 ℓ /d
    - Urine ~ 0.6 – 1.5 ℓ /d
  - Average addition per person per year
    - Faeces = 0.3 ℓ /d × 365 d/year = 110 ℓ /ca.year
    - Urine = 1.2 ℓ /d × 365 d/year = 440 ℓ /ca.year
  - Total volume added: 550 ℓ /person.year

Accumulation rate in pit latrines: Data

- Faeces added ± 110 ℓ /person.year
- Measured solids accumulation rates:

Solids content: approx 330g/kg

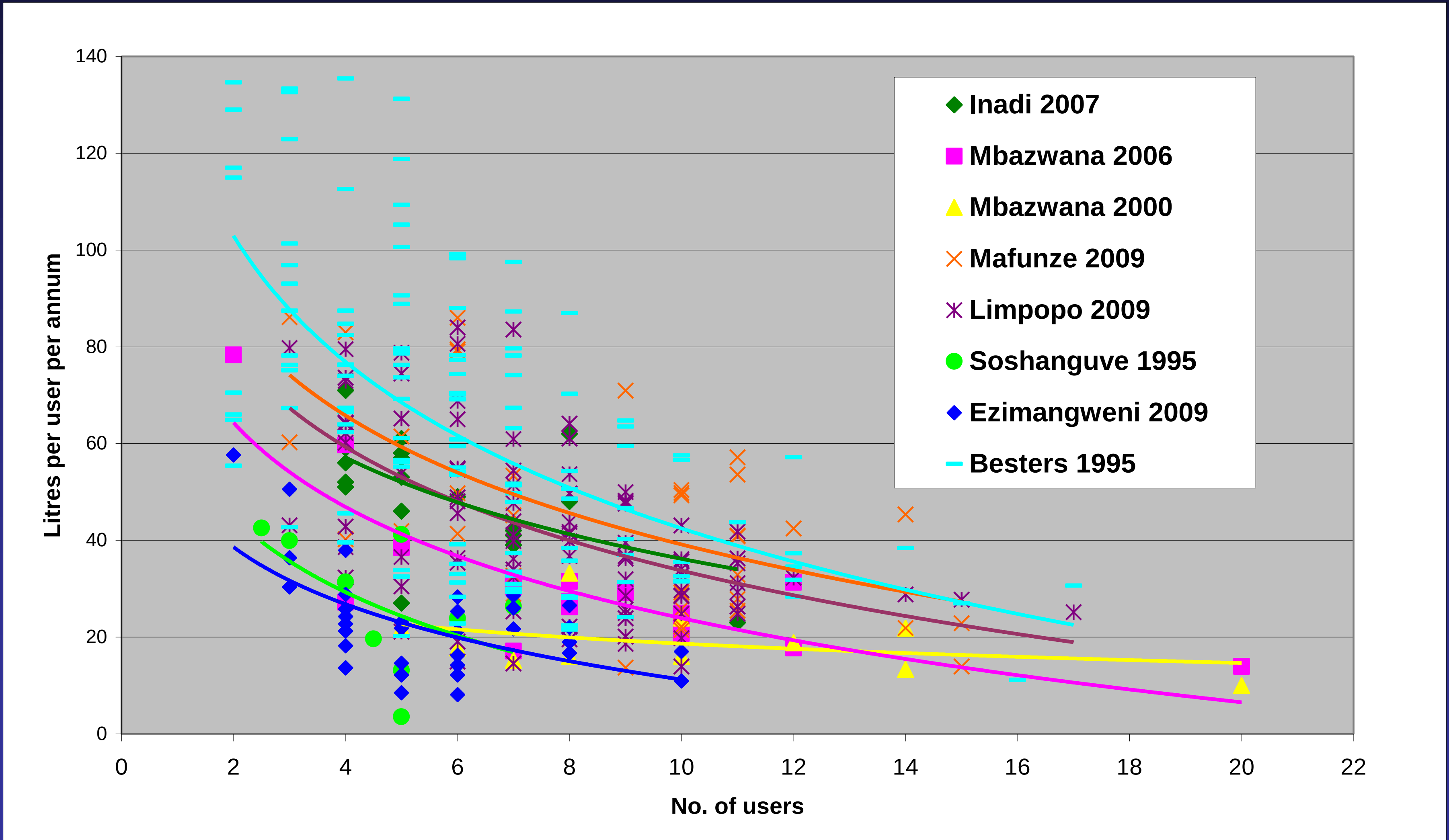
Study area	**Filling rate [ℓ/person.year]**	**Reference**
Soshanguve	24	Norris (2000)
Philippines	40	World Health Organisation (1958)
Besters Camp (eT Muncip.)	<20 to >80 (70)	City of Durban
Mbazwana (northern KZN)	10 to 78 (25)	Partners in Development
Limpopo	43	Tsonang NGO
Mafunze	11 to 146 (48)	Partners in Development
Ezimangweni (eT Muncip.)	27±10	UKZN
Savana Park (eT Muncip.)	31±21	UKZN
Folweni (eT Muncip.)	44±46	UKZN

Don't forget toilet paper!

Accumulation in pit latrines: Mass balance

- Less sludge accumulates than the amount of faeces added
  - (even ignoring rubbish and toilet paper!)
- i.e. A significant amount of solids reduction occurs in the pit
- The solids reduction is predominantly due to biological action
- Liquid mostly leaves the pit through pit walls

Sludge accumulation rate vs. no. of users



Accumulation rate in Septic tanks: Data

- Faeces added ± 110ℓ/person.year
- Measured solids accumulation rates:

Solids content: approx 30g/ℓ

Filling rate [ℓ/person.year]	**Comment**	**Reference**
64 - 92	Decreases with time	Gray (1995)
50	Decreases slightly with time	Bounds (1995)
69		PHS (1949)
64		Moore (2000)
76		Pradhan (2007)
69-106	Decreases with septic tank size	Brandes (1978)

Comparison between pit latrines and septic tanks

– Cannot compare rates in ℓ/person.year since septage is much *wetter* (more water) than pit latrine sludge
  - Using some rough density values
    - Pit sludge = 1.5 kg/ℓ
  - Using limited solids content data from literature
    - Pit sludge = 330 g Solids/kg
    - Septage = 30 g Solids/L
  - Gives average (dry) solids accumulation rates of

– Pit sludge = 19 kg dry solids/person.year

– Septage = 2 kg dry solids/person.year

Summary: pit filling rates

- Pit latrines:
  - Wide range of numbers observed in field
    - 40ℓ/person.year seems a reasonable mean
    - 60ℓ/person.year reasonable figure for design
  - Accumulation rate *decreases* with number of users
  - Accumulation rate *decreases* as pit fills (rate of filling slows with time)

Summary: Septic tank filling rates

- Septic tanks:
  - Wide range of numbers observed in field
    - 60ℓ/person.year seems a reasonable mean
    - 80ℓ/person.year reasonable figure for design
  - Greater volumes of sludge generated than in pit latrines, but solids content is much less (10%).
  - Accumulation rate *decreases with time*

Removed sludge

- In both cases, the sludge is fairly well stabilised (little residual biodegradability)
- Should not be put into WWTP!

Helminth eggs

- Most human pathogens (virus, bacteria) are deactivated in pit latrines and septic tanks
- Helminth eggs are the most persistent
- UKZN/PID studies on Ascaris egg viability in exhumed pit latrine sludge

Helminth eggs in pit sludge - results

- Total egg counts: 0 – 3500 eggs/g sludge
- % of eggs possibly viable: 0-96%
- % of eggs with visible larva: 0-40%
- % of eggs definitely infectious: 0-9%
  - (motile larva)

- Material from *emptied pits* therefore average age >5 years

Helminth eggs in septage

- Literature indicates values between 10^2 and 10^3 eggs/g sludge

- *Indicates that long residence in a pit latrine or septic tank does not deactivate helminth eggs*

Filling rates: implications for design

- Design around maintenance programme:
- Approach (1)
  - Design for government/municipal/NGO emptying programme (householder not responsible)
  - t = Frequency of emptying (e.g.10 years)
  - r = Design filling rate (e.g. 60ℓ/person.year)
  - n = Average number of users in household (e.g. 6 people)

- Design equation: Pit volume = V = r×n×t

e.g. V= 60ℓ/person.year × 6 people × 5years

= 3 000 ℓ

= 3 m^3

Filling rates: implications for design

- Design around maintenance programme:
- Approach (2)
  - Large pits are difficult to empty
  - Require *professional* emptiers
  - Require specialised equipment
  - 100% risk of helminth infection

- Therefore, if no local capacity for organised emptying programme, build shallow pits that can be emptied by householder.
- Or, if high capacity for organised emptying programme, build shallow pits that can be quickly emptied with reduced risk of helminth infection.

Design of septic tanks

- More complicated since design includes
  - Sludge accumulation
  - Liquid flow
- Many standard design texts
- Bigger tanks require less frequent desludging.

What next?

1. What do you do with the emptied pit contents?
2. Improved design, better operation requires better understanding of what happens in pit latrines.

Acknowledgements

- Water Research Commission
- eThekwini Municipality