Vapor-permeable membranes:
Three potential uses in fecal sludge management for safe sanitation and resource recovery

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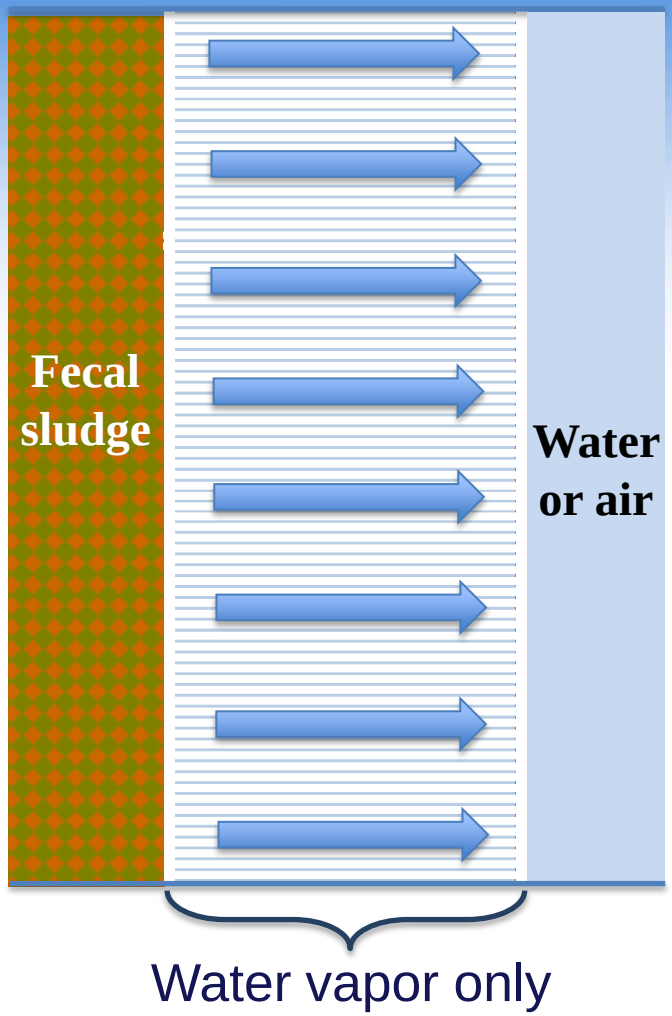
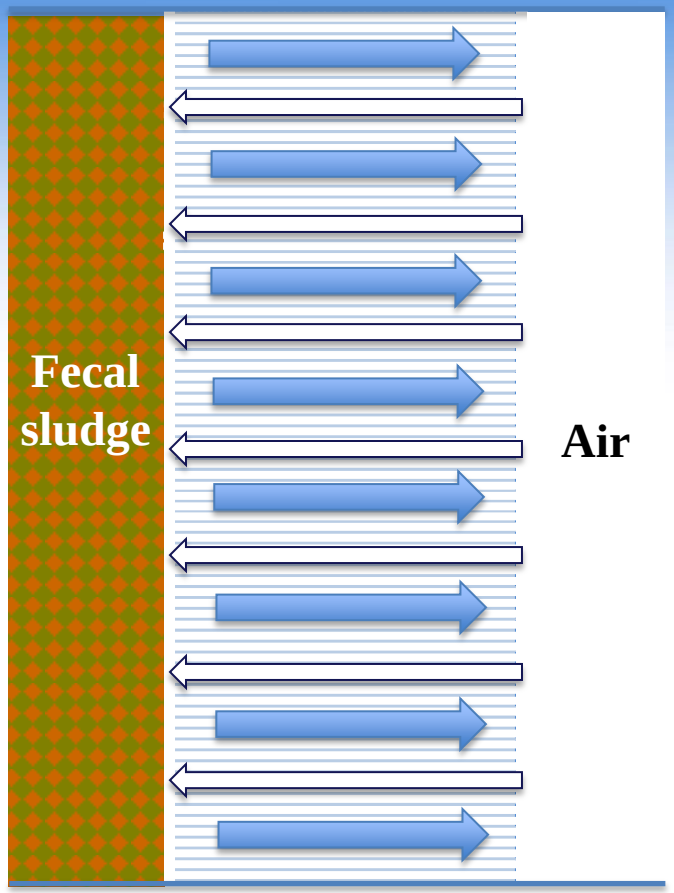
First, what are the characteristics of a "vapor-permeable membrane"
(also termed a "breathable" membrane)

- Permeable to water vapor
- Not permeable to liquid water
- Very hydrophobic
- Passages are not wetted: only contain air or water vapor
- Won't allow solutes to pass through
- Won't allow particulates of any size
- "Non-stick" like a PTFE frying pan



First, what are the characteristics of a "vapor-permeable membrane"
(also termed a "breathable" membrane)

- Fecal sludge has minimal contact with the membrane, so clogging is unlikely
- With no clogging, the fabric can be re-used multiple times
- The fabric has considerable tensile strength: can support weight of fecal sludge
- Air can diffuse into the fecal sludge while moisture is diffusing outward



Now, a bit about our specific project:

Project Objectives

Phase I ($100K)

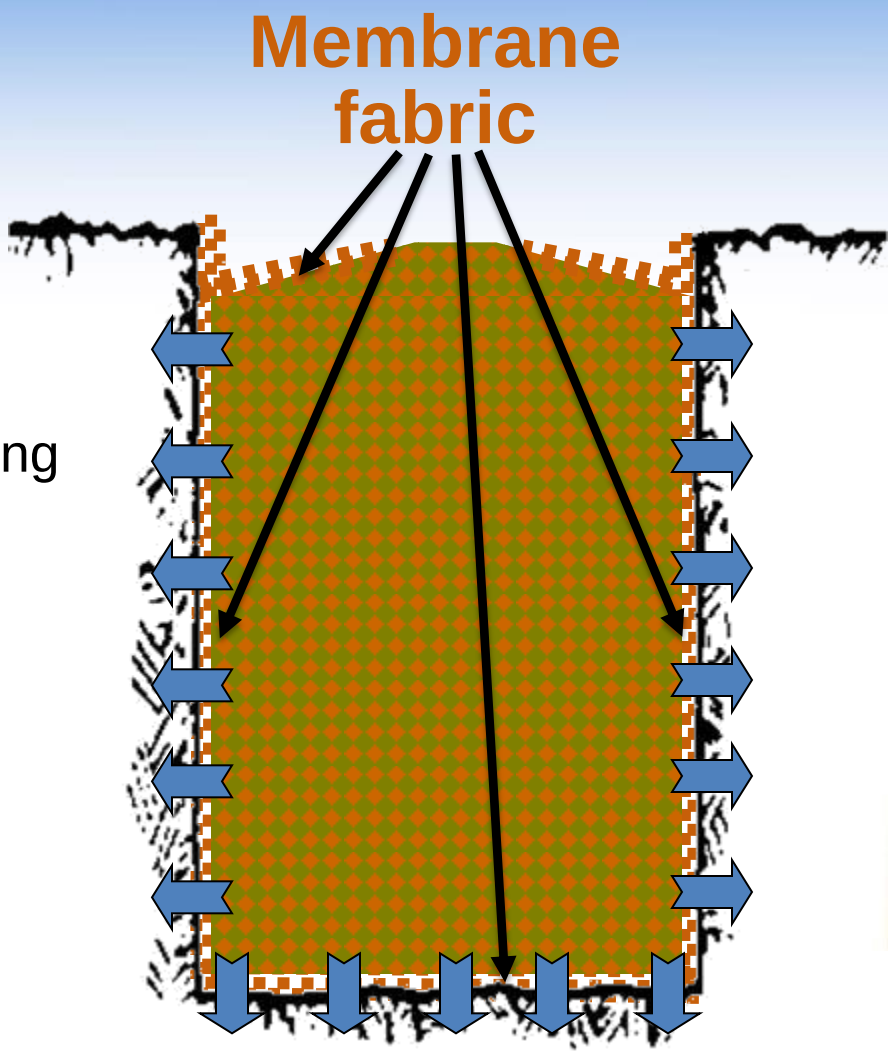
- Establish membrane performance
- Estimate scale-up possibilities as pit enclosure

Phase II Year I ($100K):

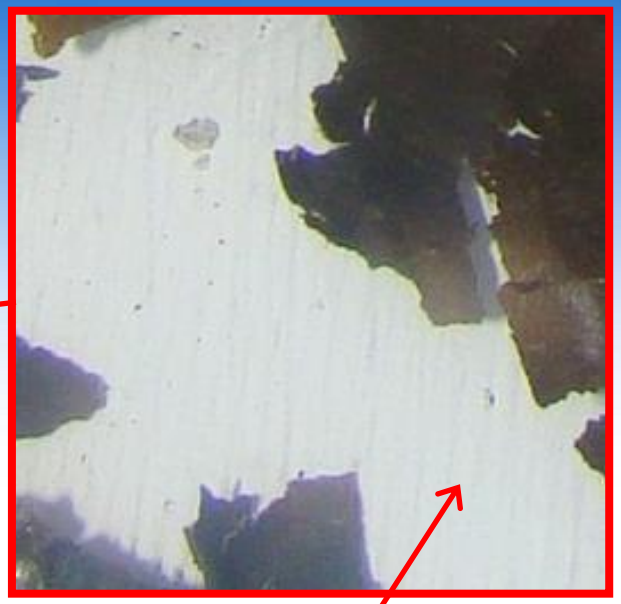
- Provide more evidence of non-clogging
- Identify more promising applications

Phase II Year 2 ($150K):

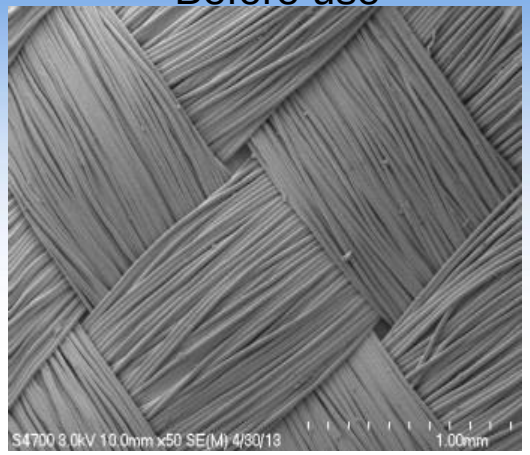
- Locate high potential partnering opportunities
- Test proposed applications on-site



Despite much skepticism, the membranes do not foul or clog

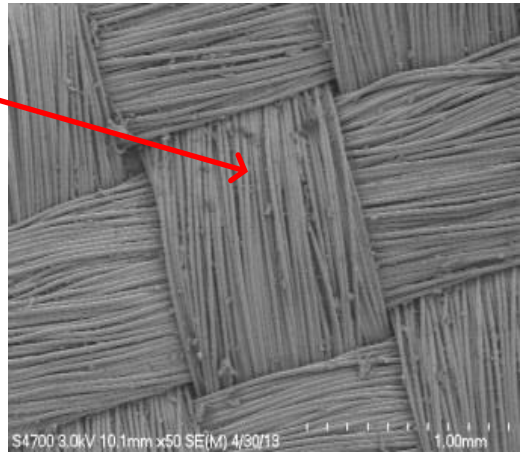


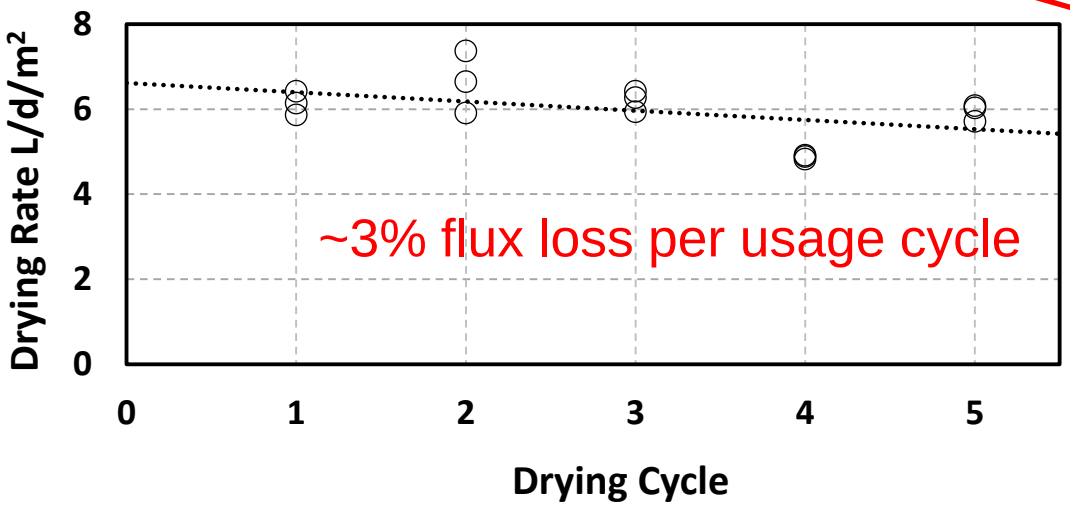
Before use



No significant fouling or deposition

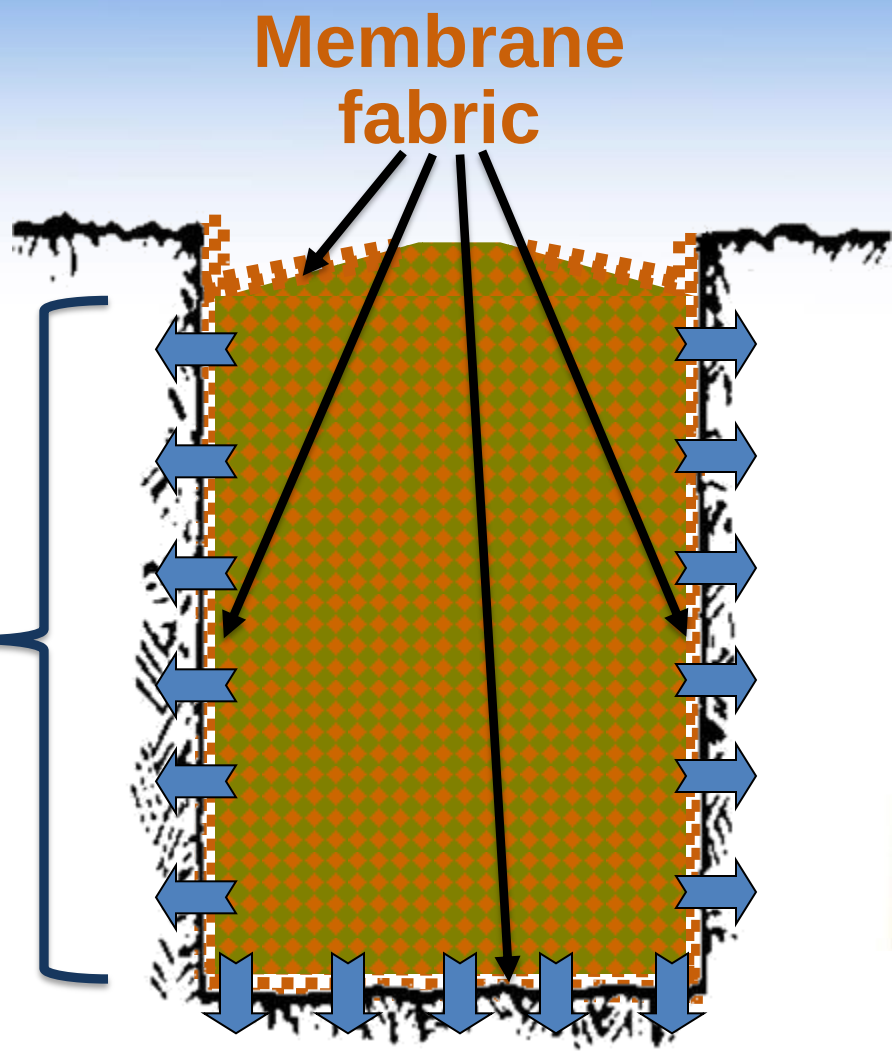
After use





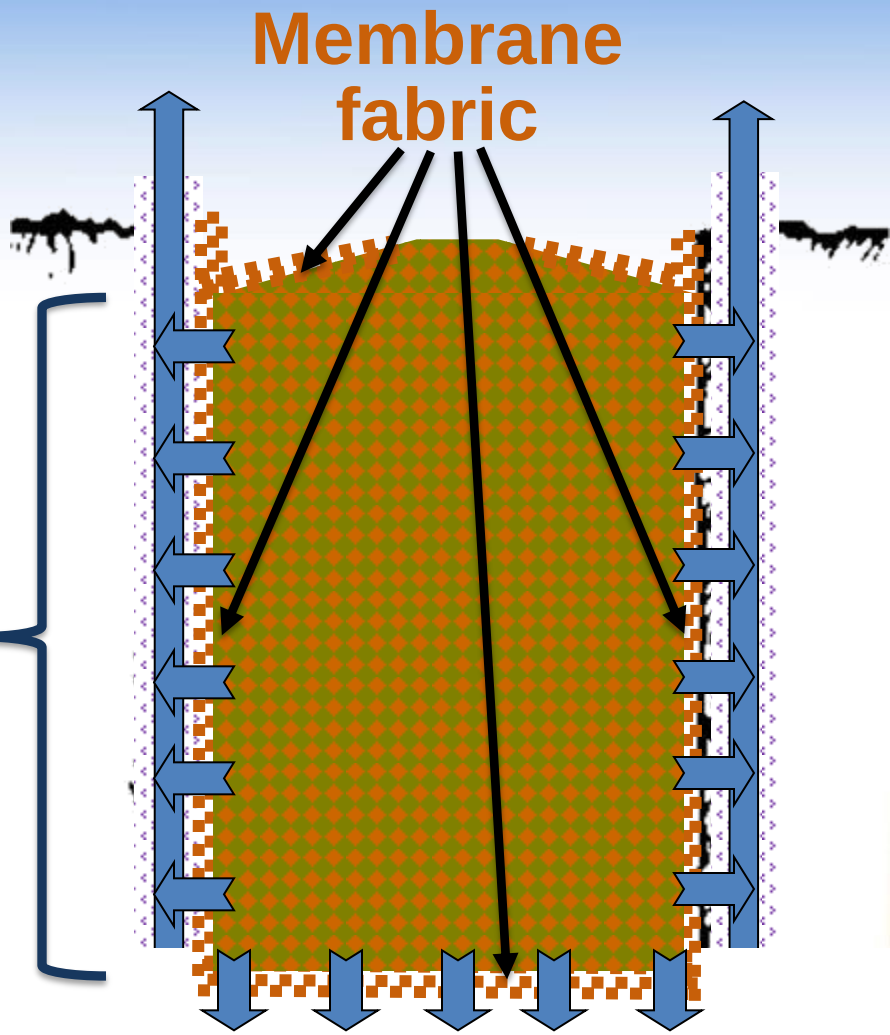
Three potential uses of the membrane fabric

Original idea:
how to improve it?



Application #1: Passive ventilation around (or through) the membrane

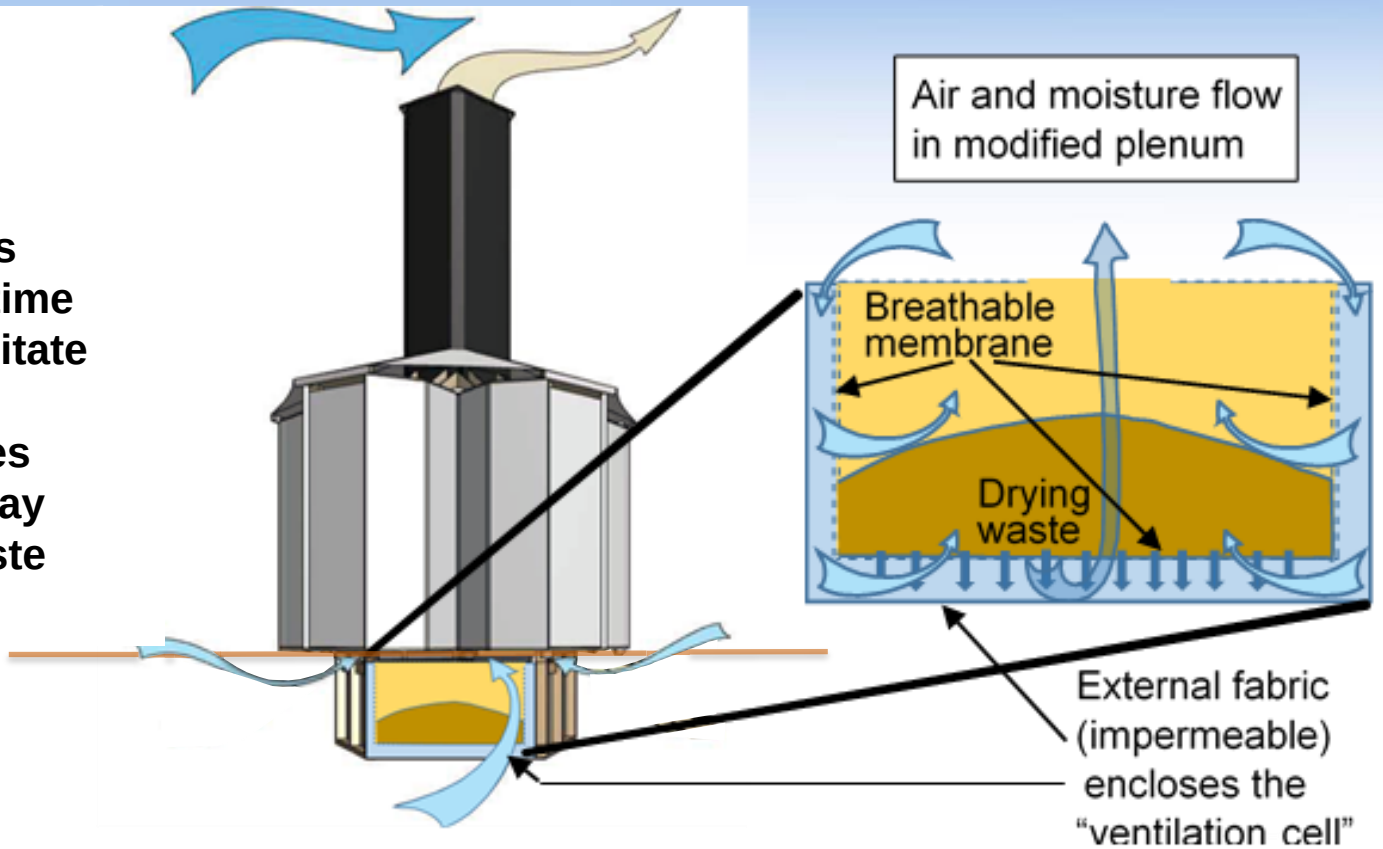
Ventilation space



Application #1: Passive ventilation around (or through) the membrane

Air flow maintains dry air across membrane from the waste

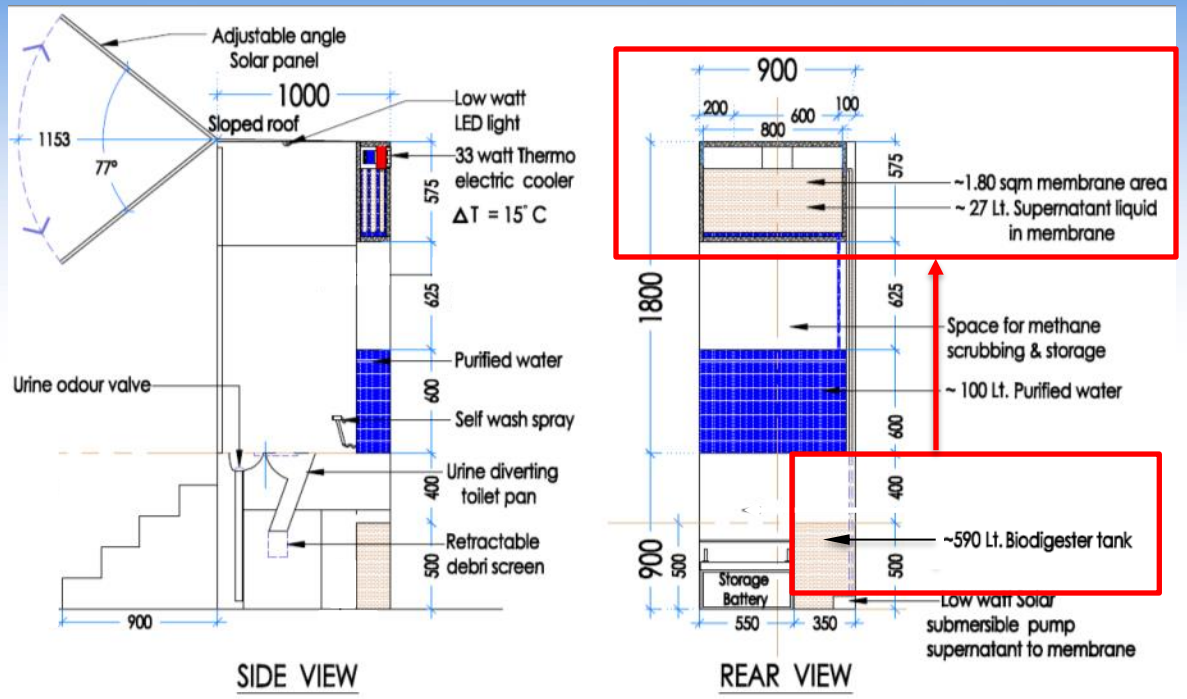
- **Drying increases storage time**
- **May facilitate aerobic processes**
- **Fabric may ease waste removal**



Latrine "cluster" shown in this configuration

Illustration adapted from Larsen (2013)

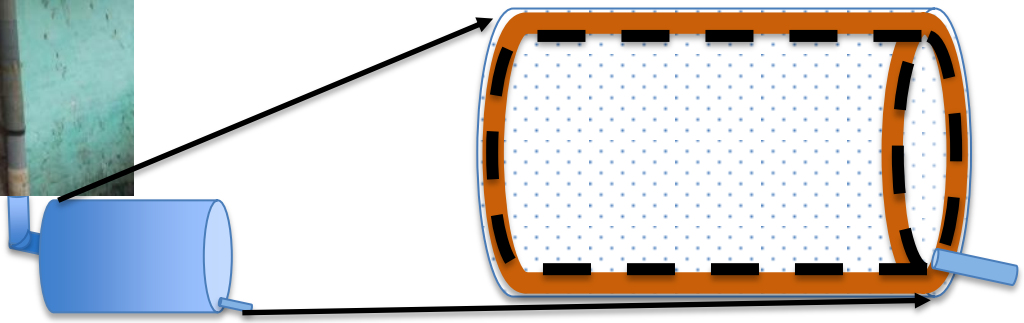
Application 2: Water extraction from biodigestion of fecal sludge



- **Biodigester may be from single or group latrines or collected waste**
- **Digester supernatant is problematic due to pathogen content**
- **Membrane could be used to help remove excess water from biodigester**

Application 3: enclosure for above-ground waste collection

- Roof latrine necessary in dense urban areas
- Excreta collected in metal or plastic drum
- Holes punched to allow drying, air circulation
- Membrane fabric sewn in cylindrical shape and inserted
- Sand between drum and membrane
- Dark color drum to enhance solar heating
- Latrine on roof minimizes garbage in waste
- Fabric sac and drum can be emptied and reused
- Simple and inexpensive (<$20)



All 3 applications still have uncertainties…that's why we're not done!

Final notes

- Resource recovery: composted “humanure”
- Small amount of water is recoverable in theory
- Energy may be acquired by biodigestion (but only 1-3 W per person’s waste maximum)
- On-site tests planned in Kanpur, India with WaterAid (application #3 and others)
- Priorities are low cost, low maintenance, and simplicity

Thanks for listening!

Please, tell me what you think….
or what you're wondering.

Contact me at dentel@udel.edu

Extra slides

Typical Membrane Fabric Structure

The membrane is contained in a three-layer fabric

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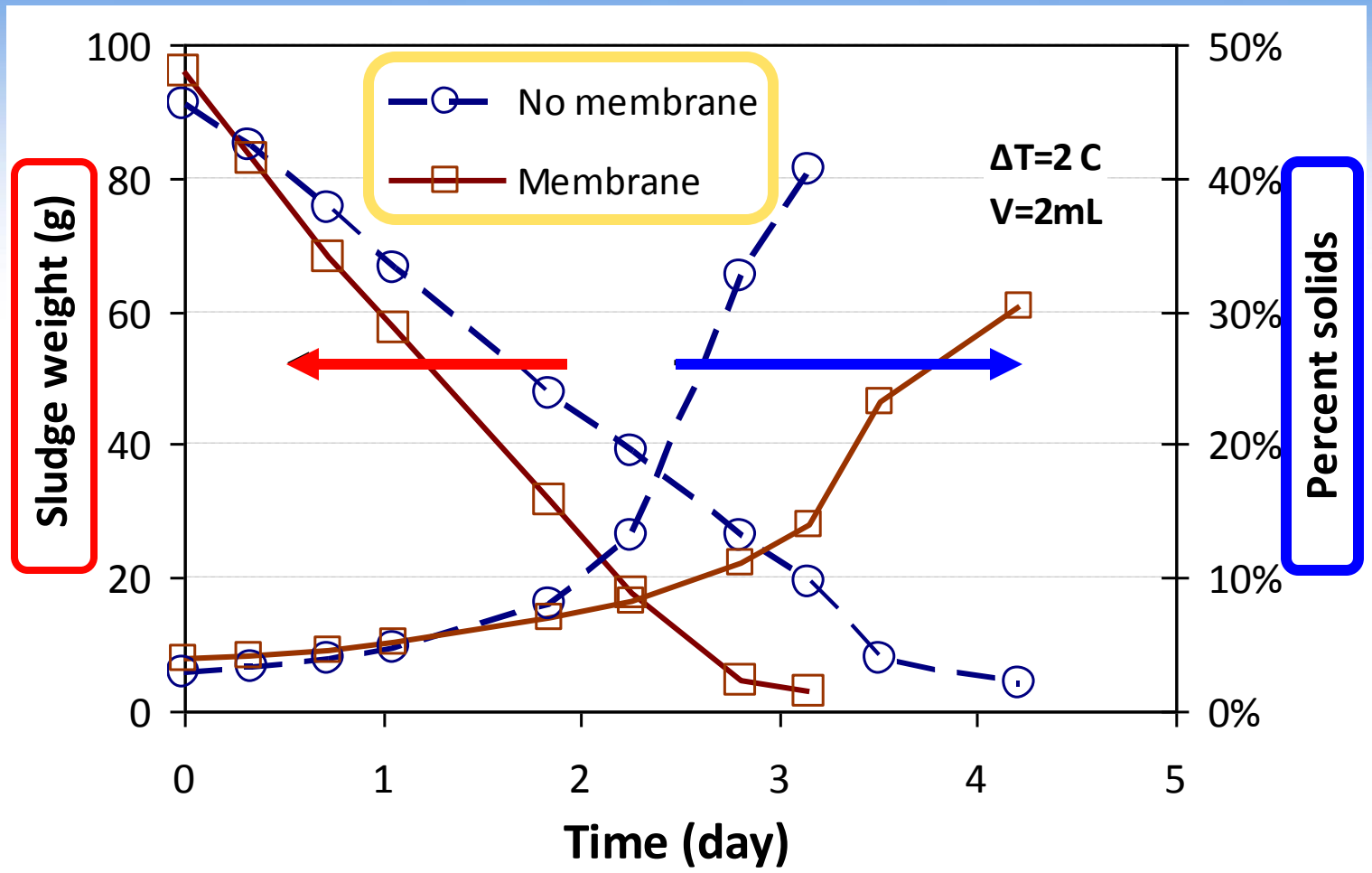
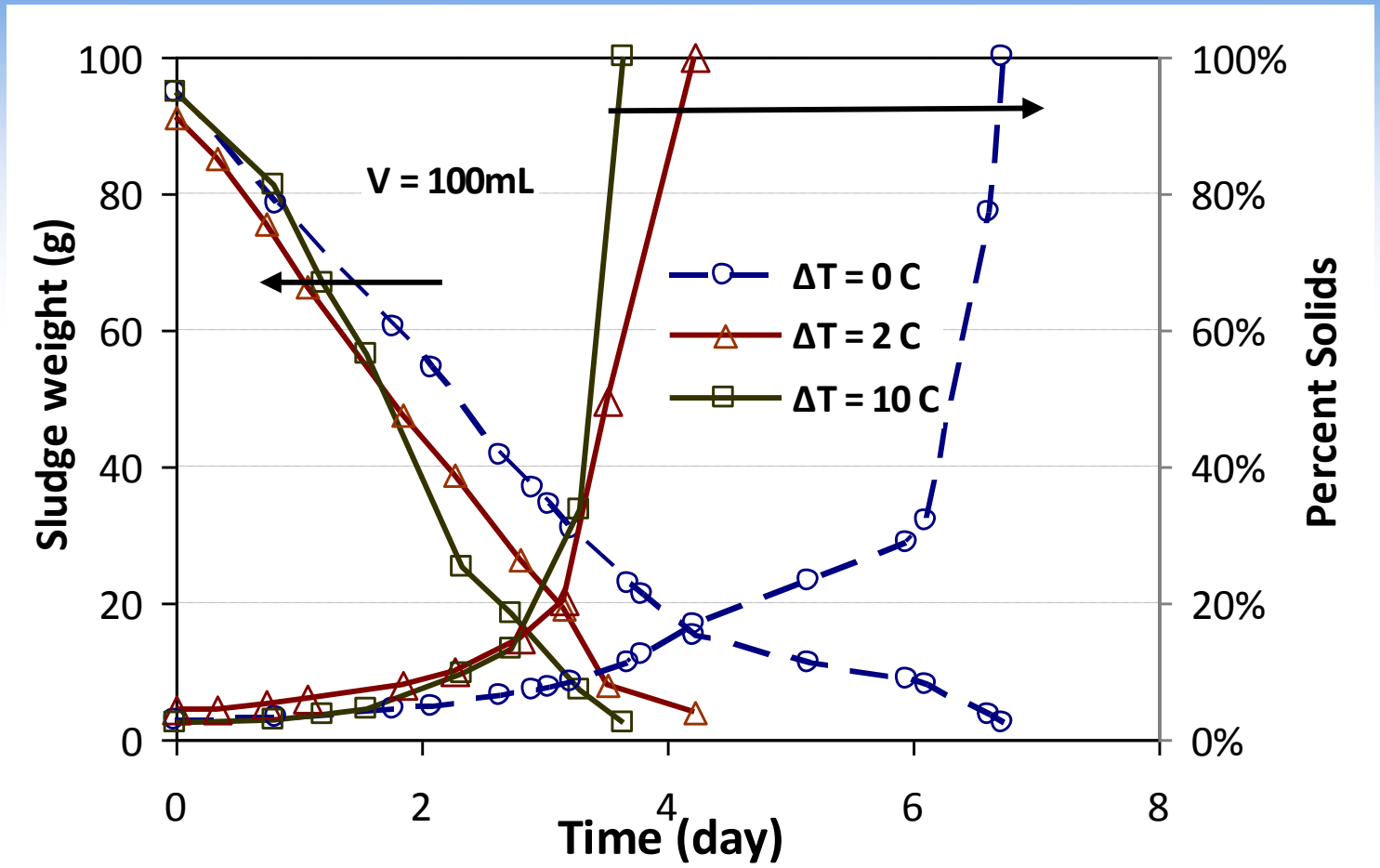
Results

Drying with/without membrane

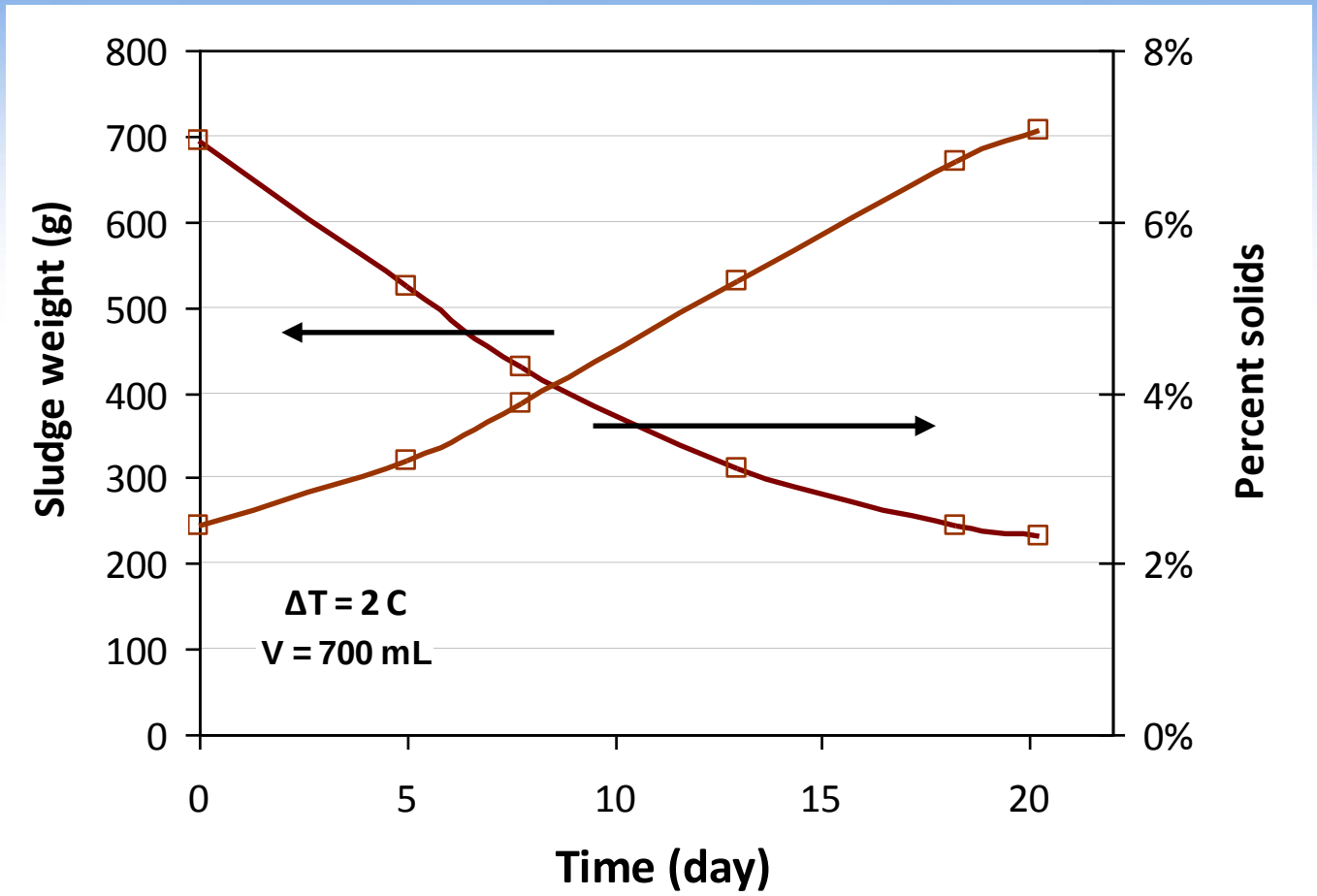


Effect of temperature difference (ΔT)



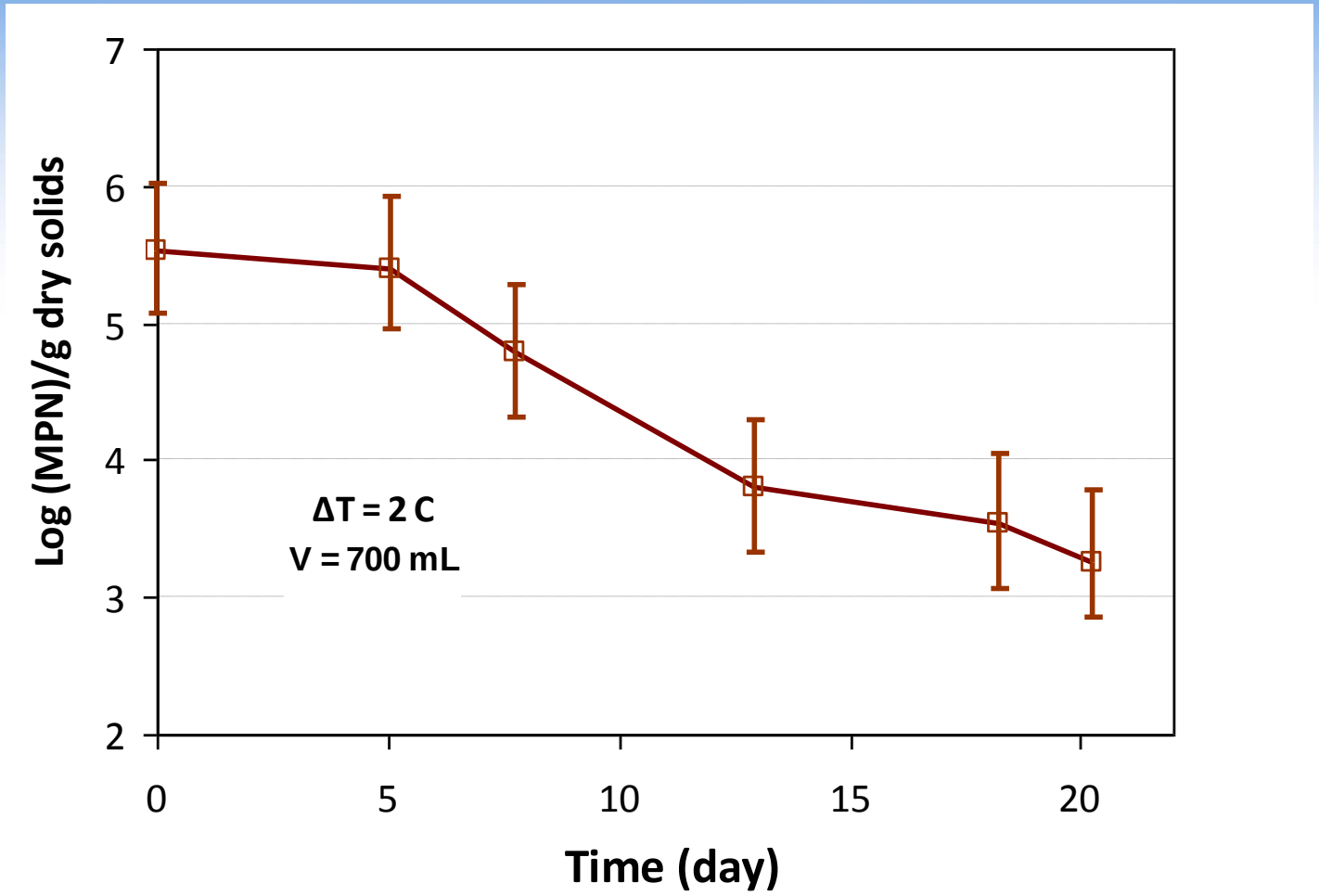
Greater ΔT speeds up drying, but 2C difference seems sufficient

In contact with water instead of air



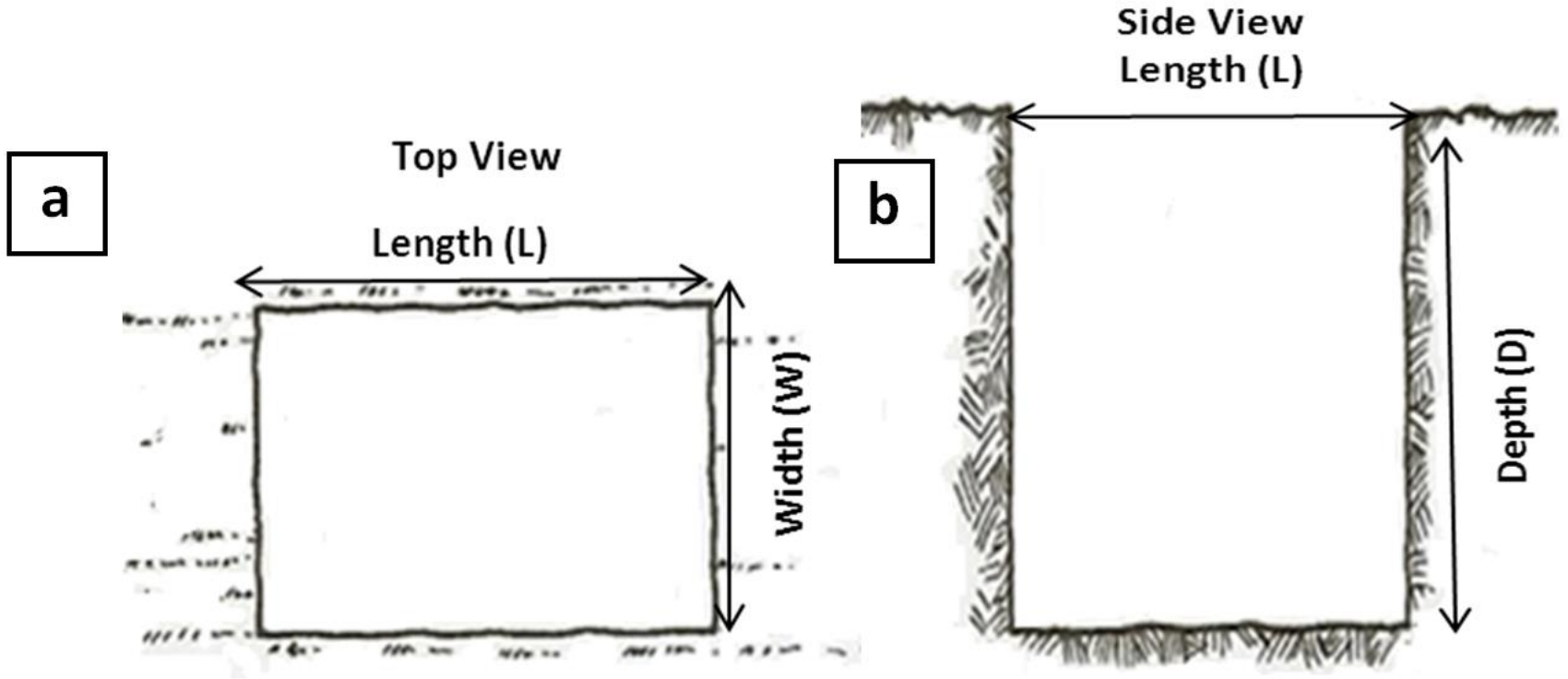
Slower water removal, but 2/3 of water is still removed

Bacterial die-off



99.4% removal of fecal coliform. ND across membrane.

Drying rate depends on membrane surface area, and thus on pit dimensions



Typical pit latrine design criteria. L= 1.2m, W=1.1m, and D= 2.1 m. From (Franceys, 1992).