11.479J / 1.851J Water and Sanitation Infrastructure in Developing Countries
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On-site Sanitation

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Water and Sanitation Infrastructure
in Developing Countries
Mass. Institute of Technology

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On-site Sanitation

- Sanitation ladder: options in sanitation
- Ecological Sanitation
- Case Study: Ecosan in Kenya

Improved sanitation

- connection to a public sewer
- connection to septic system
- pour-flush latrine
- simple pit latrine
- ventilated improved pit latrine

The excreta disposal system is considered “adequate” if it is private or shared (but not public) and if it hygienically separates human excreta from human contact.

"**Not improved**“ = service or bucket latrines (where excreta are manually removed), public latrines, latrines with an open pit.

Sanitation “Ladder”

Technology

Hygiene

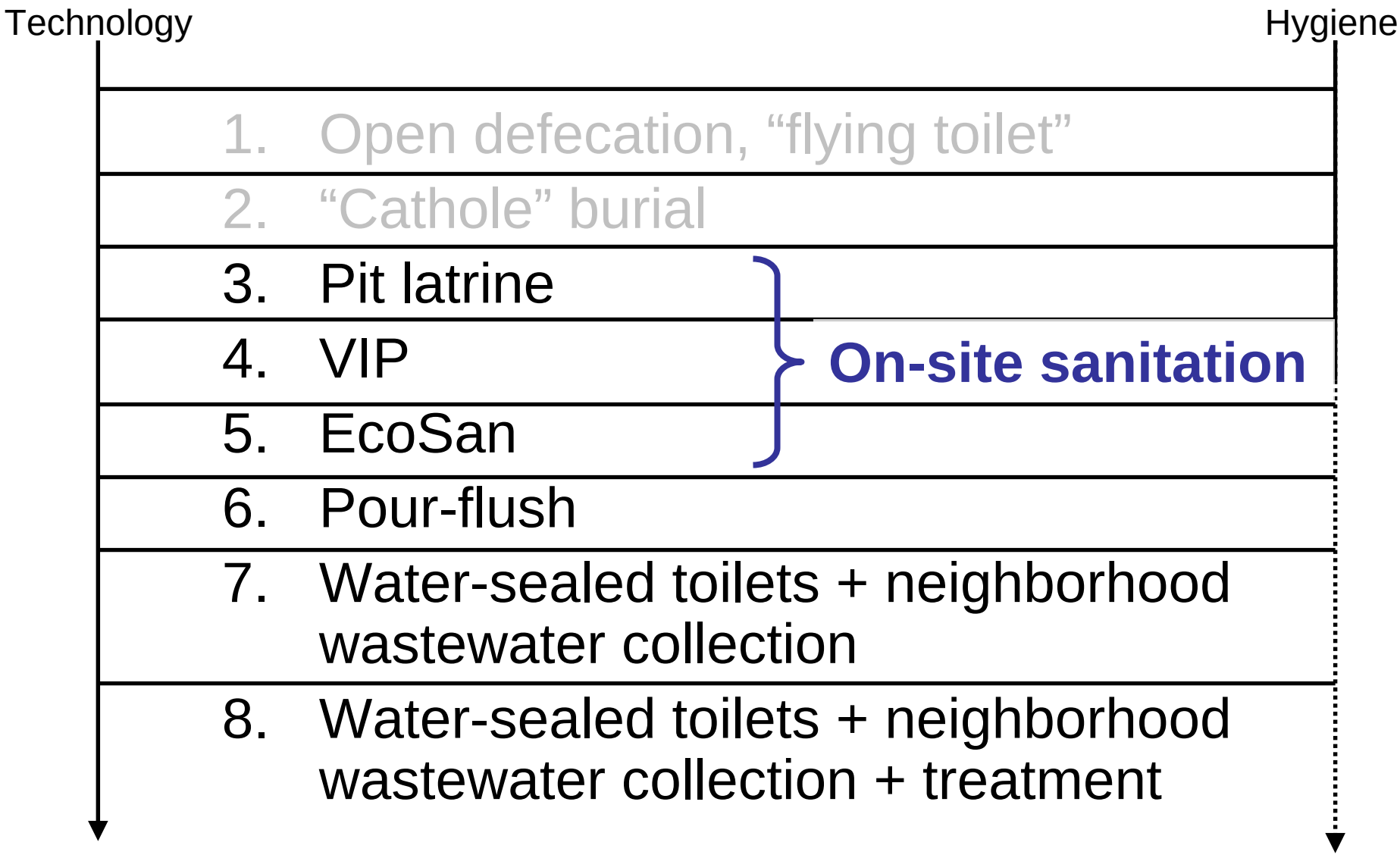
1. Open defecation, “flying toilet”
2. “Cathole” burial
3. Pit latrine
4. VIP
5. EcoSan
6. Pour-flush
7. Water-sealed toilets + neighborhood wastewater collection
8. Water-sealed toilets + neighborhood wastewater collection + treatment

1. No sanitation

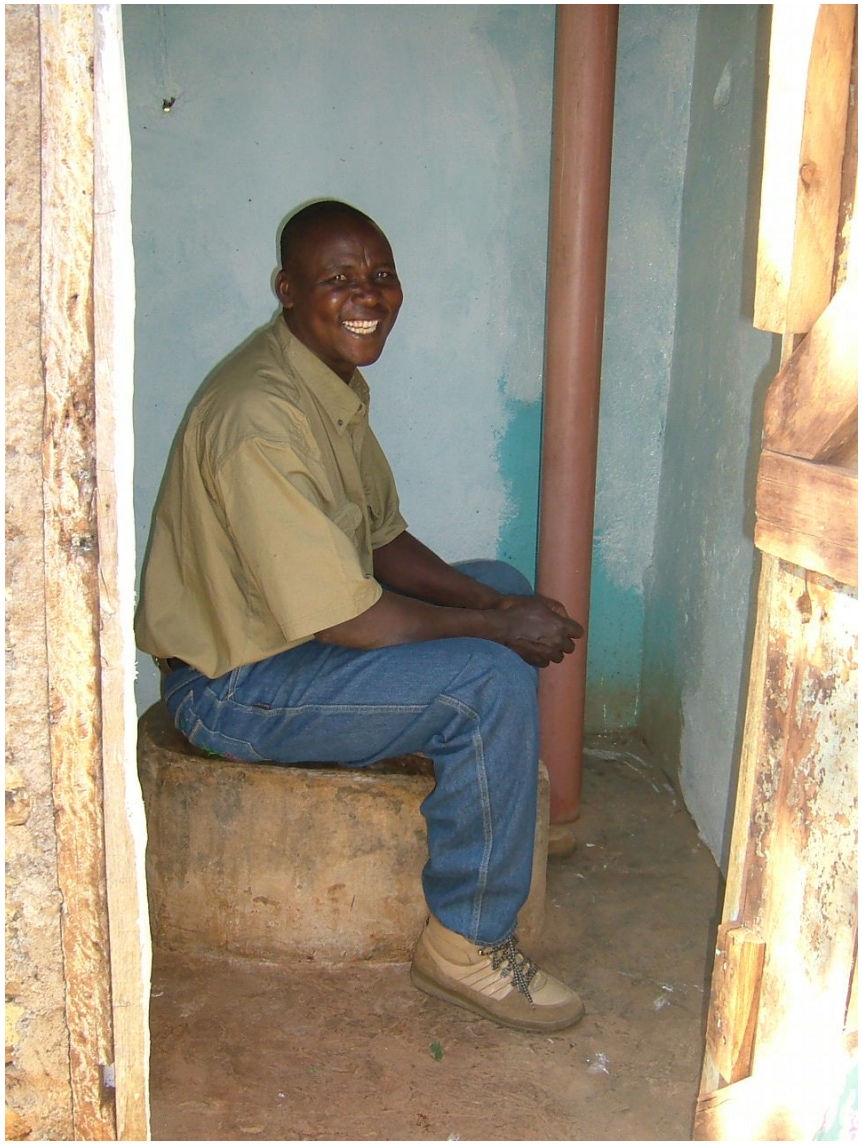
*S. Murcott

2. “Cathole” burial

Sanitation “Ladder”



3. Pit latrine – with pit




Drainage?
3. Pit Latrine, No Pit

4. Ventilated improved pit latrine (VIP)

A dry latrine system, with a screened vent pipe to trap flies and often with double pits to allow use on a permanent rotating basis. Considered a safe, hygienic means of excreta disposal.

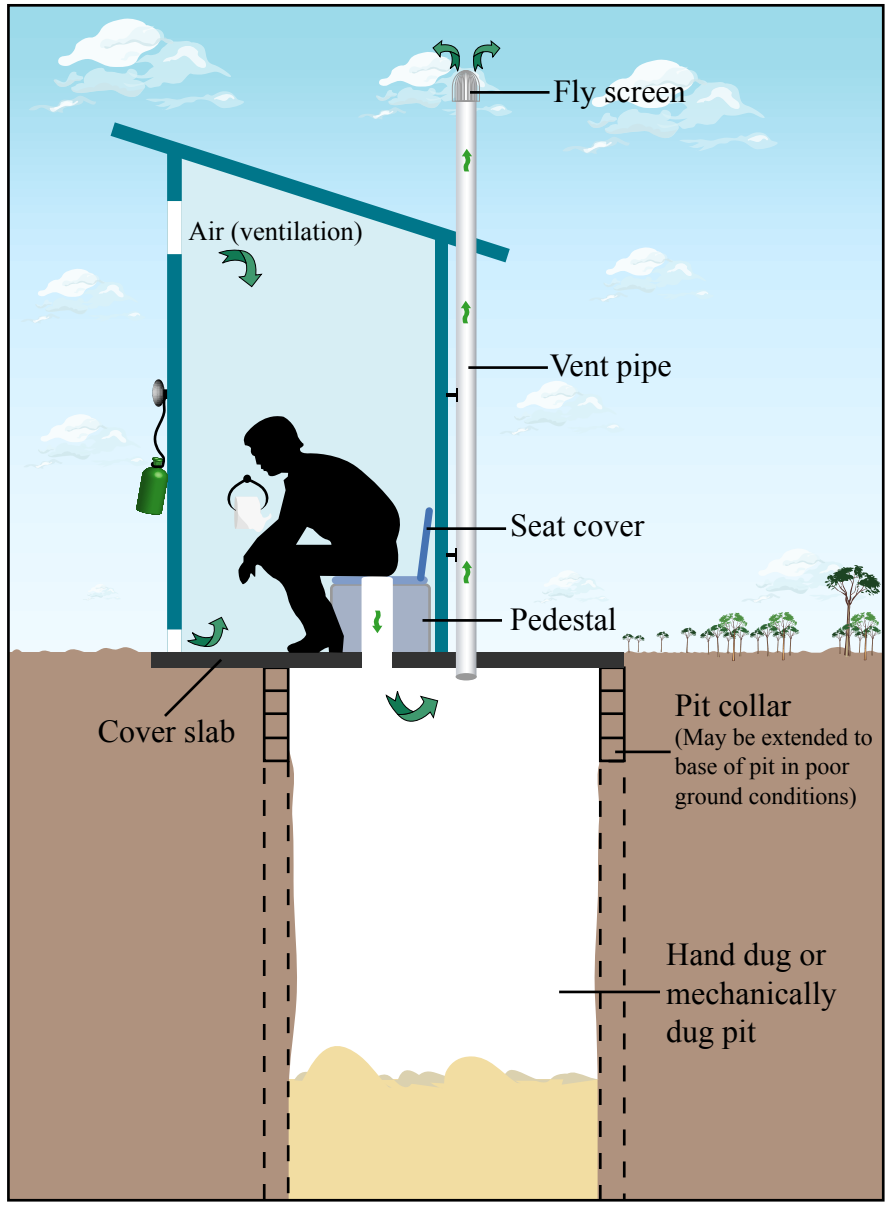


Figure by MIT OpenCourseWare.

http://web.mit.edu/urbanupgrading/

VIP Latrine

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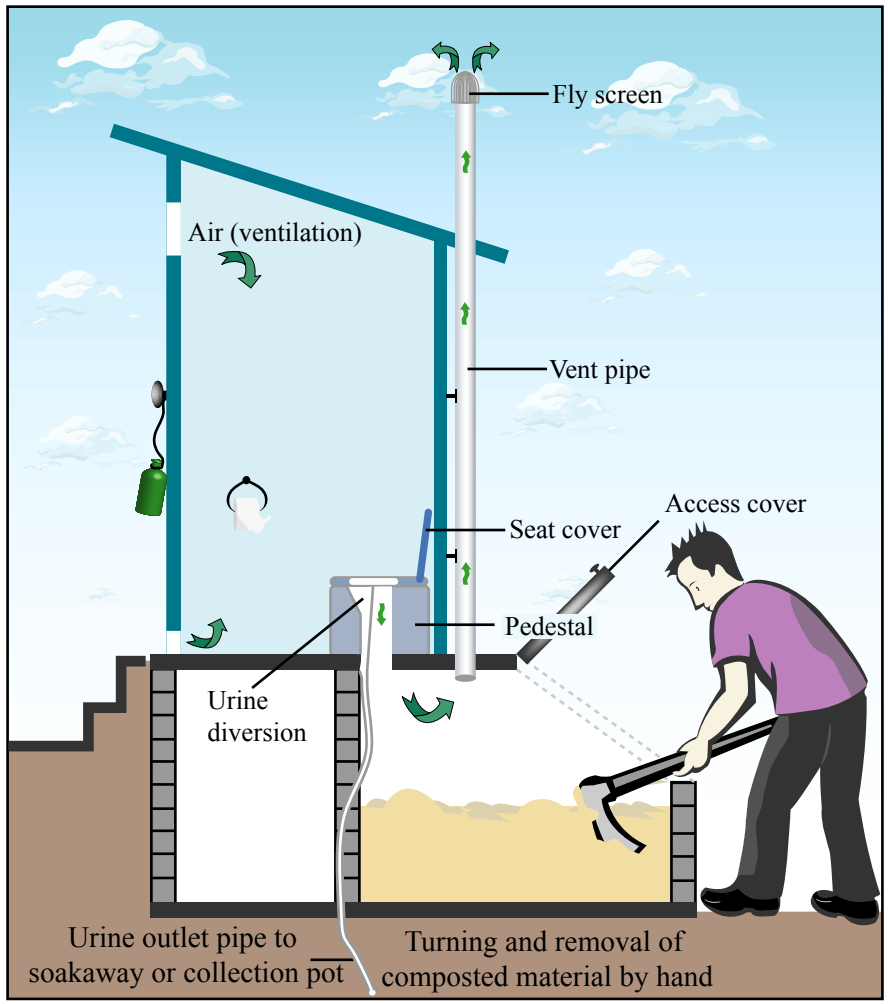
All those fill up!

Vac-U-Pump is one solution, but:

- Cost of pumping
- Physical space for tractor, pump
- Who's responsible
- Need pits, structured vaults

5. Ecological Sanitation

Ecosan refers to the on-plot handling (with or without urine separation) of excreta with minimal use of water so that urine nutrients and sanitized biomass are the end products.



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5. Ecological Sanitation

How Does It Work?

Decomposition by Dehydration

- Dry sanitation (<20% moisture)
- Addition of ash, soil, or lime
- Residence time: 6-12 months

OR

Decomposition by Composting

- Pathogen destruction by aerobic microbial activity
- Temperatures >60ºC
- Proper moisture content, C:N ratio, pH

5. Ecosan in Kenya

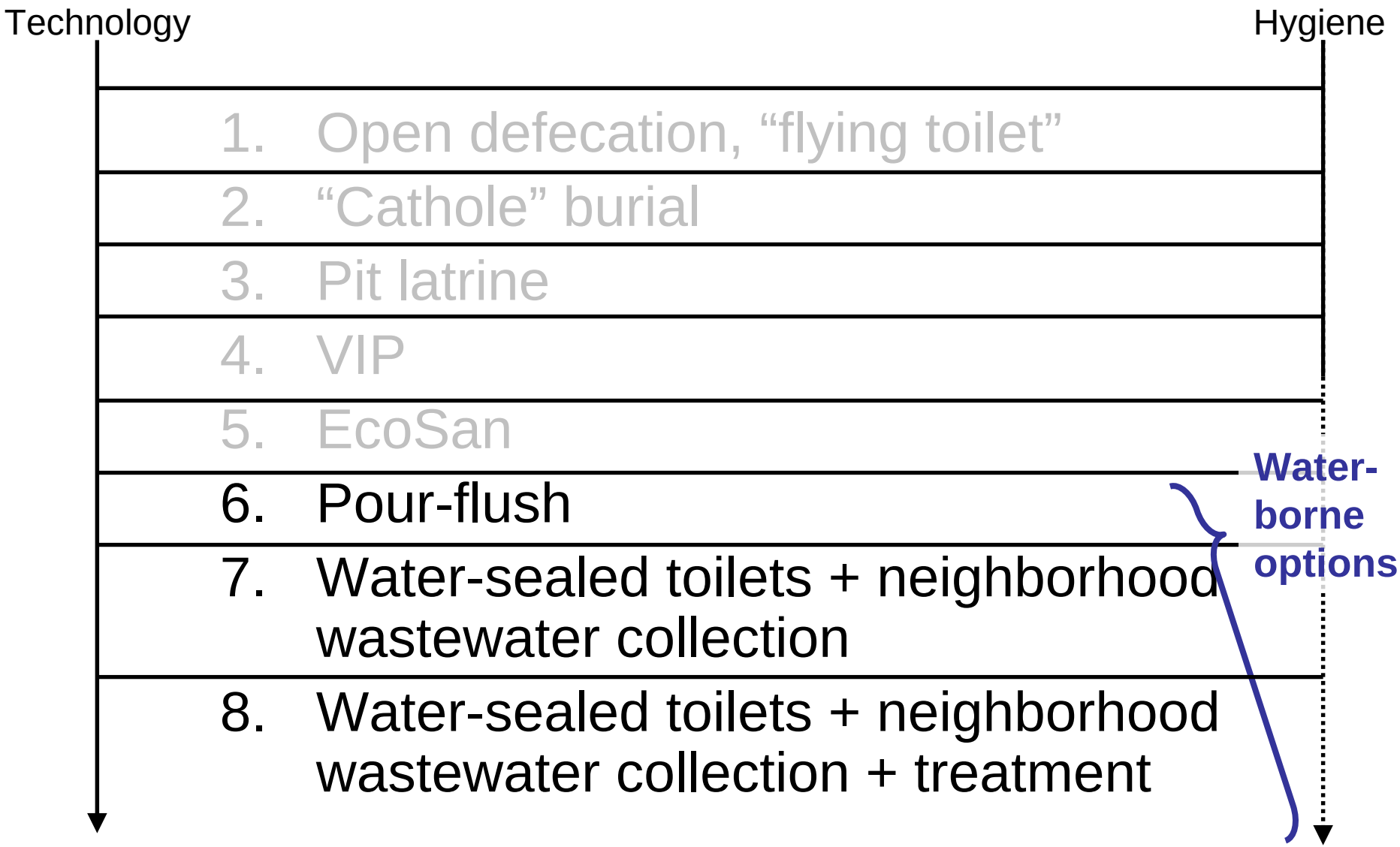
Ecological Sanitation

Composition of Excreta

	Urine	Feces
Nitrogen	88 %	12 %
Phosphorus	67 %	33 %
Potassium	71 %	29 %
Wet Weight	90 %	10 %

Adapted from Sida, 1997

Sanitation “Ladder”



6. Pour-flush toilet

But then where does it go?

7, 8. Septic tank and soakaway or small bore solid free sewer

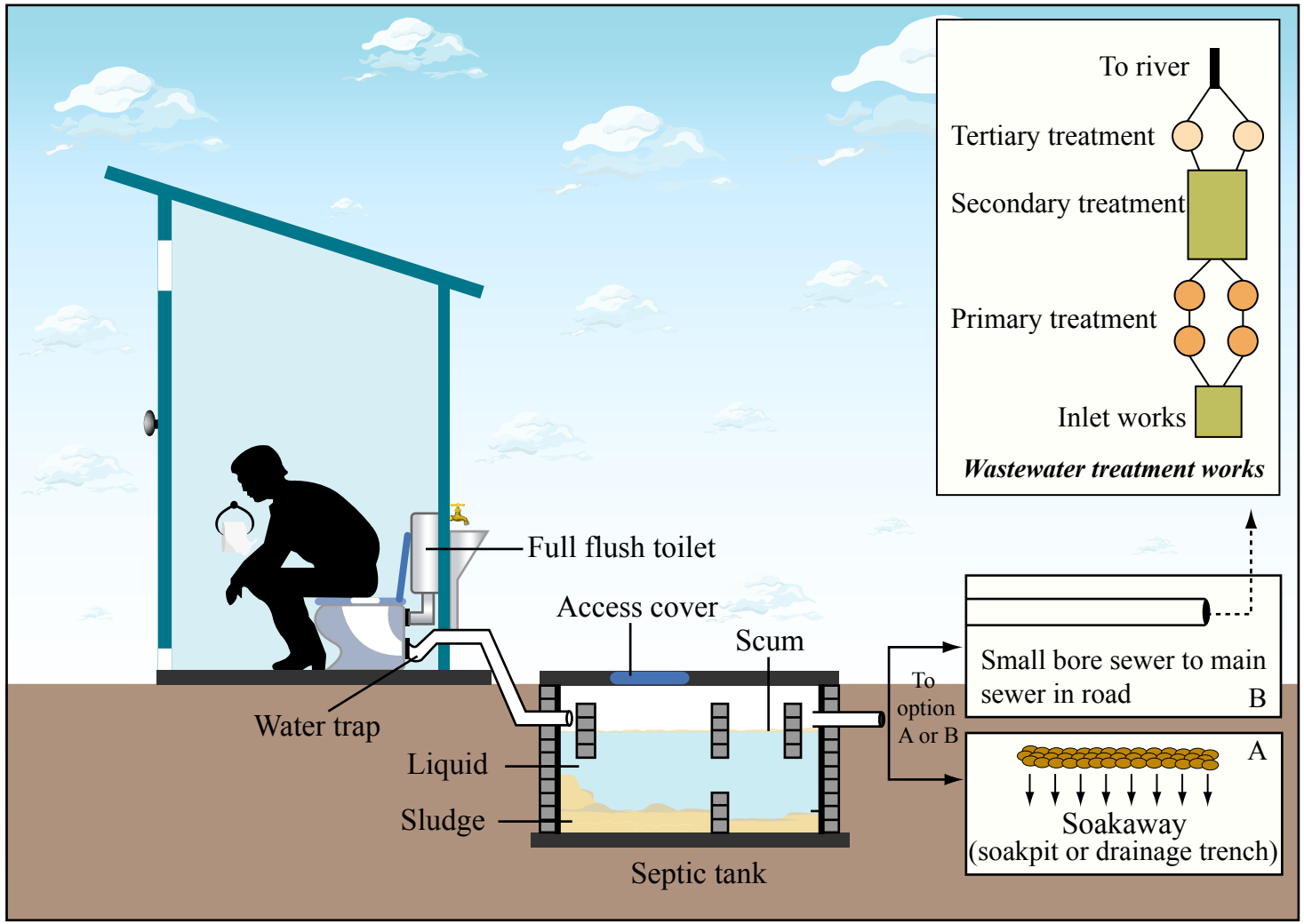


Figure by MIT OpenCourseWare.

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Potential confounder
for flush systems:
Open Drainage

Treatment Methods

Facility Type \ Treatment Site	Onsite	Offsite	Reuse
Pit latrine			
VIP			
Pour-flush	Septic	WW treatment	
Water sealed	Septic	WW treatment	
Community	Septic	WW treatment	

Treatment & Management Options

- Onsite Treatment Options:
  - Pit, composting, EcoSan, aquaprivy, septic
- Offsite Treatment Options:
  - Stabilization ponds, Night-soil treatment ponds (bucket), cartage, wetlands, drainfields, wastewater treatment facilities
- Demand Management Options
  - Conservation, point of use controls, demand elimination
- Reuse Treatment Options:
  - Biogas, Thermophilic (aerobic) composting, Mesophilic (anaerobic) composting

Teku Septage Treatment Plant

Greywater Recovery -> Constructed wetlands

Demand Management

- Voluntary conservation
- Flow-restricting fixtures and aerators
- Water-conserving appliances
- Low-flow toilets or tank displacement systems
- Drip/bleed irrigation distribution systems

Demand Management

- Point-of-use Controls:
  - Automatic shutoff controls
  - Water fuses
  - Thermal bleed systems
  - Instantaneous hot water heaters
  - Timed or moisture-based irrigation control systems

Eliminating Demand

- Water-free toilets/urinals
- Leak repair
- Xeriscaping
- Ozonated laundering

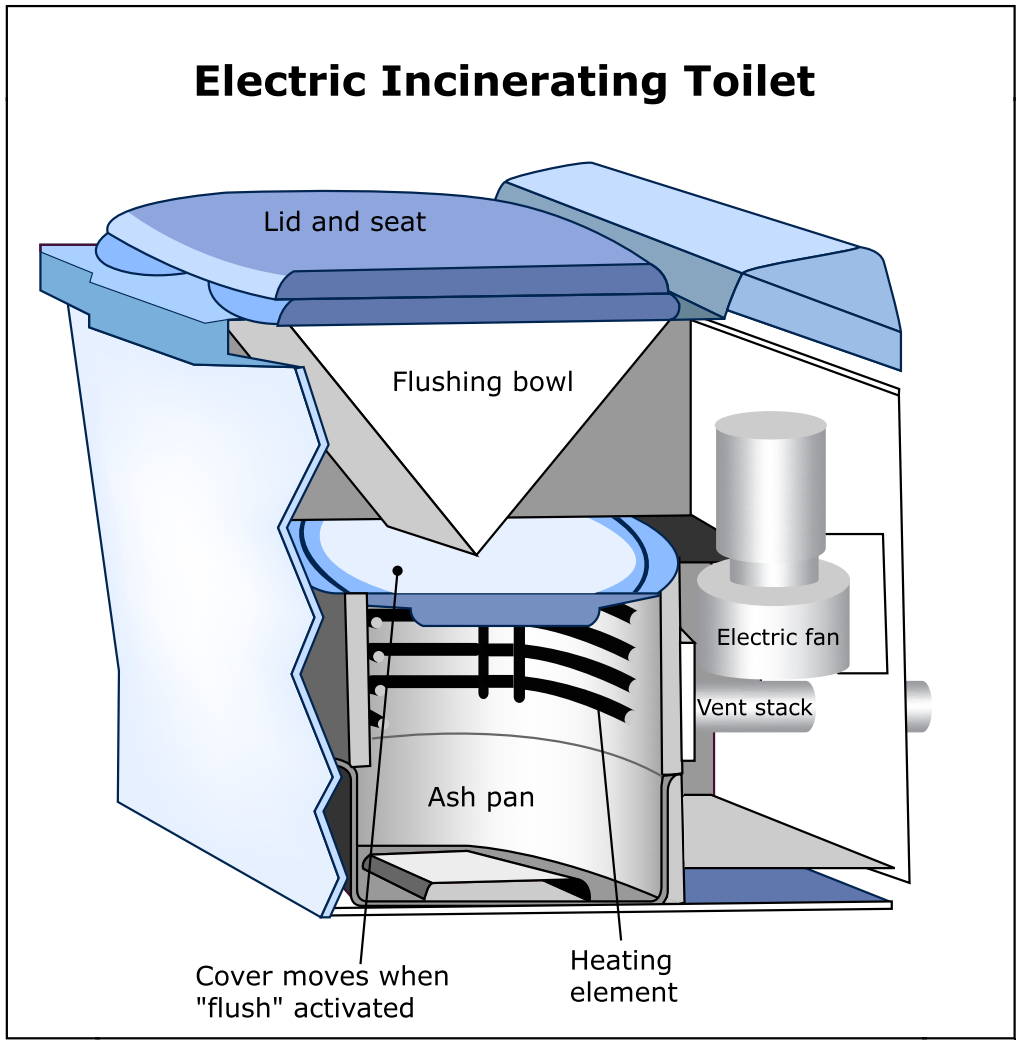
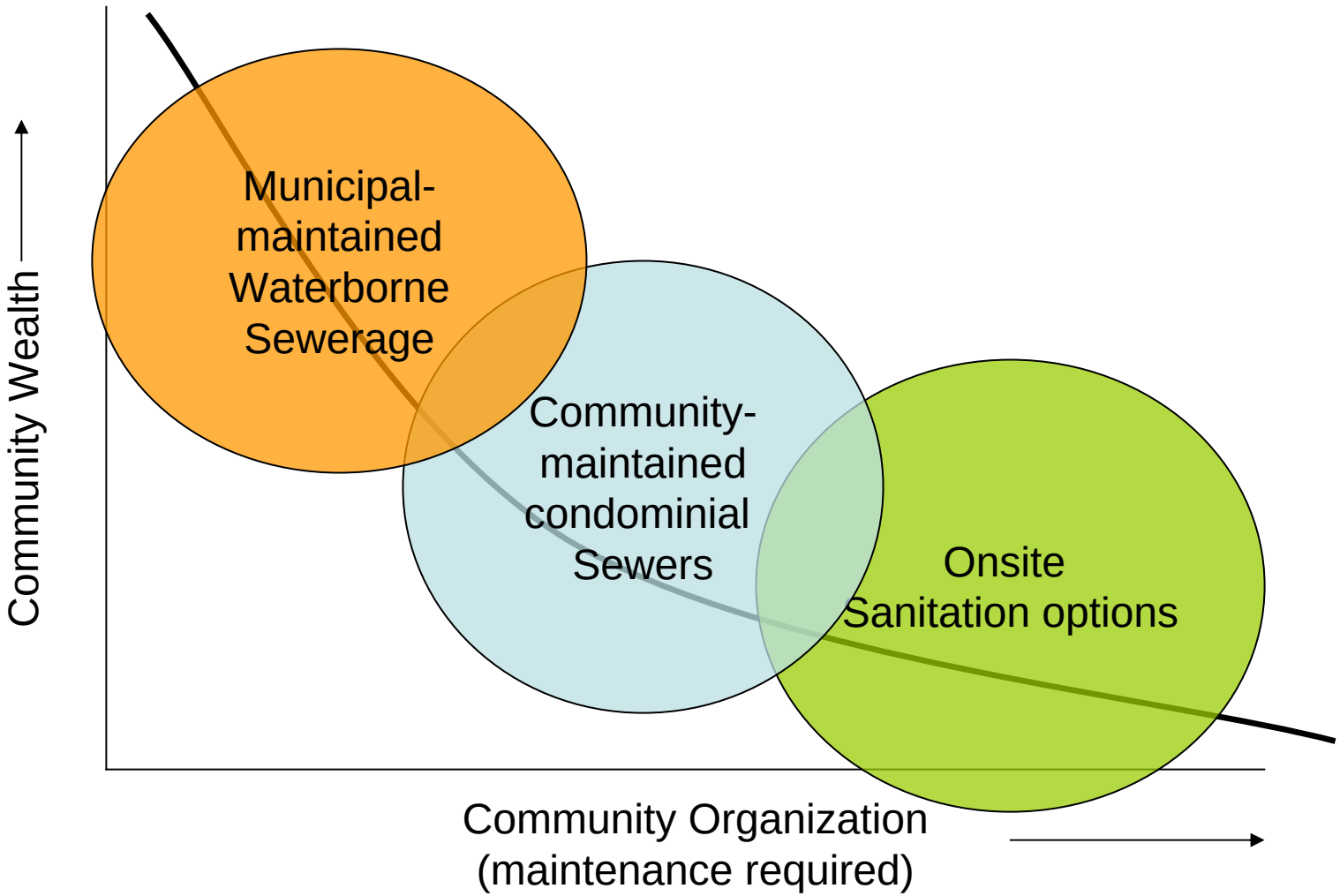


Figure by MIT OpenCourseWare.

Institutional & community-capacity issues:

- What community involvement/cleanup options are there?
- How organized is the community?
- What level of maintenance/involvement is the community willing to take?
- Level of agriculture and household income; is there any demand for reuse?

Community Factors that affect sanitation options



Ecological Sanitation

Industrialized Sanitation

Linear Flow

Images removed due to copyright restrictions: a straight line arrow goes from a sewer outfall, to a wastewater treatment plant, to a body of water where effluent is discharged.

Ecological Sanitation

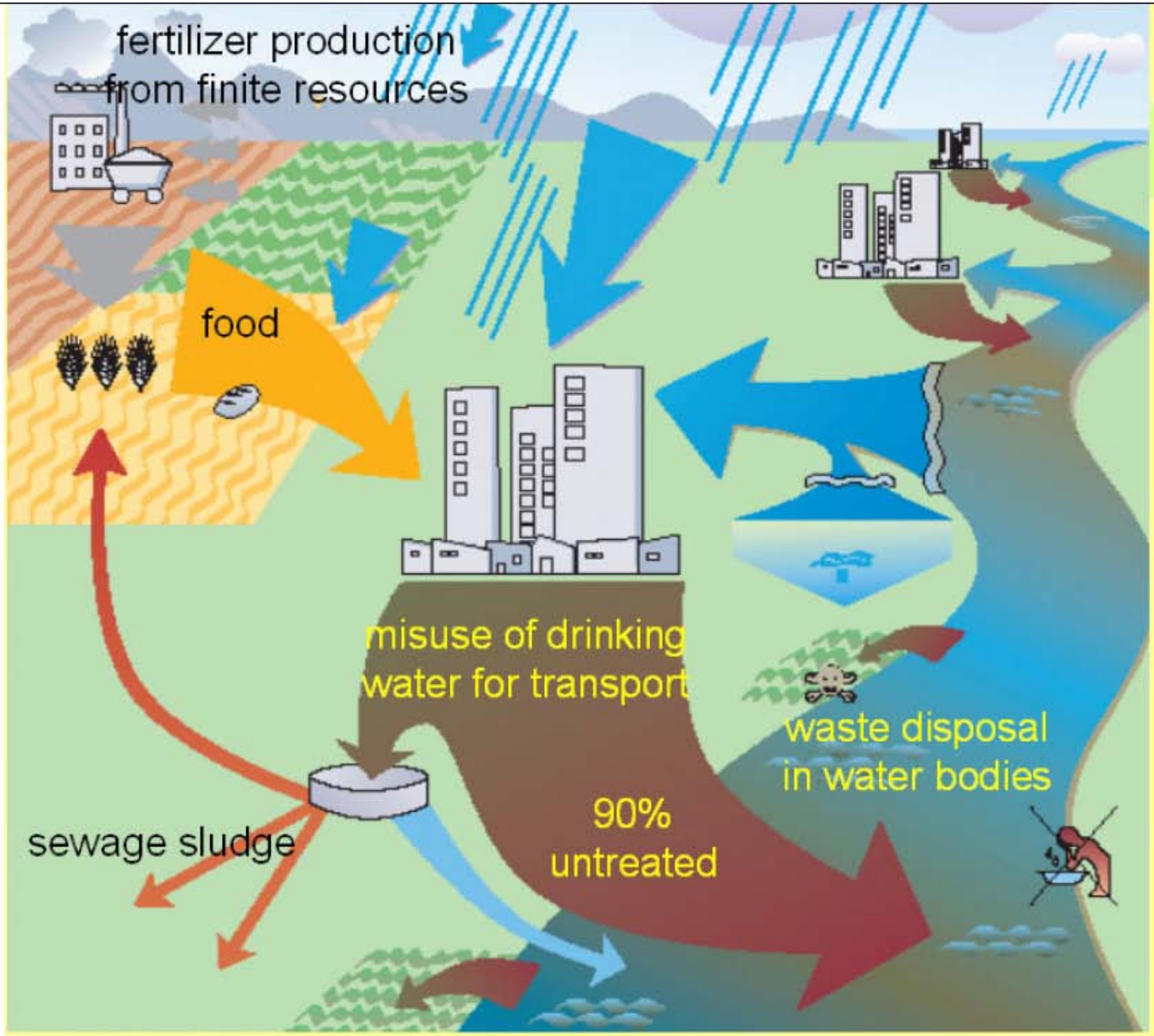
"Closed Loop"

Images removed due to copyright restrictions: two arrows in a loop, connecting a drawing of an outhouse, crop fields fertilized with human waste, and fully grown corn.

Definition of ecosan

"Any sanitation system that reuses the water and nutrients in human excreta or domestic wastewater is considered ecological sanitation."

Application of ecosan and ecosan literature typically focuses on low-tech, recycling toilets.



misconception of current sanitation

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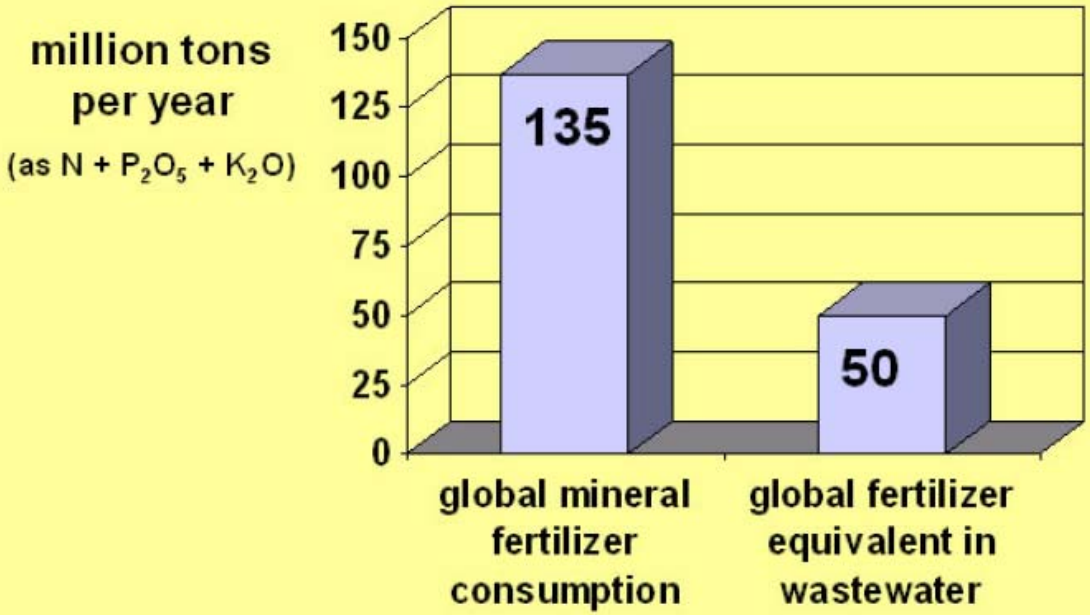
ecosan
ecological sanitation

excreta are a valuable resource



(www.fertilizer.org)

- more than 1/3 of global mineral fertilizer consumption can be covered by the reuse of human excreta
- over 15 billion US$ fertilizer equivalent are annually flushed down the toilet

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Closing the loop between sanitation and agriculture

Courtesy of the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). Used with permission.

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benefits of ecological sanitation

- **safe sanitation**

Source: Johannes Heeb

ecosan-toilets in Bangalore, India

- **healthy environment**

(http://www.virtualmuseum.ca)

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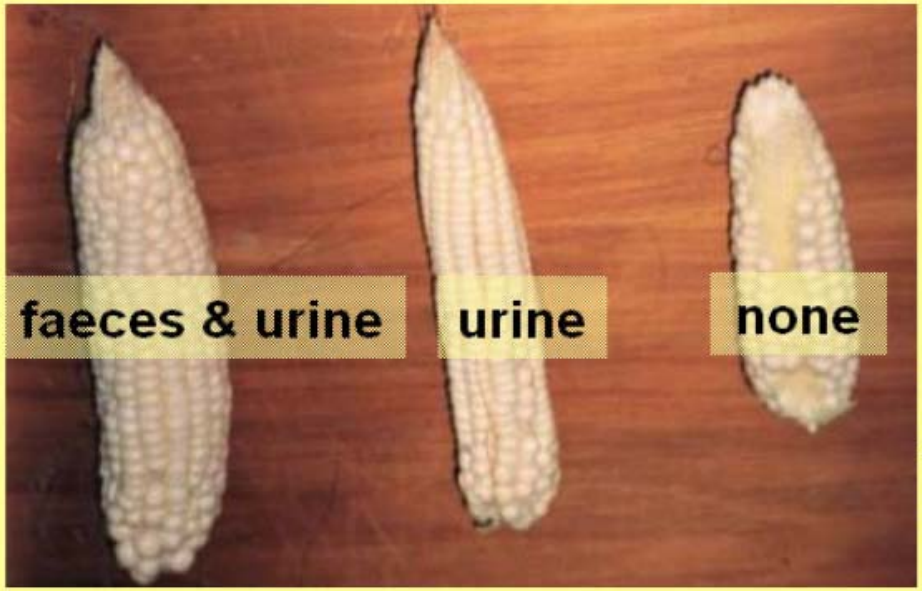
benefits of ecological sanitation

- **restored soil fertility through nutrient reuse**



(Vinnerås, 2003)

- **improved soil quality through reuse of organics**

Source: Petter Jenssen

after one week without water

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benefits of ecological sanitation

Source: Petter Jenssen

- **recovery of energy content**
  (covering about 20% of cooking energy needs for a typical family in a developing country)
- **energy savings in fertilizer production & wastewater treatment**

- **reuse of water**

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examples of ecosan technologies

urine-separating dehydration latrine

Source: Aussie Austin

constructed wetlands

membrane technology

biogas plant

(http://www.abr-w.de)

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examples of urban applications

KfW headquarters, Germany

Vacuum blackwater collection and greywater recycling

GTZ headquarters, Germany

Urine separation and nutirent recovery planned

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main challenges

- increasing awareness
- integration of reuse into planning
- revision of legal frameworks & technical standards
- establishment of full cost analysis and risk comparisons
- finding innovative investors and adapting financing instruments
- **implementation of large scale urban projects**

Greywater treatment in Norway

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Conclusion

- "business as usual" will not allow us to meet the MGDs, as conventional systems have failed
- we cannot continue to waste our non-renewable resources
- ecological sanitation must be recognized and introduced as the new promising holistic and sustainable approach to provide safe and decent sanitation, reduce poverty, contribute to food security, preserve our environment and maintain our natural basis of life on earth

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Ecosan Case study: Kenya

Town: Kombewa

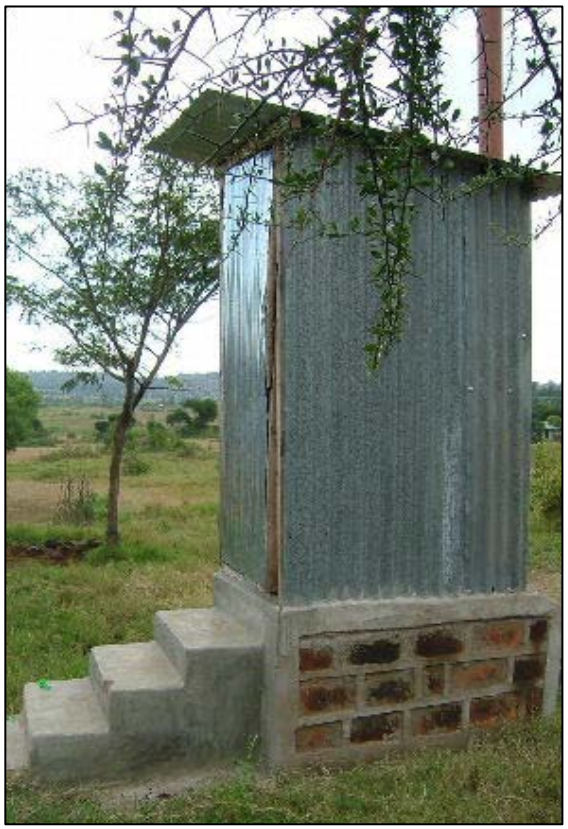
All households:

- Rural
- Practice household agriculture
- Low income

Toilets: 33 urine-diverting
“Skyloos” = a type of ecosan

The Skyloo

Decomposition by Dehydration



- Dry sanitation
- Add ash, soil, or lime to feces
- Storage: 6-12 months

Urine diversion plate

Agricultural Worth

The average household produces (annually):

4 kg of nitrogen

0.6 kg of phosphorous

Same nutrients in **a hectare** (10,000 m^2) of fresh corn, spinach and watermelon

Economic Worth

Locally available fertilizer is about 18% nitrogen

(at cost of $0.52 USD / kg)

22 kg of fertilizer = 4 kg of nitrogen

Economic value of urine from ecosan:

$1 USD per month

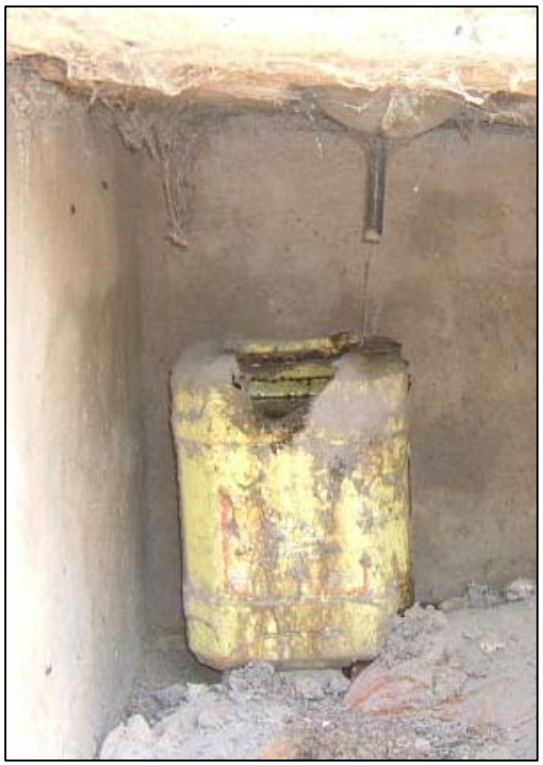
GDP per capita ~ $1,100 in 2001

=

20 % or 100% Savings

$1/month represents 20% of average expenditure on fertilizers. Of homes that do not use any fertilizer (presumably because they cannot afford it), they realize a 100% "savings."

Reuse Practices



Urine

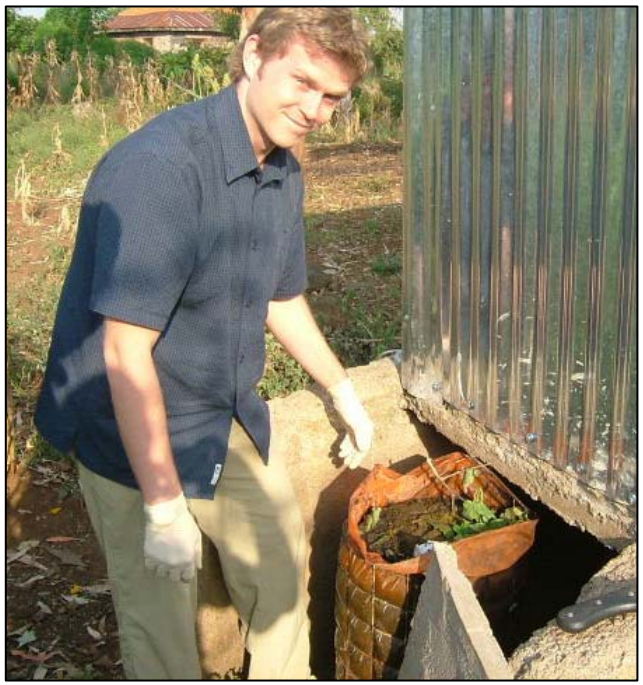
- 67% of households claim to reuse the urine in farming
- 33% dump it out

Storage time

Recommended: 1 month

Actual: 2 months (average)

Reuse Practices



Feces

- 65% reuse the feces
- 28% bury feces

Storage time

Recommended: 6 months

Actual: 4 ½ months (average)

What Influences Household's Adoption?

Positives

1. Manure/Fertilizer
2. No Smell
3. Cheap
4. Aesthetics
5. Social Status

Negatives

1. Training
2. Construction
3. Handling excrement

Theoretical Advantages	Users Say…	Research Says…
Reuse in agriculture	~2/3 of owners	Economics?
Economic savings	Inexpensive toilet	…because of NGO subsidy
Aesthetics	Important	
Sanitation	Not high on priority list	Not always used correctly
Way to deal with excreta	Challenging	

Conclusions

Why would a household adopt an ecosan toilet?

Major benefits:

1. Agricultural product
2. Aesthetic value/social status
3. Low upfront costs

Eco-sane or Eco-insane?

The Mara argument

By his calculations, the value of nutrients over the lifetime of an ecosan toilet still make an ecosan toilet more expensive than a VIP toilet. Why would anyone use this? Moreover, not everyone likes the idea of using their waste.

Counters to Mara's argument

- Groundwater pollution. Is it worth it to pollute drinking water sources?
- Why waste money on a VIP if its cheaper to just defecate on the roadside?
- Are his calculations right? Actually more fertilizer than Mara calculated, and the productivity of the toilet pays for itself. Even more important when you consider poor households that could not afford fertilizer in the first place.
- If there's a high water table, how to dig a pit?
- Value in ecosan's theoretical approach to sanitation

More information:

http://web.mit.edu/urbanupgrading/waterandsanitation/levels/index.html

www.sewerhistory.org

http://wedc.lboro.ac.uk

http://www.wsscc.org (WASH Campaign)

http://web.mit.edu/watsan

Robinson, B. “Master of Engineering Thesis and Final Presentation on Ecological Sanitation. MIT CEE Dept. April, 2005. http://web.mit.edu/watsan -> documents -> Kenya ‘05