Dry Sanitation, Urine Management, Containment Methods and Reuse Potential in Agriculture

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Stockholm Environment Institute

International Symposium
Coupling Sustainable Sanitation & Groundwater Protection
Hannover October 14-17, 2008

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Key Elements of Dry Sanitation

- Minimize or eliminate use of flushwater in toilets and urinals – save water and prevent surface and groundwater discharges
- Greywater not mixed with toilet products
- Stormwater not mixed with greywater or toilet products
- Minimize or eliminate the discharge of pathogens and nutrients into the environment

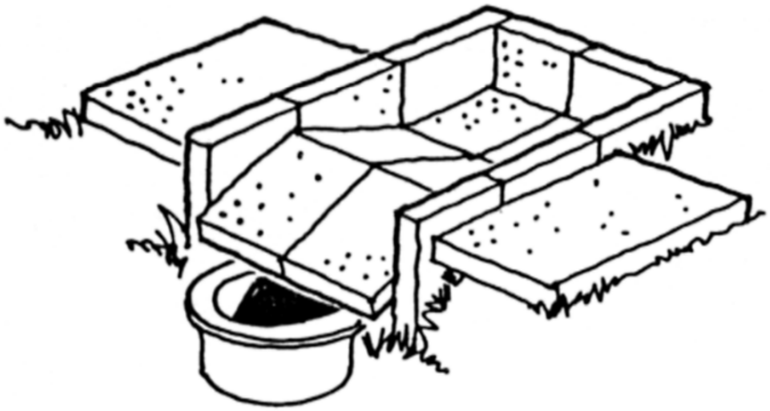
2 examples:

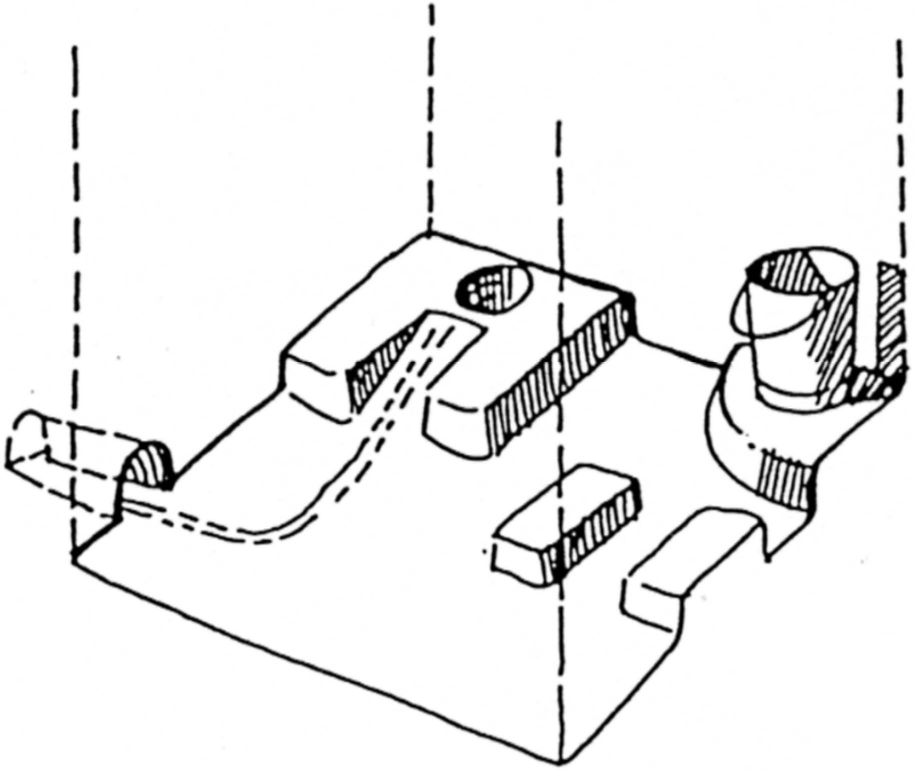
UDDT

• source separation of urine, faeces
• containment of fractions
• treatment of fractions
• agro-reuse of the products

Compost toilet

• shallow pit
• soil composting of urine and faeces
• agro-reuse of compost



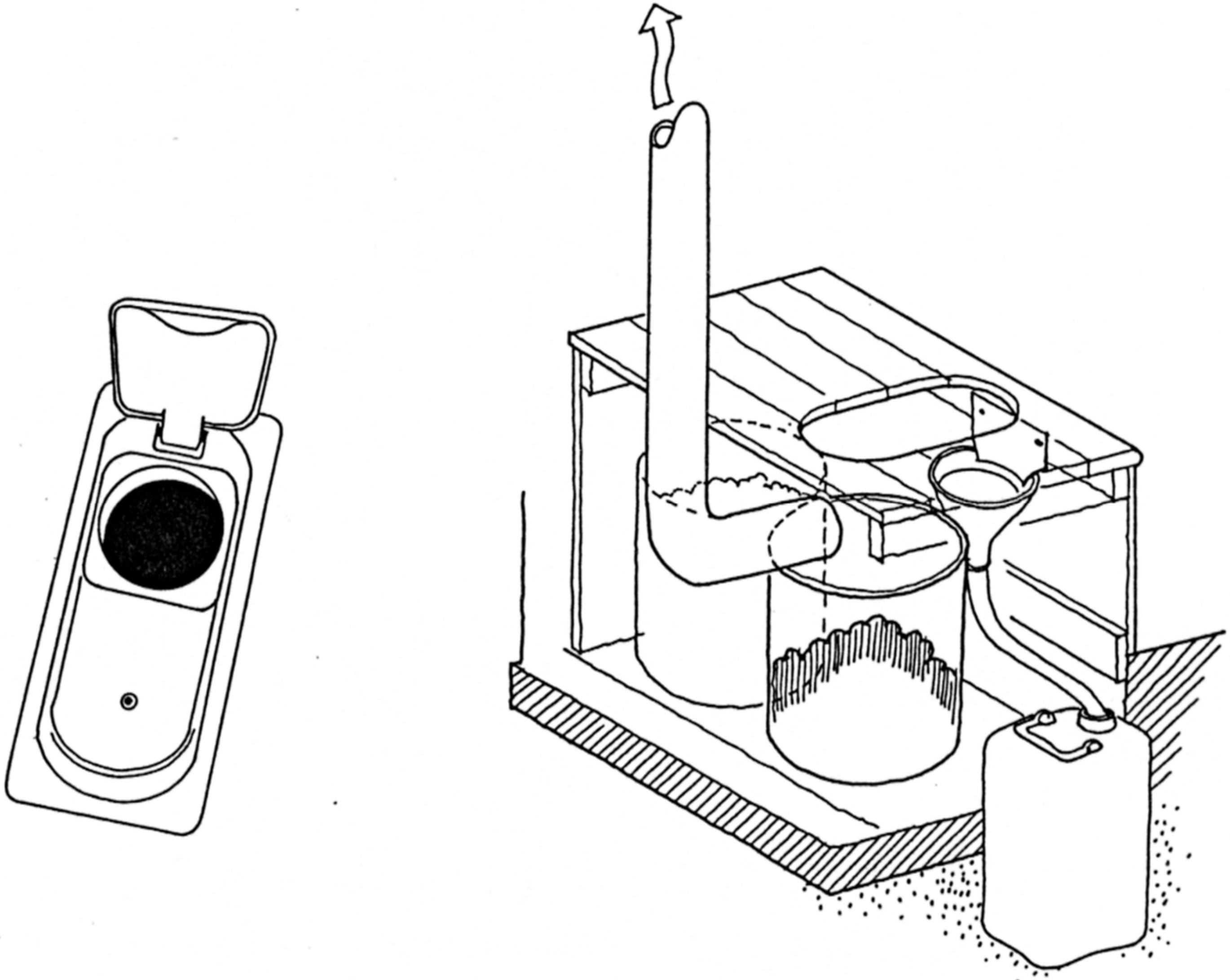


Historical examples of urine diversion. From China (left) emptied every day, urine used directly fertilizer and faeces composted with animal manure. From Yemen (right), urine is evaporated and faeces dehydrated and reused as fuel.

Winblad & Simpson Hebert, eds. 2004

Figure 2. Urine diversion in the on-site low population density context. a) South Africa, photo: Aussie Austin b). Sweden, Separett is a dry urine diverting toilet for indoor use. Photo: Mats Johansson.

Kvarnström et al 2006



Urine diversion: A prefabricated PE squatting pan from China (Lin Jiang), and a bench-type seat riser from Bolivia (Uno Winblad), built of wood and with a standard plastic funnel as urine collector.

Winblad & Simpson Hebert, eds. 2004

Double-vault urine-diverting dry ecotoilet
used in e.g. China, Vietnam, Mexico, Bolivia, India, Sri Lanka, W. Africa, S. Africa, Ethiopia, Uganda, Kenya, etc…..

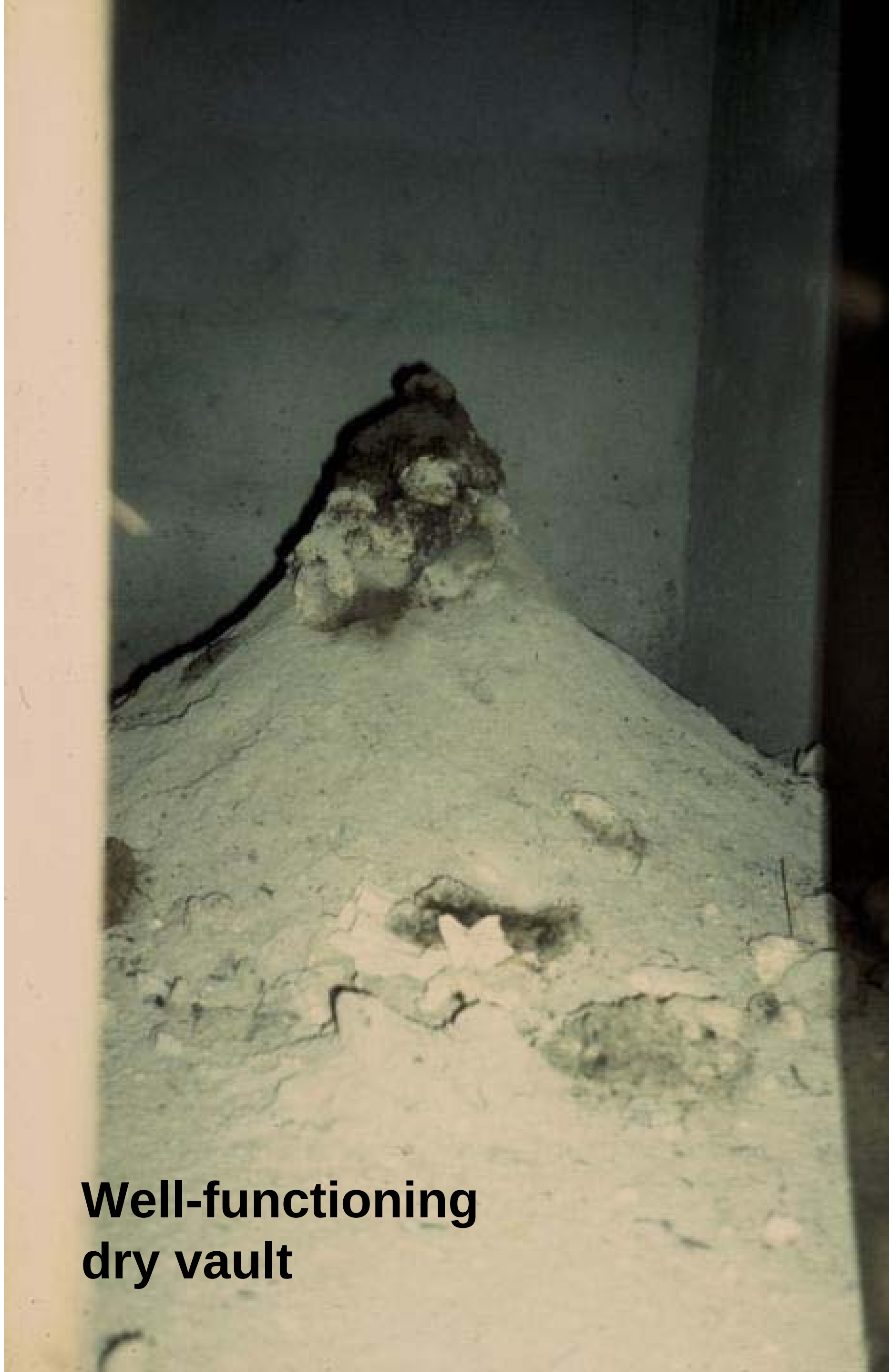
SARAR, Mexico

Lin Jiang, Guangxi

Sweden Urine-diverting Toilets, Gebers

Urine diversion toilets for washers

India – Trichy, TN (Scope)

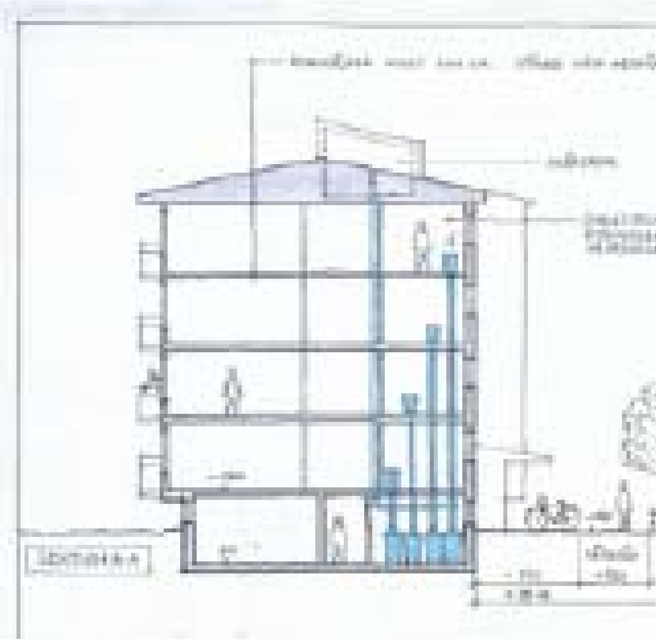


Well-functioning dry vault

South Africa - Kimberley

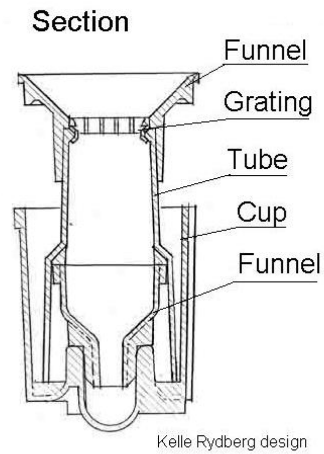
Urine-diverting dry toilets
100 households completed – 2000 planned

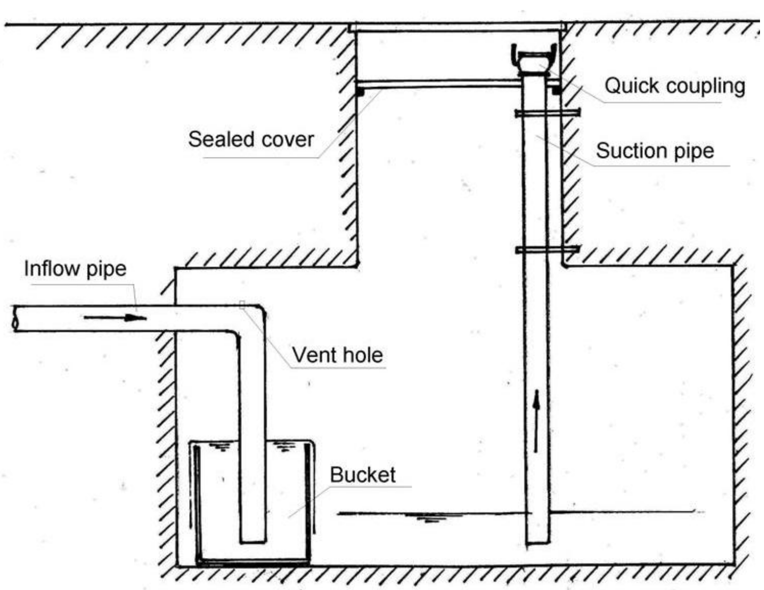
China-Sweden Erdos Ecotown Project



832 apartments completed

Erdos urine management





, Urine crystal on the odor lock

Soaked in 15% HCL solution 15 min

25% NaOH solution 40 min

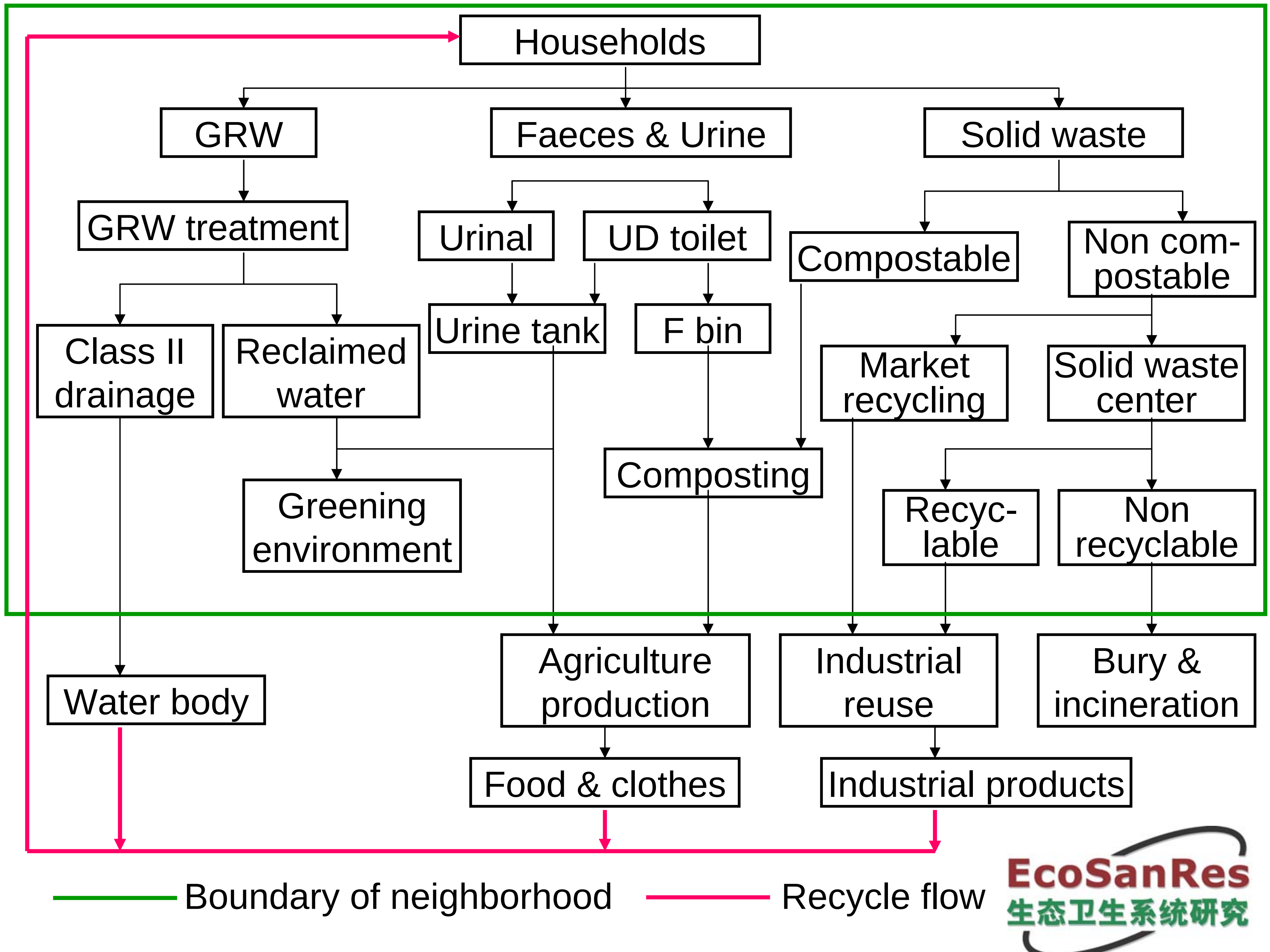
Vinegar 15 hrs

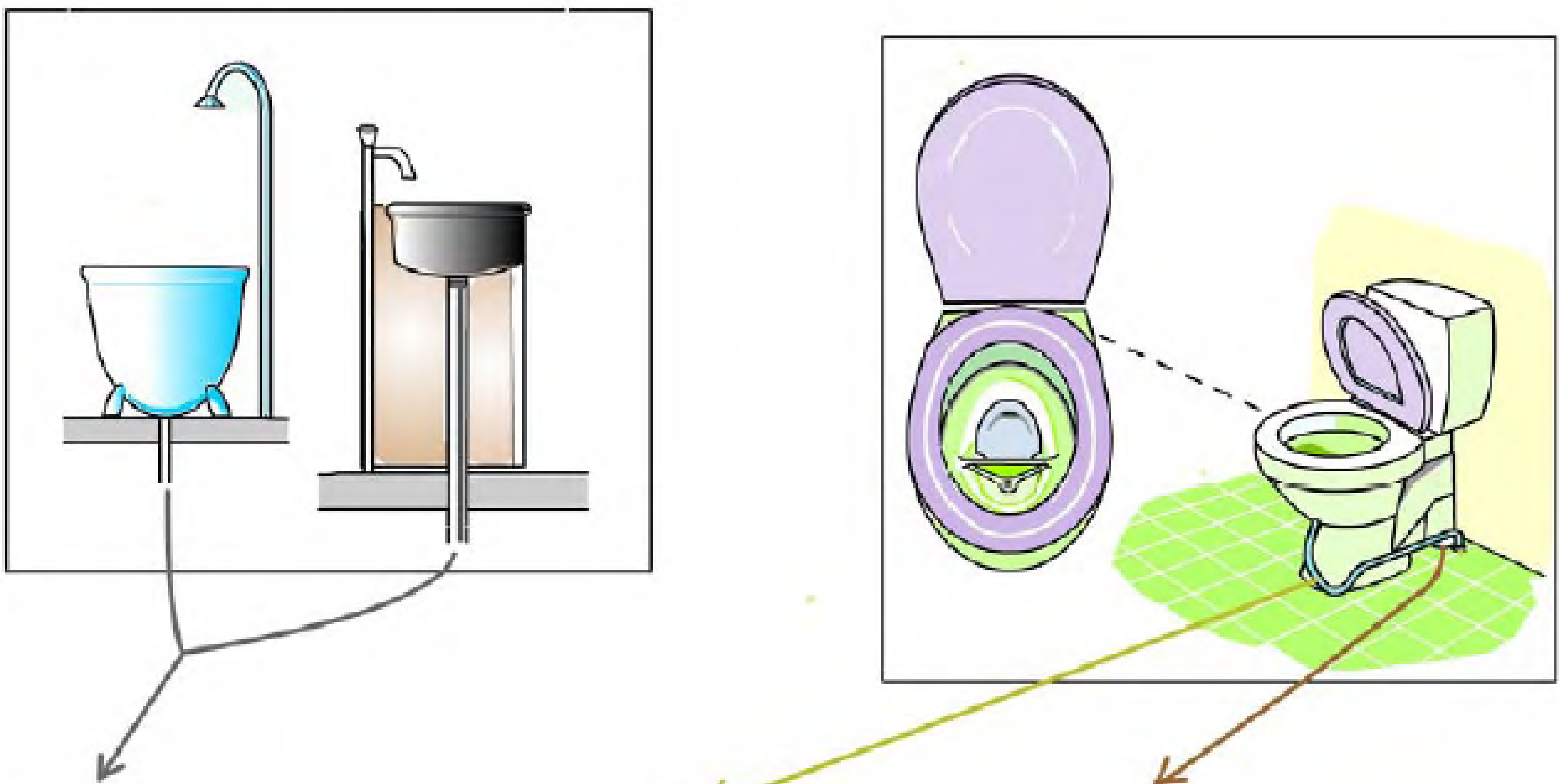
Ecosmellstop (Addicom)

Erdos on-site composting

Compost chambers 6 m^3 forced aeration and cable warming through the floor; exhaust air treated in aqueous filter to reduce odours.

Compost heap 35 –day cycle using EM (effective microbes) to enhance the process; designed for 1200 kg faeces/sawdust mixture per day; compost to be bagged and sold


Households
GRW
Faeces & Urine
Solid waste
GRW treatment
Urinal
UD toilet
Compostable
Non com-
postable
Class II
drainage
Reclaimed
water
Urine tank
F bin
Market
recycling
Solid waste
center
Greening
environment
Composting
Recyc-
lable
Non
recyclable
Water body
Agriculture
production
Industrial
reuse
Bury &
incineration
Food & clothes
Industrial products
Boundary of neighborhood
Recycle flow
EcoSanRes
生态卫生系统研究



Greywater

- Represents appr. 20-200 L/p, day.
- Contains appr. 0.3 - 0.4 kg N and 0.07 - 0.37 kg P per pe and year
- Chemical/microbial quality reflects the habits* and the use of chemicals by the household.

Urine

- Represents appr. 1.5 L/p, day.
- One person excretes approximately 2-4 kg N and 0.2 - 0.37 kg P per year in urine
- Extremely low metal content and low content of pathogens**

Feces

- Represents appr. 0.15 kg/p,day.
- One person excretes approximately 0.3 - 0.55 kg N, 0.1 - 0.2 kg P, and
- Low metal content and high pathogen content

Kvarnström et al 2006

Breakdown of urine

- In fresh urine the greater part of the nitrogen appears in organic form as urea $CO(NH_2)_2$
- The hydrolysis of urea is catalysed by the enzyme urease, an enzyme which many microorganisms possess (occurs mixed w/ faeces or if exposed to air)
- During the hydrolysis pH is increased and ammonium and bicarbonate ions are produced

$$CO(NH_2)_2 + 3H_2O \xrightarrow{\text{urease}} 2NH_4^+ + HCO_3^- + OH^-$$

Ammonium is in equilibrium with dissolved ammonia

$$NH_4^+ + OH^- \leftrightarrow NH_3(aq) + H_2O$$

Dissolved ammonia is in equilibrium with gaseous ammonia in sealed containers and is released & a source of odour if not contained

$$NH_3(aq) \leftrightarrow NH_3(g)$$

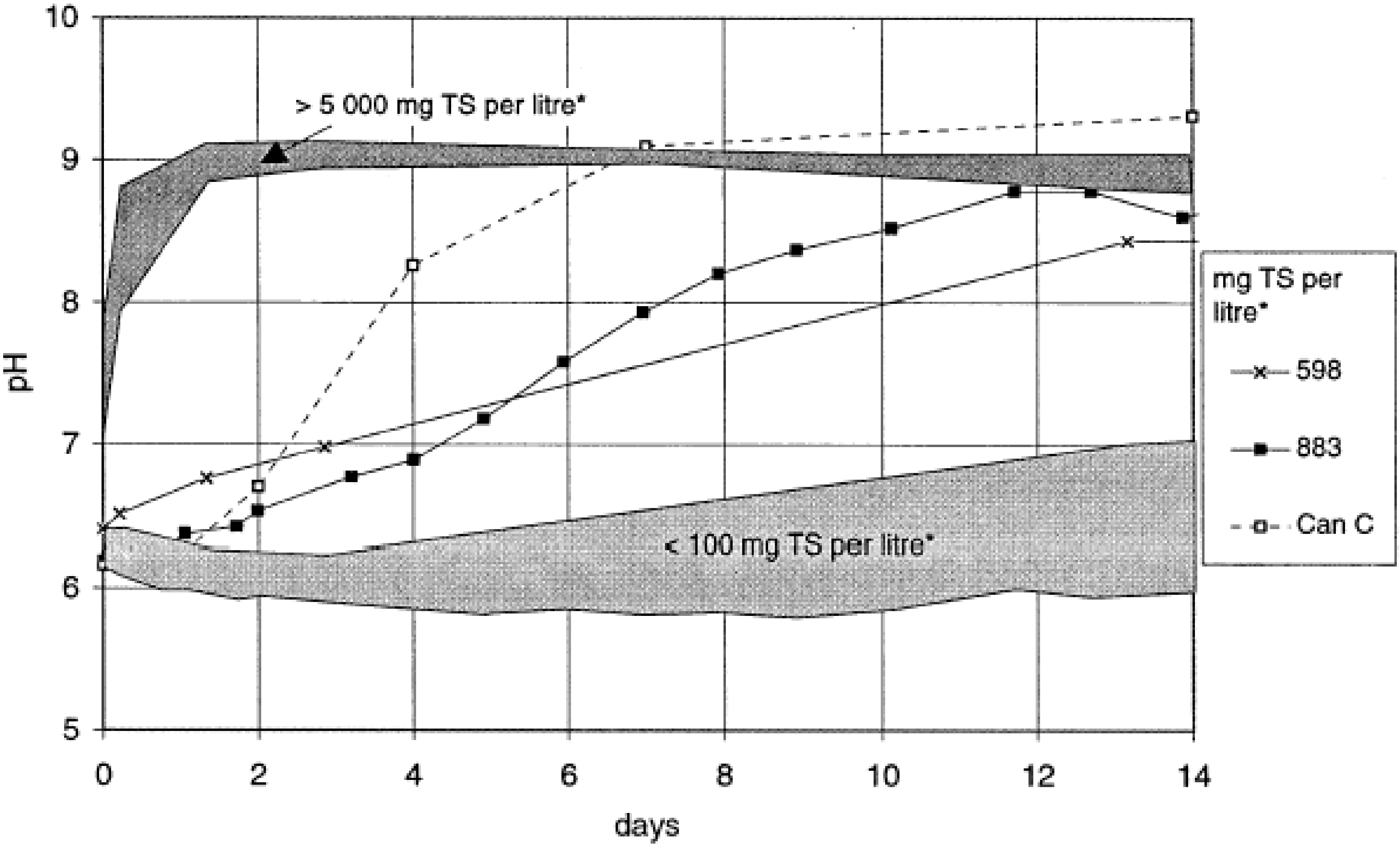


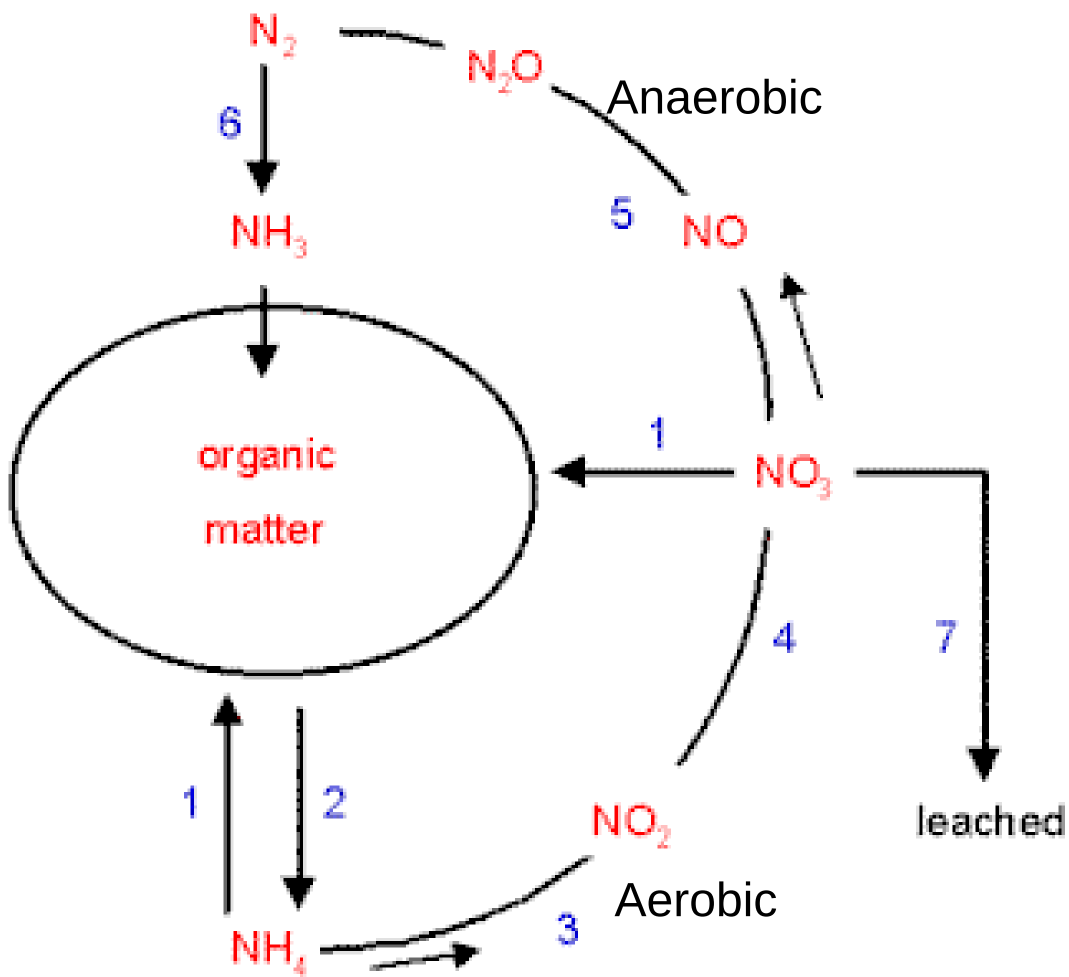
Fig. 2. Variations of pH during storage of urine with different concentrations of faeces (*the concentrations of faeces are expressed as mg TS per litre undiluted urine) or wastewater. All bottles were stored at 20–23°C. Can C, a plastic can containing a mixture of 2.5 l urine, 7.5 l distilled water and 0.4 l wastewater, was stored at 5°C (Hanæus et al., 1996).

Nitrogen Cycle

1. Uptake of NH_4 or NO_3 by organisms
2. Release of NH_4 by decomposition

3,4. Microbial oxidation of NH_4 (yields energy in aerobic conditions)

5. Denitrification (NO_3 respiration) by microbes in anaerobic conditions (NO_3 is used instead of O_2 as the terminal electron acceptor during decomposition of organic matter)
6. Nitrogen fixation
7. Nitrate leaching from soil



Storage of urine

- Urine contains few disease-producing organisms, while faeces may contain many.
- Storing undiluted urine for one month will render urine safe for use in agriculture.
- Undiluted urine provides a harsher environment for micro-organisms, increases the die-off rate of pathogens and prevents the breeding of mosquitoes.
- At the household level, where crops are intended for the household's own consumption, urine can be used directly.
- It is recommended, however, that there should be 1 month between urine application and harvesting.
- When urine is collected from many urban households and transported for re-use in agriculture, the recommended storage time at temperatures of 4–20 °C varies between 1 and 6 months depending on the type of crop to be fertilized.

Acid treatment to control hydrolysis and dissolve struvite

- Treatment of urine with sulfuric acid (reaching 3 g/L) will drop the pH to below 4 and this stops the hydrolysis of urea. The nitrogen content is stable for 250 days (EAWAG study), the odour is eliminated, any microbes are killed and even pharmaceuticals break down
- struvite $MgNH_4PO_4.6H_2O$ forms in pipes & pumps (can be controlled by keeping solution acid)

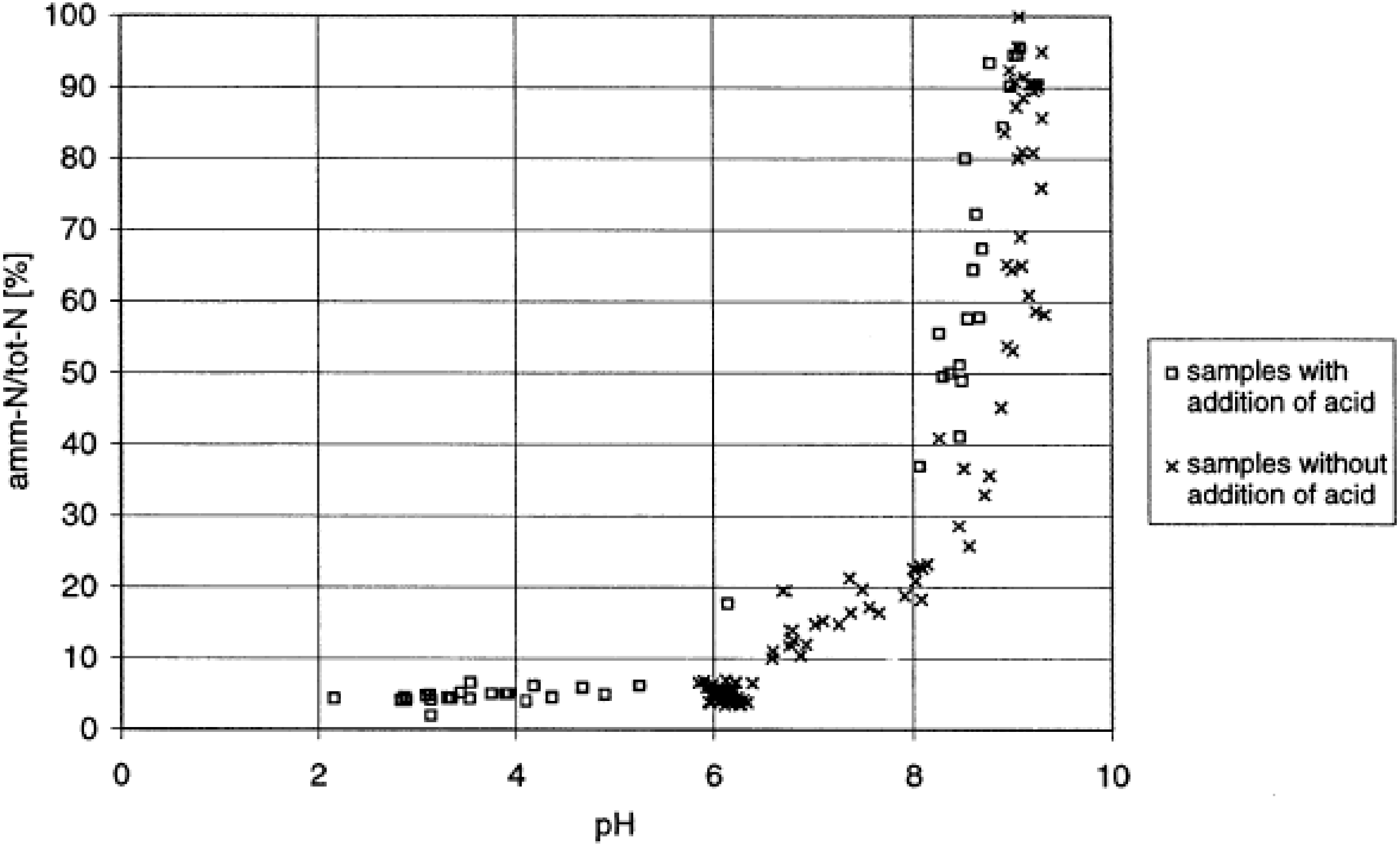


Fig. 1. Relationship between pH and the fraction of ammoniacal nitrogen (amm-N) of total nitrogen. The addition of acid varied between 0–60 meq of acid per litre of undiluted urine.

Hellström et al,1999

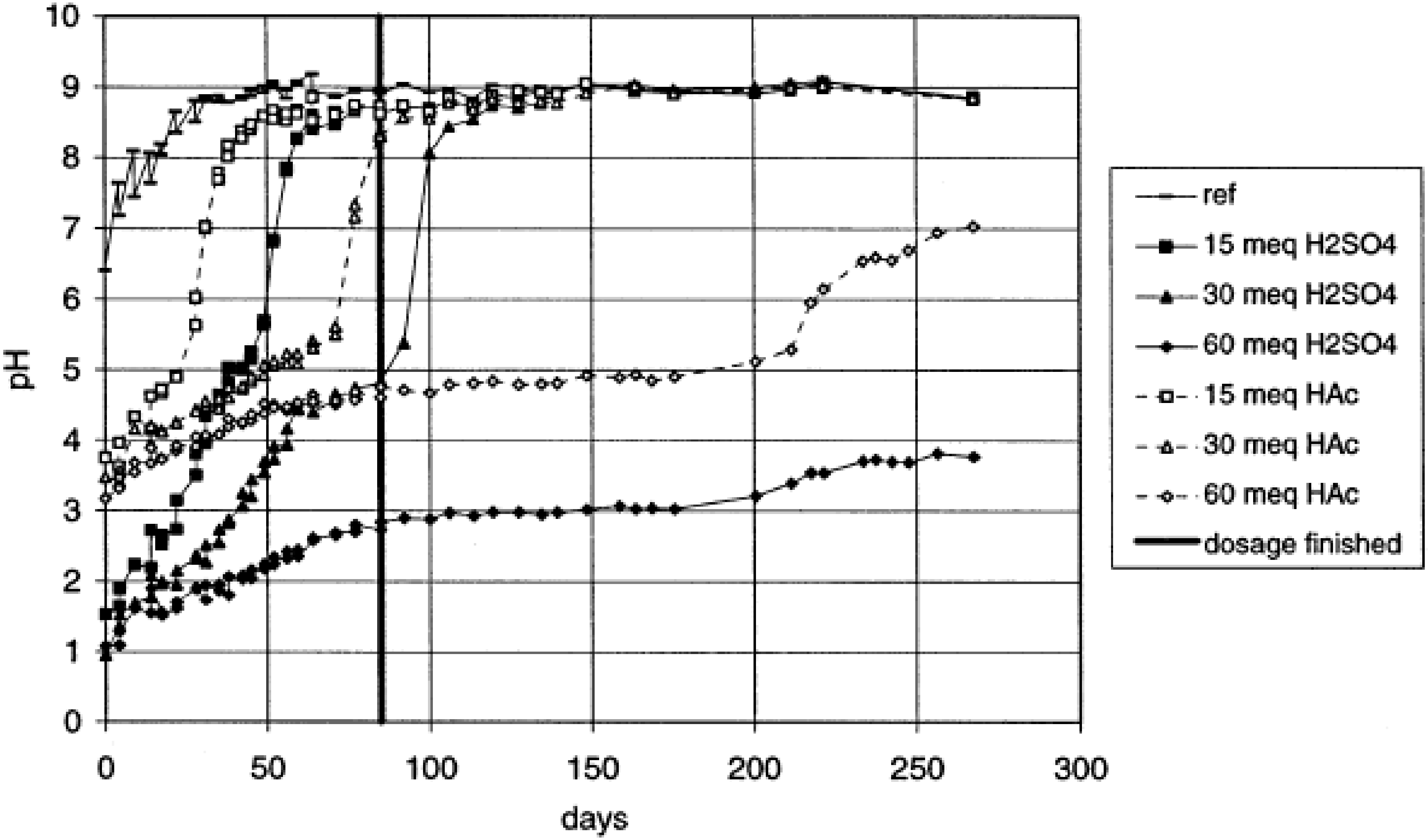
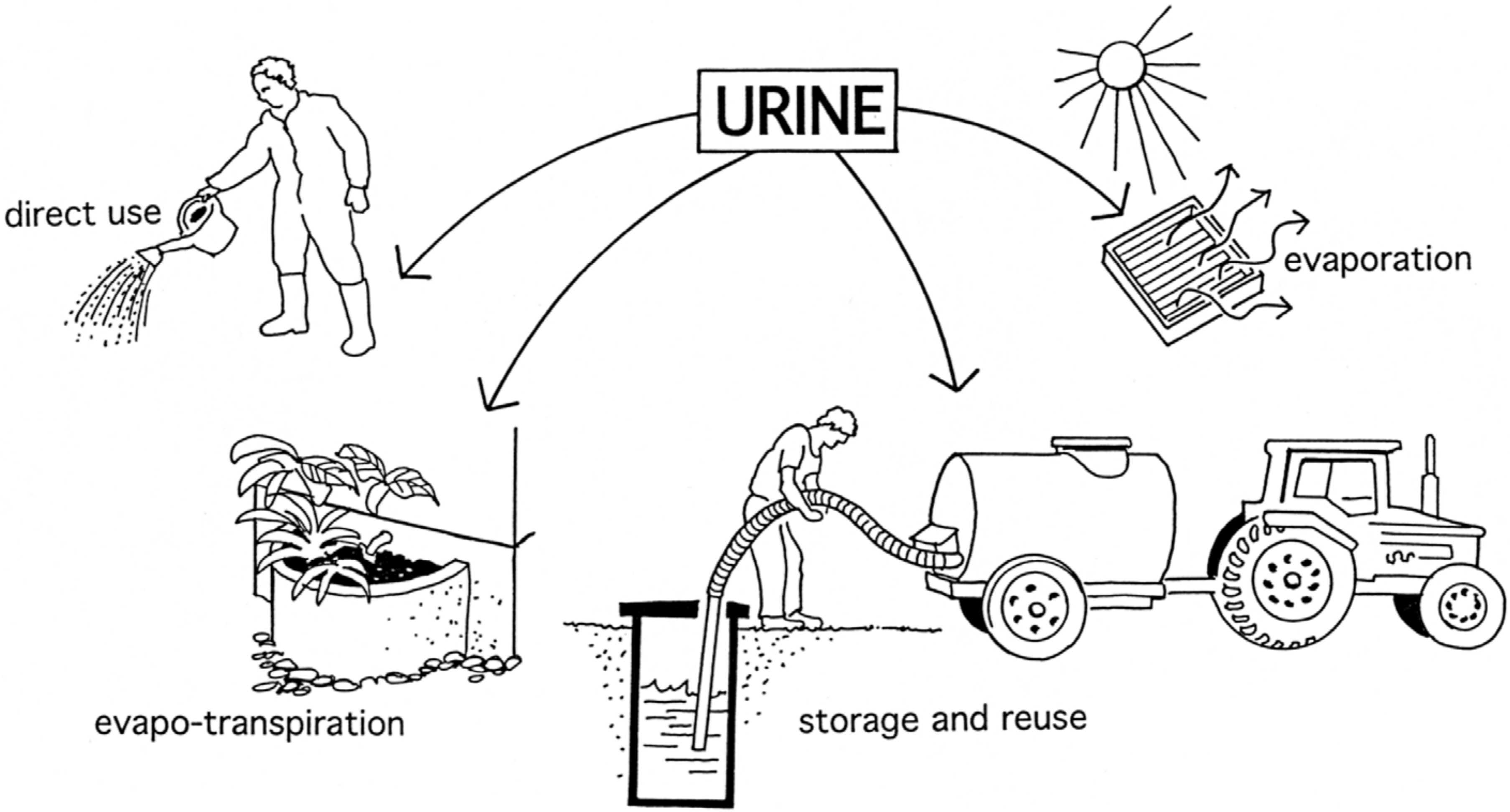


Fig. 3. Measurements of pH during storage of urine using one-time dosage of acid. The addition of urine stopped after 85 days (solid line). The reference sample (can no. 2) had no addition of acid.

Hellström et al,1999

Rules of Thumb

- Urine can be applied diluted or undiluted.
- Nitrogen concentrations in urine can be estimated at 3–7 grams per litre.
- For estimating the amount needed per crop, one should follow the recommendations given for chemical nitrogen fertilizers.
- In the absence of other guidelines, the urine collected from one person in a year is sufficient to fertilize 300–400 square metres of crop.
- This can be applied undiluted or diluted, before planting or during plant growth.



Alternative ways of handling urine diverted from faeces: used directly, disposed of in an evapo-transpiration bed, stored in a tank for later use or evaporated.

Winblad & Simpson Hebert, eds. 2004

Figure 21. Large scale application of urine using a slurry spreader with trailing hoses. Photo: Mats Johansson.

Kvarnström et al 2006

Application of urine

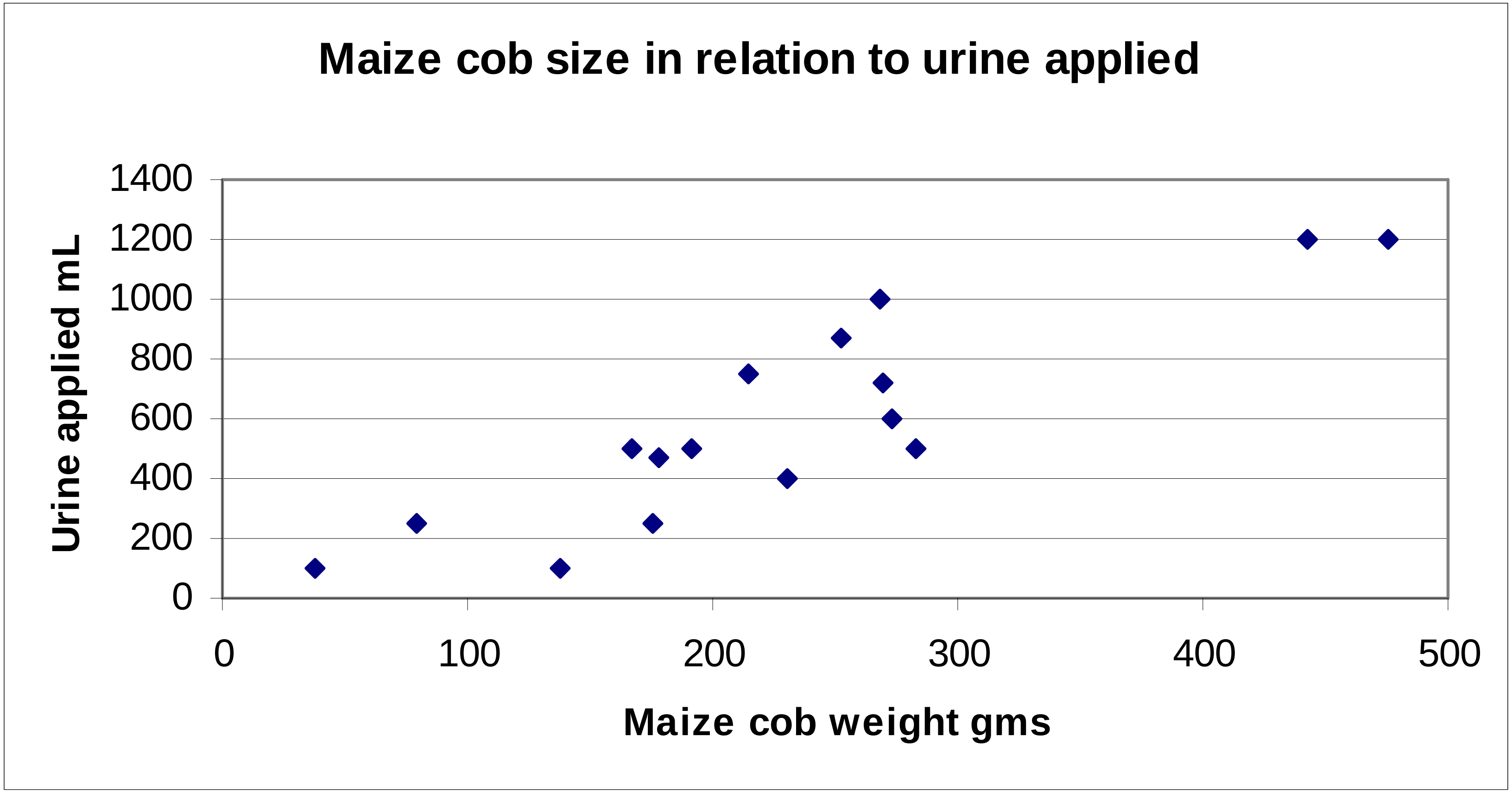
- Undiluted before or at sowing/planting or to the young plant.
- Urine can be applied in one large dose or several smaller ones during the cropping season.
- As a liquid plant food mixed with water. Diluted urine can be added to the soil where vegetables (and plants like maize) are growing – once a week or even twice or three times a week, provided that the plants are also watered frequently at other times. This addition of urine makes a big difference to the growth of plants.
- Undiluted to soil beds before planting. Bacteria in the soil change the urea into nitrate which can be used by the plants.
- As an ‘activator’ for compost heaps. The transformed organic nitrogen will be available to plants when the compost has matured.
- Concentrated fermented urine can be applied to beds of dried leaf mould, as a medium for growing vegetables and ornamental plants
- When large amounts of diverted urine are available from urban areas, is to use human urine to produce a concentrated fertilizer in powder form.

Table 5.2 *Plant trials with urine for various crops.*[22]

Plant and growth period	Weight at cropping (water application only) *grams wet weight*	Weight at cropping (3:1 water:urine application 3 x week) *grams wet weight*
Lettuce – 30 days	230	500
Lettuce – 33 days	120	345
Spinach – 30 days	52	350
Covo* – 8 weeks	135	545
Tomato – 4 months	1680	6084

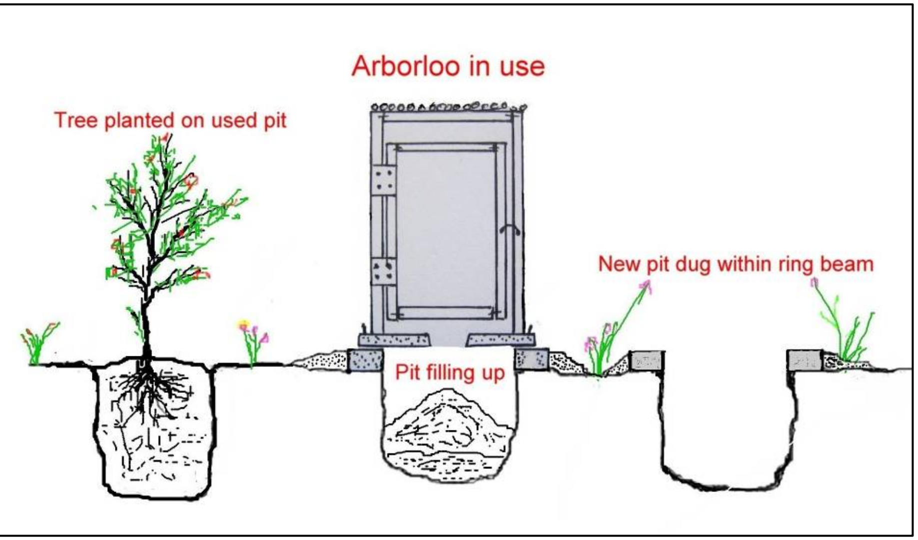
**Covo is a type of spinach used as a salad green.*

Winblad & Simpson Hebert, eds. 2004

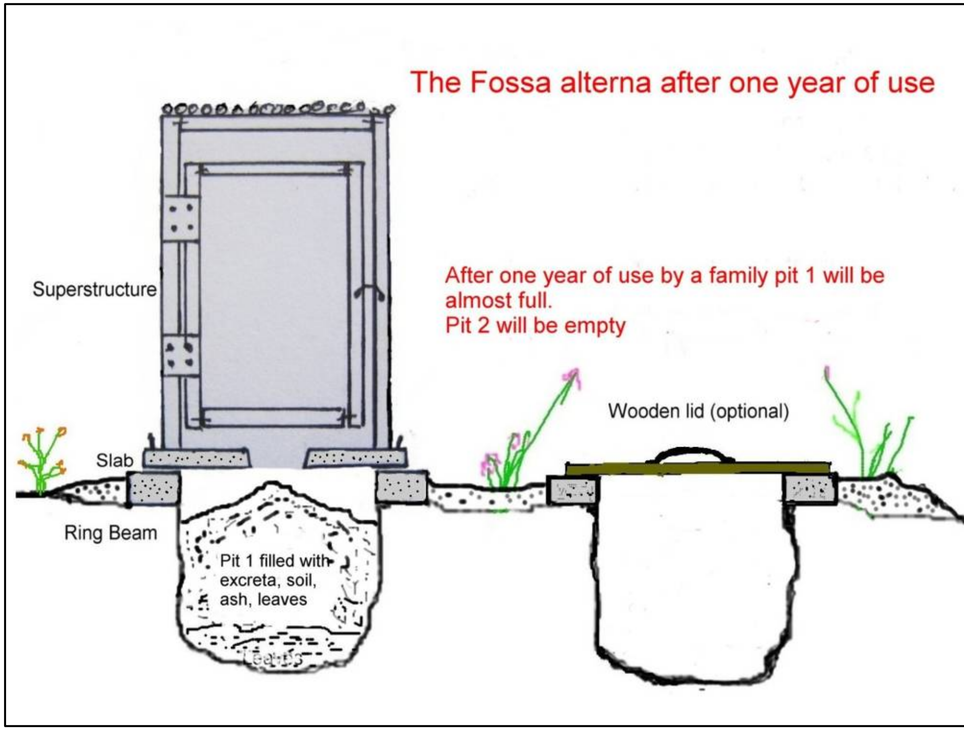


Morgan, Aquamor

Protecting Ground Water by Using Shallow pits



Arborloo



Fossa alterna

Toilet compost from the Fossa alterna

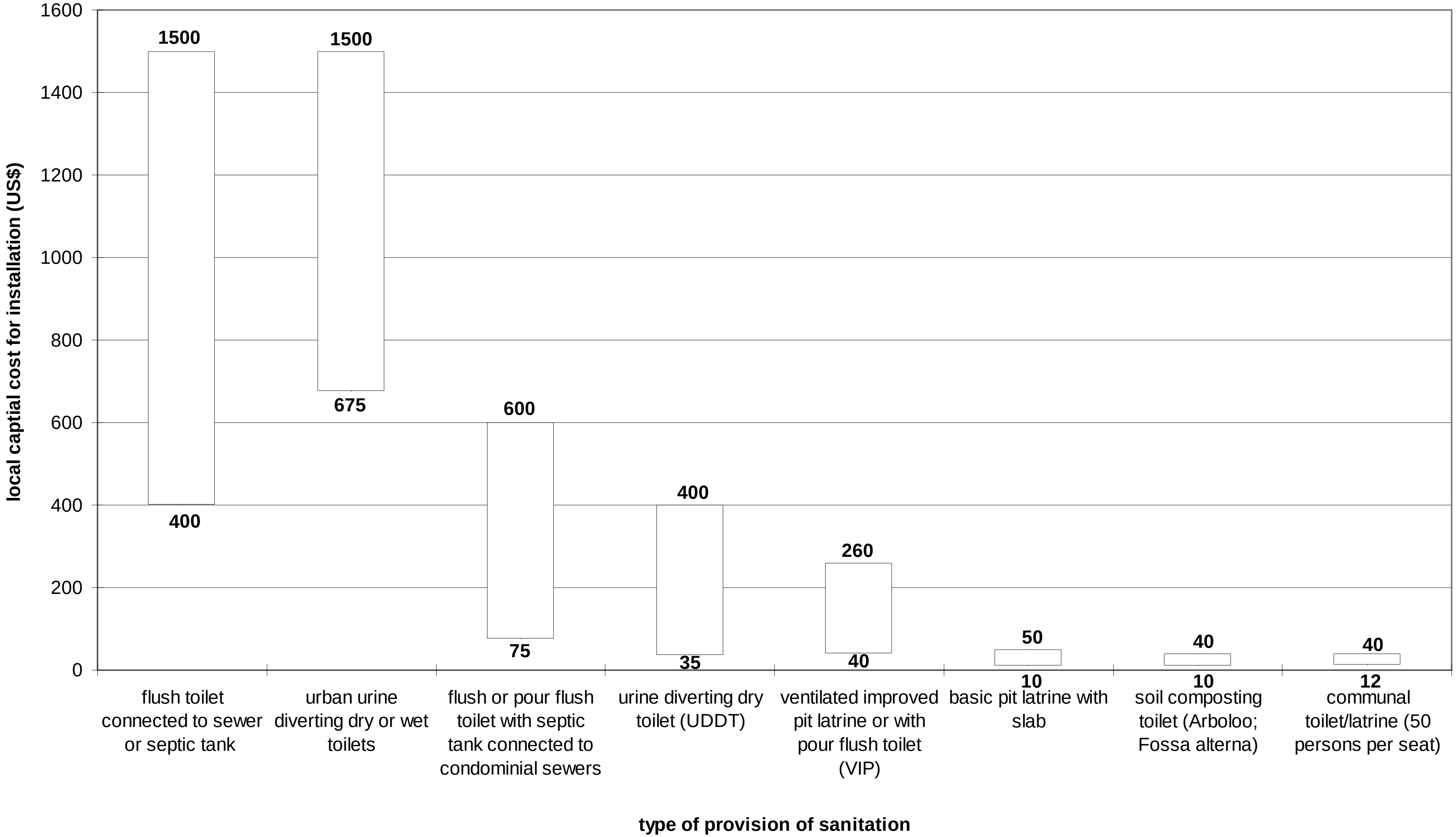
mix of faeces, urine and soil

mix of faeces, urine, soil and leaves

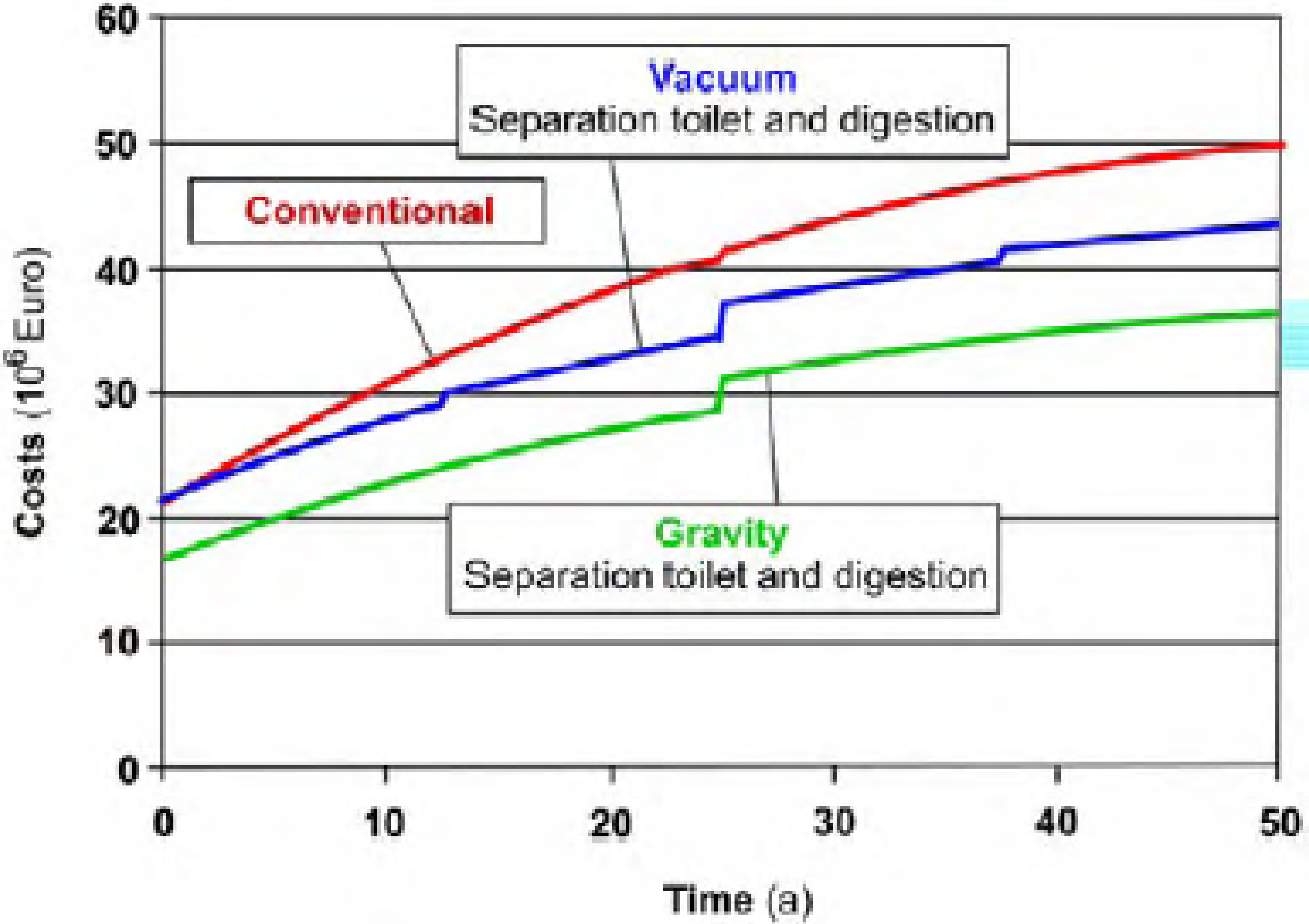
Nutrient levels in toilet compost taken from Fossa alterna pits compared to local top soils

Soil	**Nitrogen ppm**	**Phosphorus ppm**	**Potassium MEq/100g**
Top soils (Harare area) (N = 9)	38	44	0.94
Toilet compost *(Fossa alterna)* (N = 10)	275	292	4.51
Toilet compost (urine diverting)	232	297	3.06

Morgan, Aquamor



General cost ladder for various sanitation options (UNDP, 2006; Satterthwaite and McGranahan, 2007; Water and Sanitation Fund of Namibia, 2008; UNICEF-SEI India, 2008; WESnet India, 2008; SEI, 2005)



Peter-Fröhlich et al 2004

Technical and economical feasibility of Ecosan system in the urban setting

Input for the ecosan-toilet is higher than the flushing one by about USD 920 for each household, 6% of the flat cost. It can be partially paid back by reducing treatment cost of GRW compared to the mixed wastewater and saving the cost of drainage pipe network as well as recycling the human excreta and GRW.

Benefit of environment protection, human waste recycling and resources conservation in a long-term period would be much more significant than the cost spent today.

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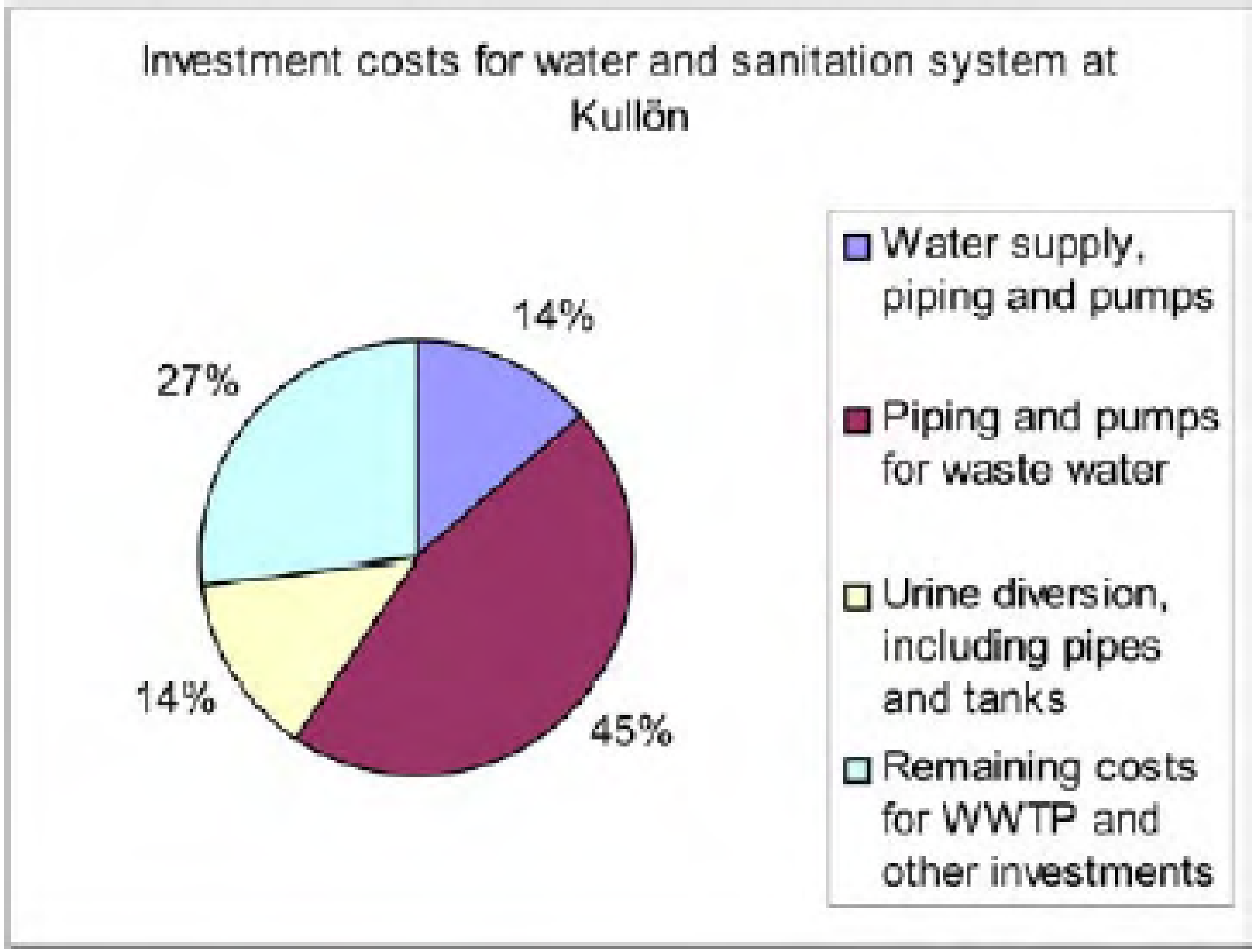


Urine diversion accounts for 14% of the total investments in water and sanitation at Kullön. Data from 2005.

Kvarnström et al 2006

Table 1. Costs for spreading of 41 m^3 urine, corresponding to the nutrients in 375 kg of NPKS 24-2-5-3[16] on one hectare[17].

	Urine (costs in SEK for 41 m^3/ha)	**Commercial fertilizer (costs in SEK for 375 kg NPKS/ha)**
Fertilizer purchase	0	1000[18]
Spreading	1000[19]	110
Soil compaction (spring fertilization on a medium clay)	300[20]	0
Total	1300	1110

3000 in 2008

[16] The figures corresponds to the percent of each of the nutrients nitrogen (N), Phosphorus (P), Potassium (K) and sulphur (S). Thus 24% of the 374 kg is nitrogen, 2% is phosphorus, 5% is potassium and 3% is sulphur.

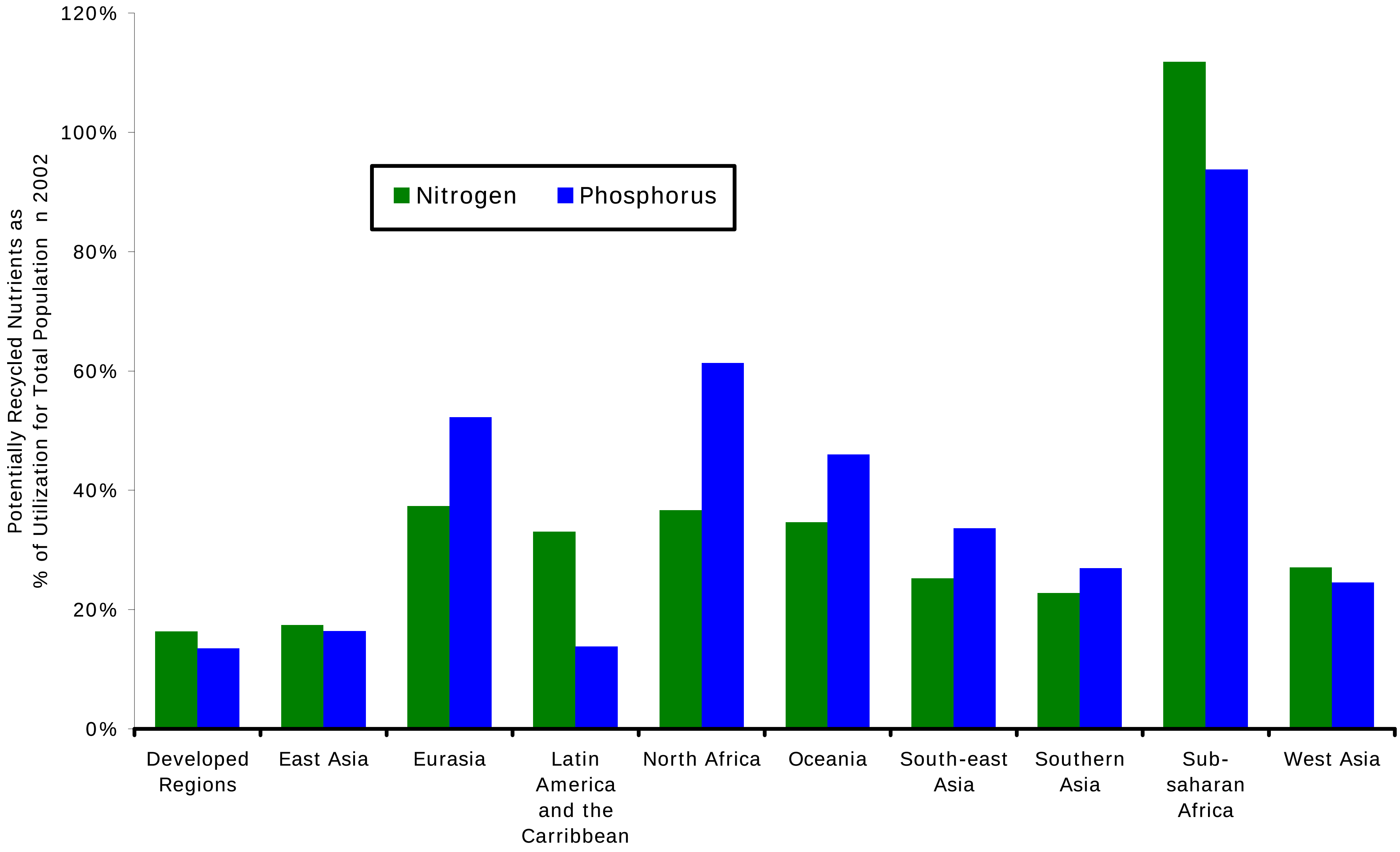
[17] Degaardt (2004)

[18] According to figures from the Swedish Farmers Supply and Crop Marketing Association, 2004.

[19] Figures from a contractor in Southern Sweden for a tank wagon with an applicator fitted with trailing hoses

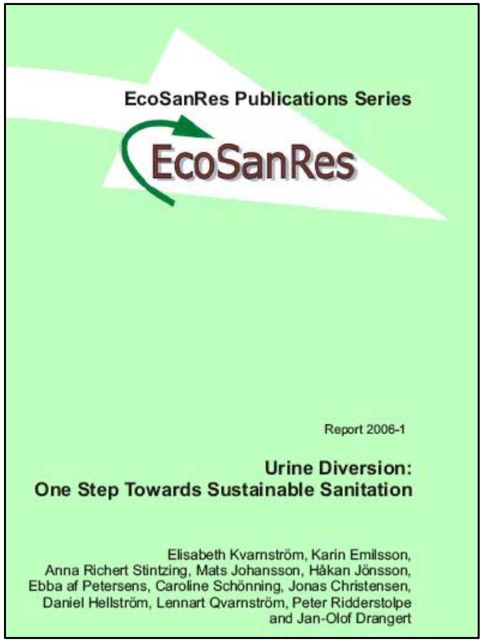
[20] Arvidsson (1998)

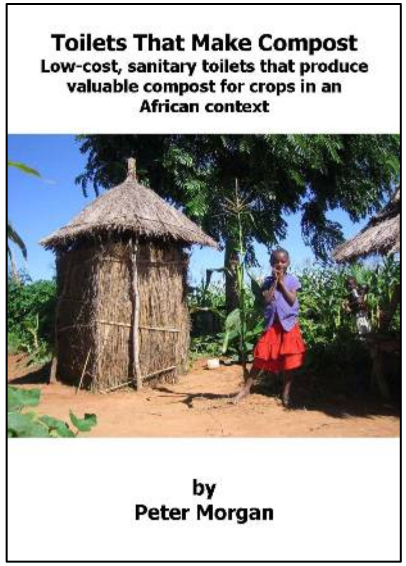
Kvarnström et al 2006

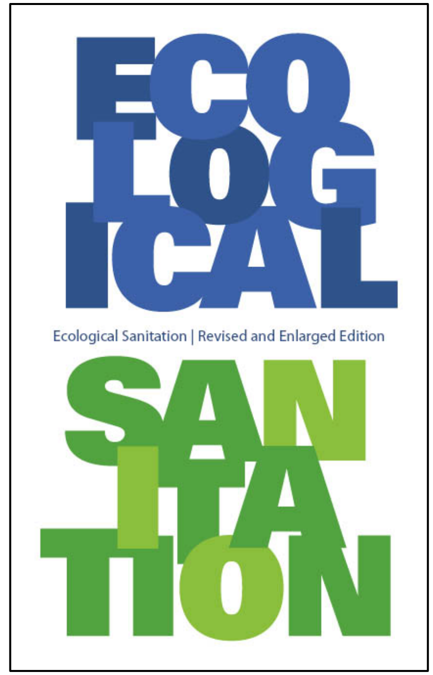


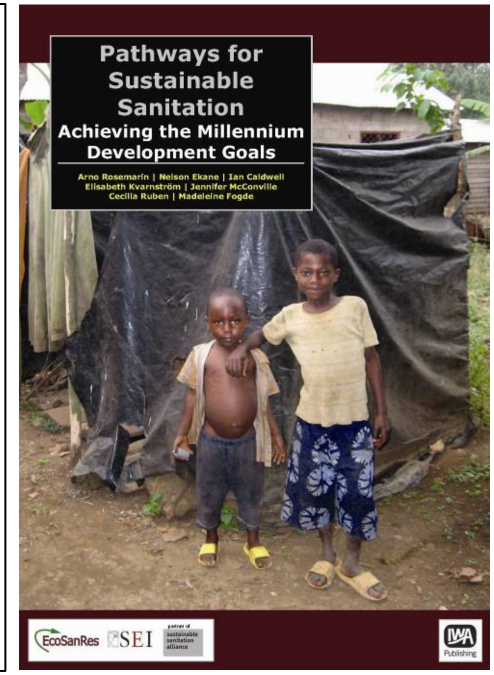
Potential capacity of ecological sanitation systems to replace chemical fertiliser used in different world regions (SEI, 2005)

Recommended reading









Nov 4, 2008

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