
SLU
SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE

Circular wastewater management systems – hygiene and technical implementation

Björn Vinnerås, Professor Environmental Engineering,
Swedish University of Environmental sciences

Mini-CV – Björn Vinnerås

- Professor in Environmental Engineering
- Chemical Process Engineer
- SLU since 1997
- 150 peer review publications
- 21 finalised PhD candidates
- Research areas
  - Hygienisation technology
  - Wastewater treatment
  - Protein production from waste
  - Recycling waste water system

- Group
  - 8 researchers
  - 4 post doc
  - 4 PhD candidates
  - 1 Research technicians
- International collaboration
  - Denmark, Germany, Switzerland
  - India, Vietnam, Malaysia, China, Cambodia, Thailand
  - Uganda, Tanzania, Kenya, South Africa, Ethiopia
  - Bolivia, Brazil, Ecuador, USA

https://www.researchgate.net/profile/Bjoern_Vinneras

Why sanitation

- Health
  - Remove pathogens from people
- Environmental impact
  - Large flows in one place
  - Limiting elements affecting environment

Nutrient flows in Swedish society 10 mil persons

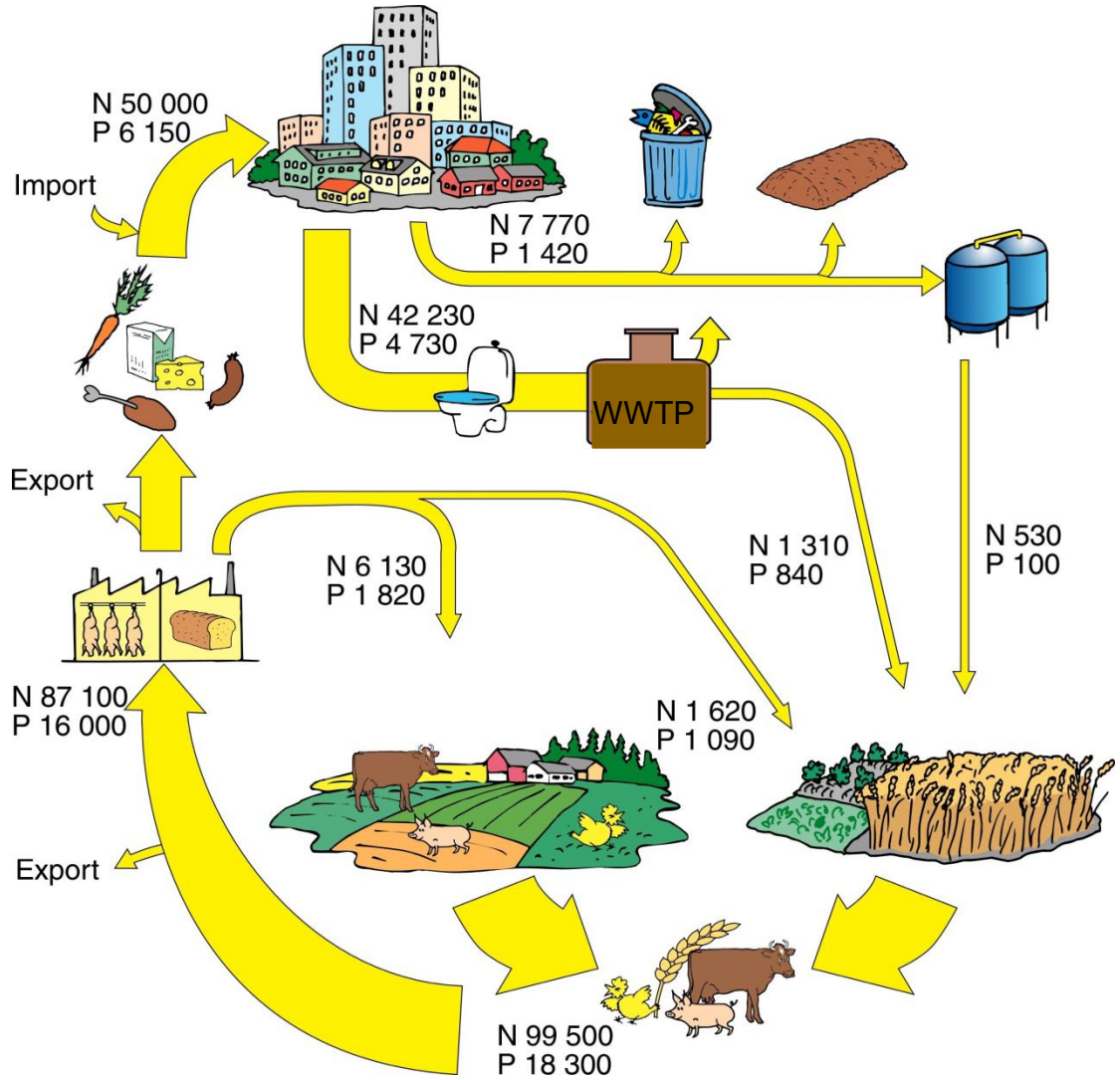
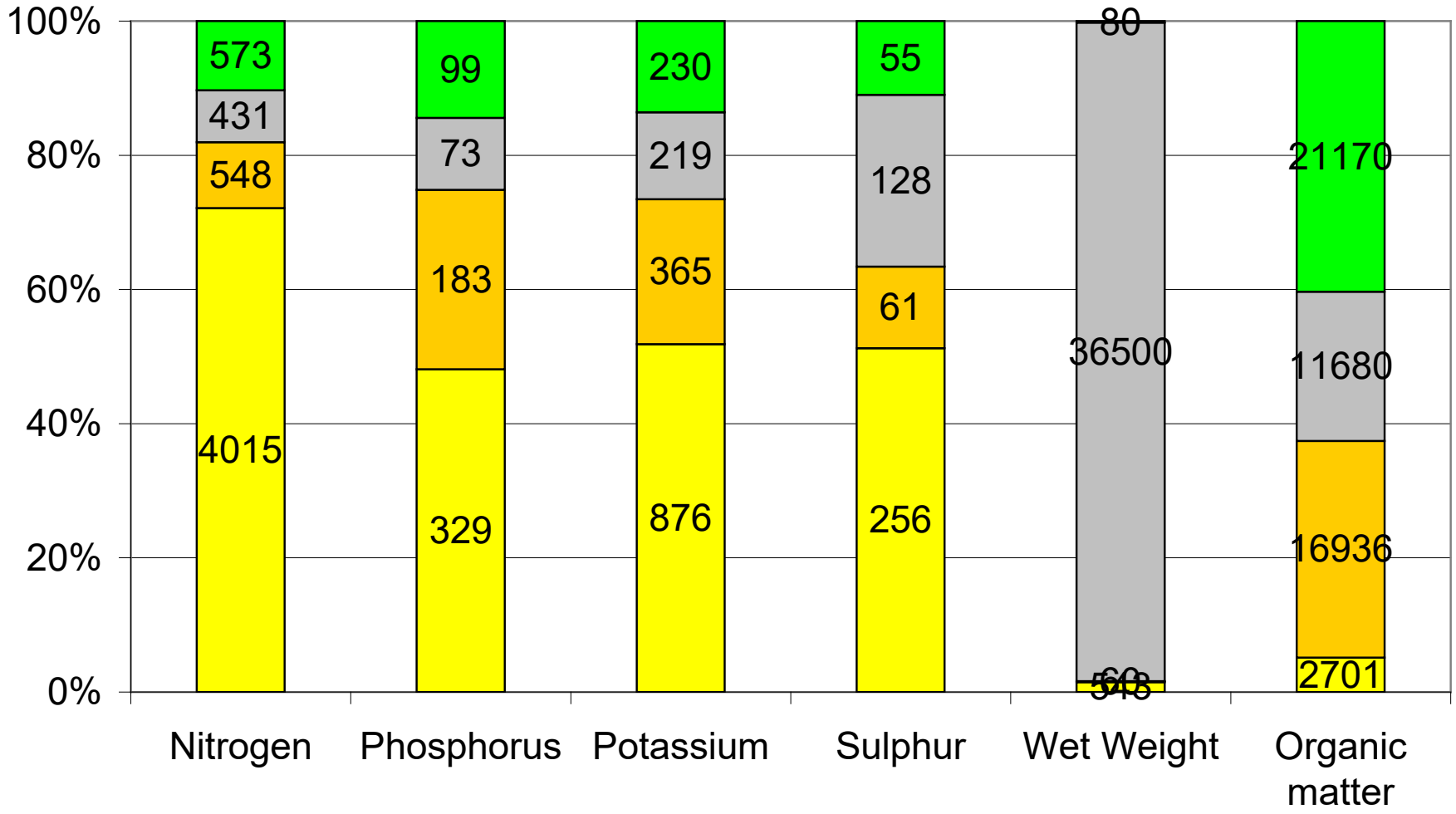


Fig: Wivstad m.fl., 2009 Artist: Gutenkunst

Backwards engineering of wastewater

- Sewage treatment plant 400L per person and day
- Removal of
  - BOD
  - Phosphorus
  - Nitrogen
- Household 150-200 L per person and day
  - Greywater 100-150L
  - Flushwater 30-50L
  - Urine 1.5L (80% of Nutrients)
  - Faeces 0.2L (>99% of pathogens)

Reseourses in wastewater and organic waste, g/p,yr; l/p,yr



0,2 g P in greywater/p,d
100 l greywater/p,d

Jönsson et al., 2005

Fractionate for hygiene

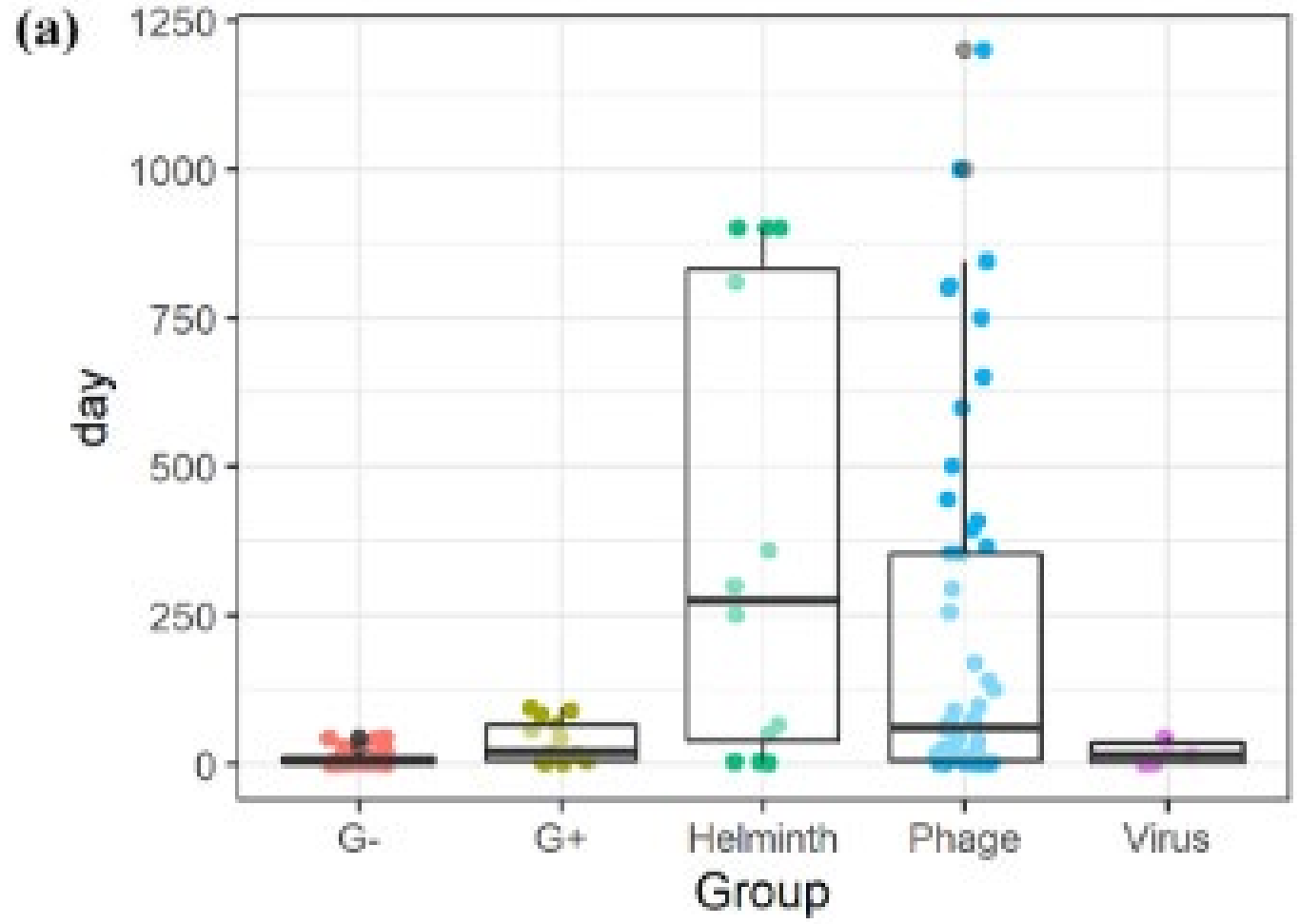
- Faeces separate management
- Dry sanitation
- Small water volumes
- Composting/storage
- Selected reuse
- Urine – clean fertiliser
- Greywater
  - Water source
  - Some pathogen content
  - High level available carbon
  - Treatment needed

WHO inactivation targets

Table 1 Target inactivation values ($\log_{10}(N_e/N_0)$) of virus/phage, helminth egg, and bacteria in urine and fecal sludge, determined according to the 2006 WHO requirements

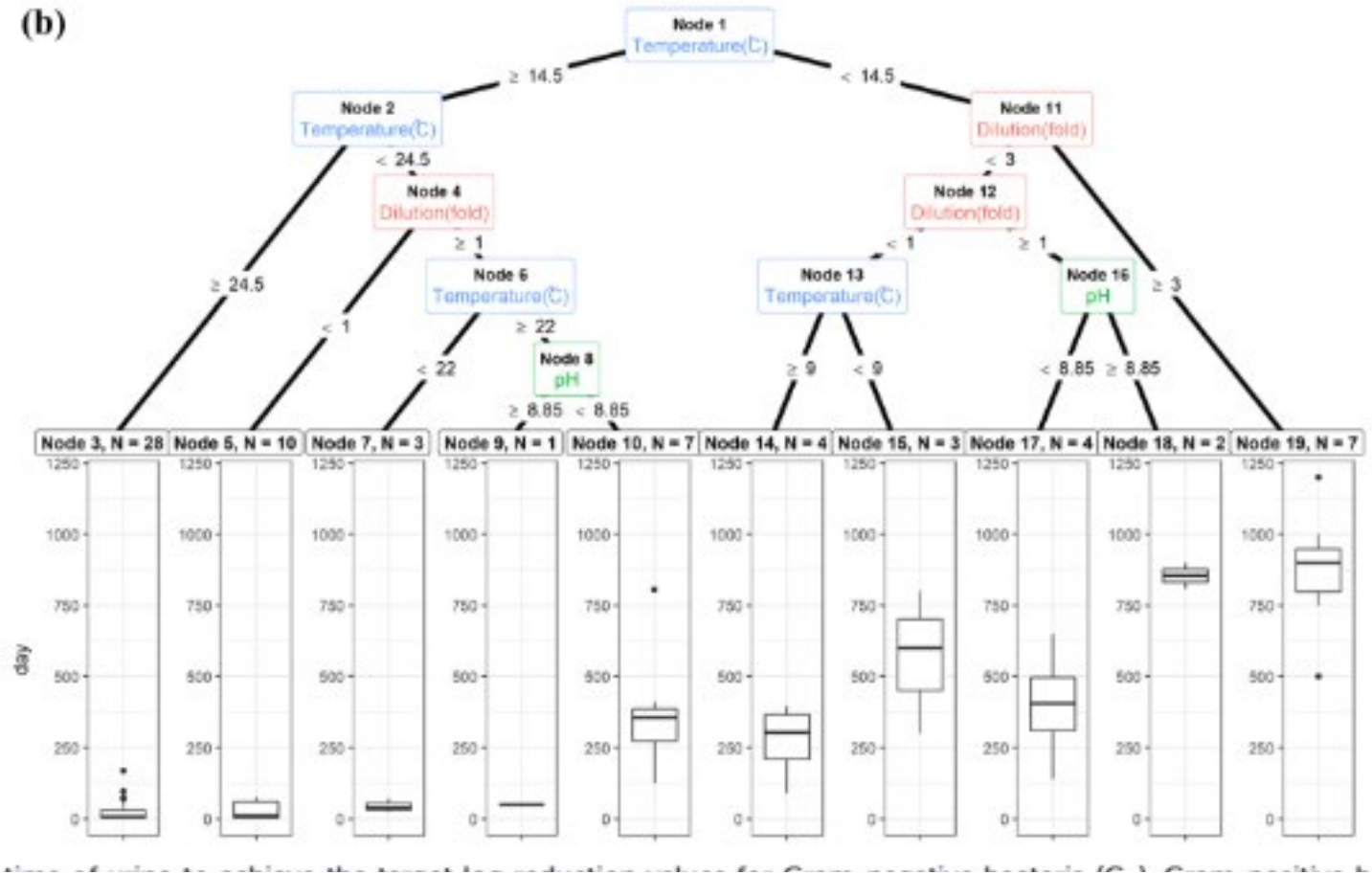
	In urine	In fecal sludge
Virus and phage	5	9
Helminth egg	1	4
Bacteria	2	6

Urine management



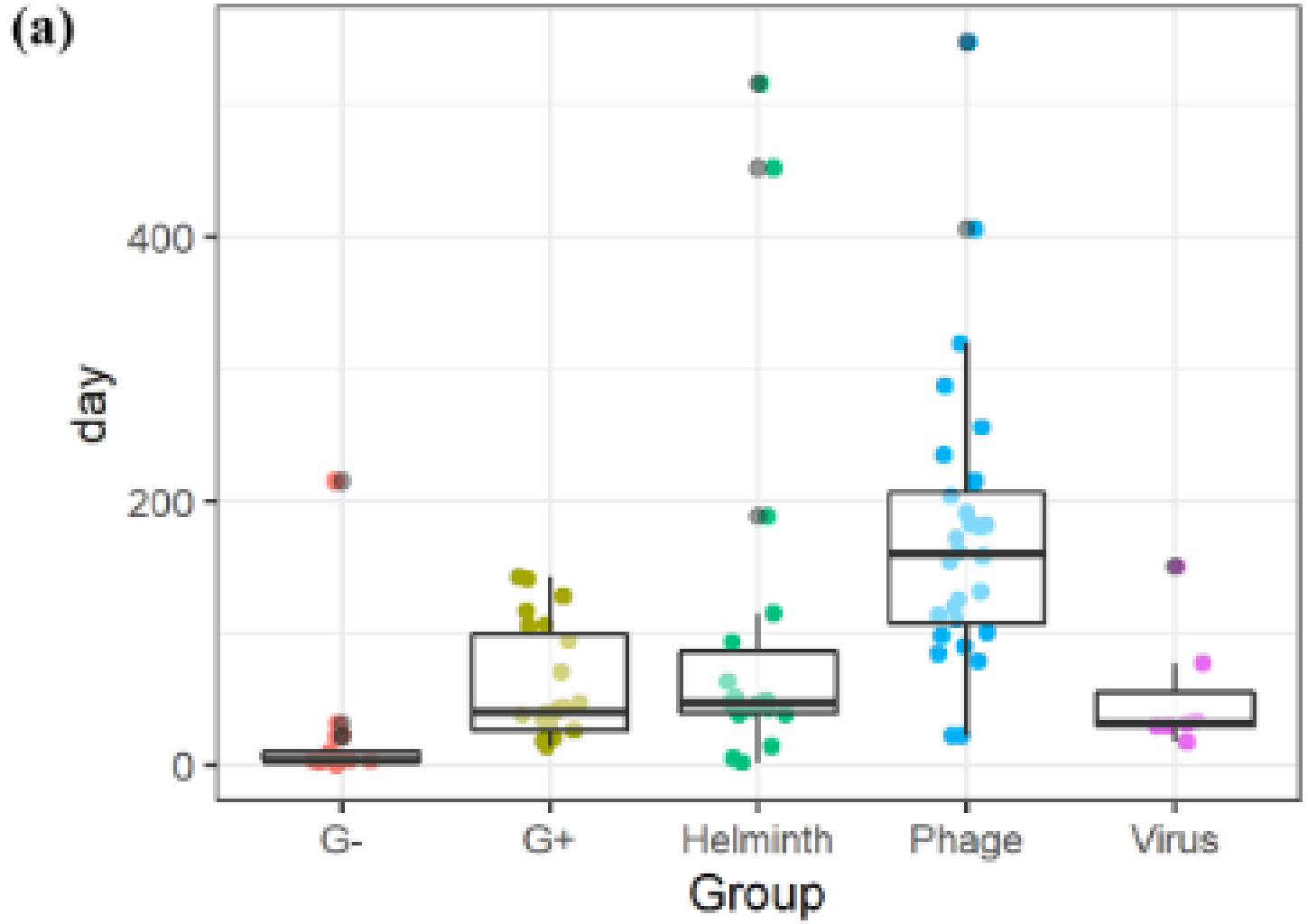
Storage time for target reduction in urine

Urine management



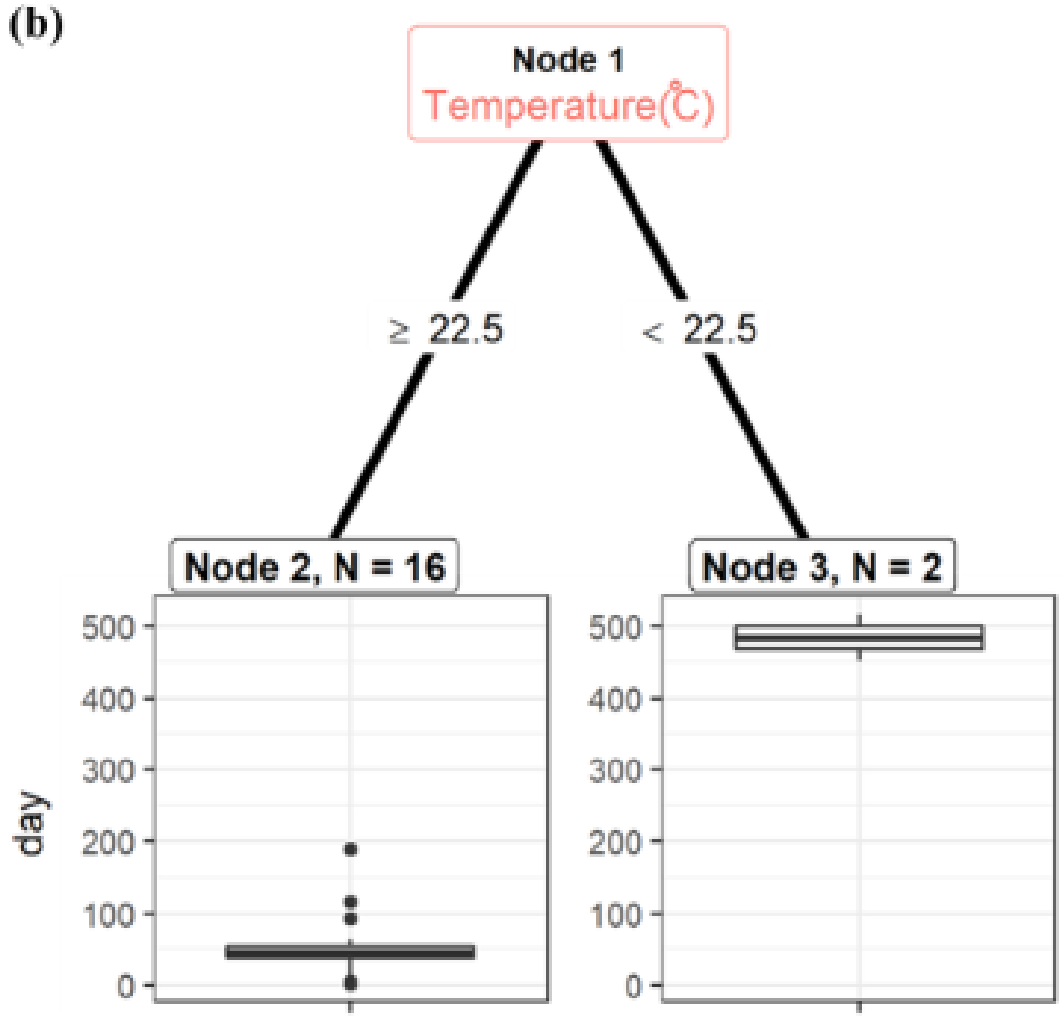
- Regression tree for storage time of urine

Faecal storage



Storage time for reaching target reduction

Faecal storage



Decision tree for storage of faeces

Control points

- Time
- Retention time
- Temperature
- pH
- NH3 concentration
- Moisture

Biocidal factors

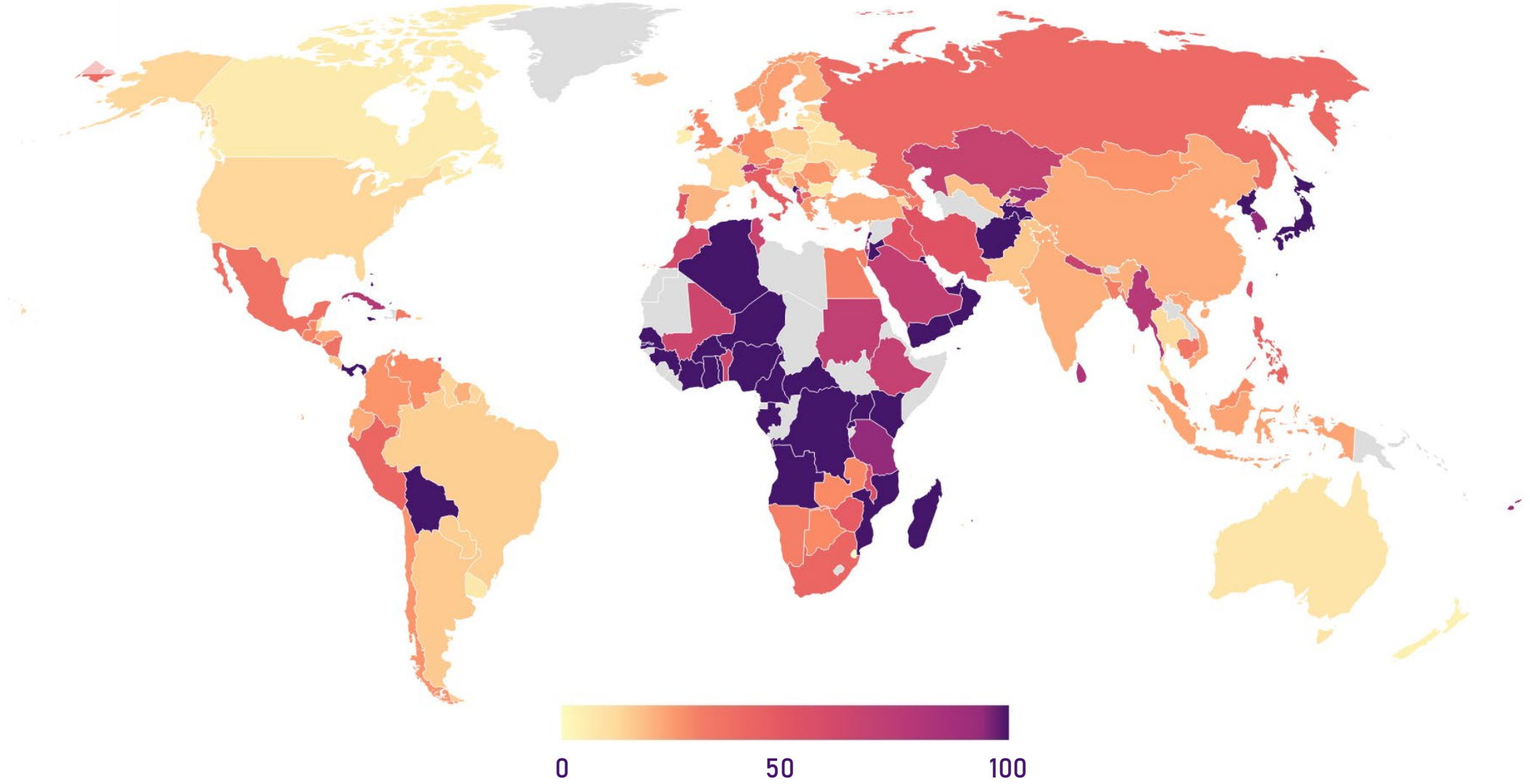
Technologies	High temperature	Alkali/acid pH	Uncharged ammonia	Desiccation	Microbial/enzymatic activity
For urine					
Storage	–	+	+	–	+
Solar heating and pasteurization	+	+[a]	+[a]	–	–
Nitrification and distillation	+	–	–	–	+
Membrane technologies	–	+[a]	+[a]	–	–
Struvite precipitation	–	–	–	+	–
Alkali dehydration	–	+	–	+	–
Ion exchange/sorption	–	–	–	–	–
For fecal sludge					
Storage					
- Bucket latrine and container	–	+	+	–	+
- Single pit latrine	–	+	+	–	+
- Septic tank	–	–	–	–	+
- Twin pits for pour flush toilet	–	+	+	–	+
- Double alternating dry pit	–	+	+	+	+
- Double dehydration vaults	–	+	–	+	+
Alkali sanitization	–	+	+	–	–
Ammonia/urea sanitization	–	+	+	–	–
Solar drying and pasteurization	+	–	–	+	–
Composting	+	–	–	+	+
Vermicomposting	–	–	–	–	+
Black soldier fly composting	–	–	–	–	+
Lactic acid fermentation	–	+	–	–	+
Anaerobic digestion	+	+	–	–	+
Drying	+	–	–	+	–
Microwaving	+	–		+	–

[a] Not significant (–) when urea-hydrolysis is inhibited.

Conclusion - hygiene

- Time is most important
- Chemical factors and temp affects time
- Still lacking a lot of data
- Long time storage often recommended
  - Can have negative environmental impacts

Replacing Synthetic Nitrogen (HABER-BOSCH)



Slide by Prithvi Simha

Author Created using Datawrapper; Data: FAOSTAT 2020 & Jonsson & Vinnerås, 2004

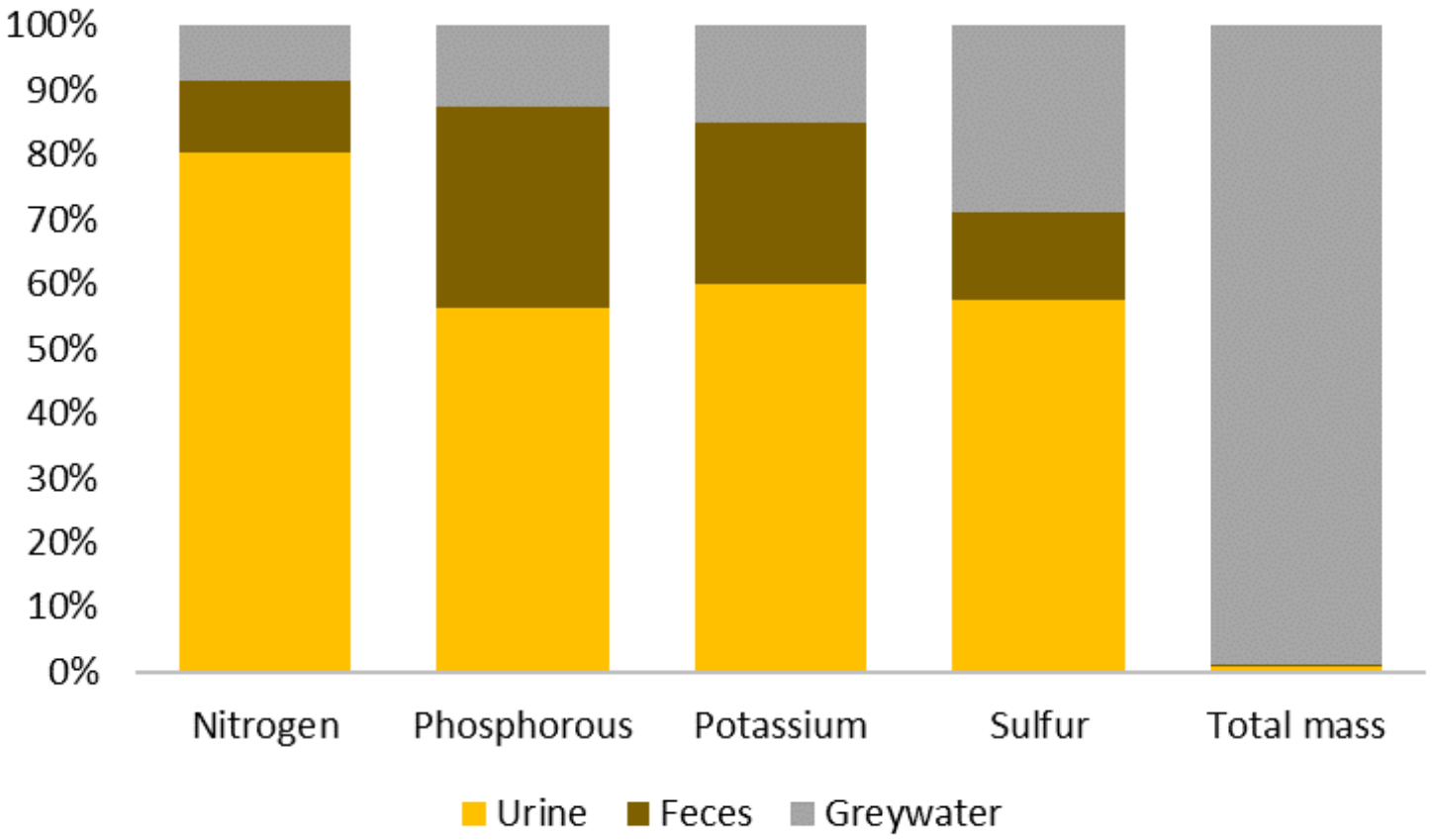
Urine diversion - simple solution to a difficult problem

- **Simple** system - both **small and large** scale, both **developed and developing** countries
- **Recirculation** of large amounts of unpolluted plant nutrients with good hygienic standard
- Substantially decreased nutrient **emissions**
- Saves **energy**, phosphorous and potassium
- **Information and motivation** important
- Can be source to **dry fertiliser** production

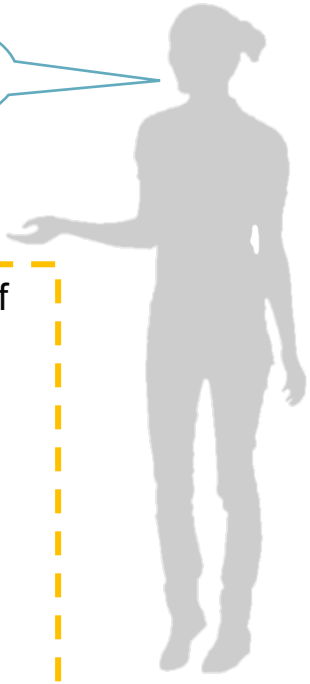
⇒Ready for **immediate implementation**

Urine dehydration

At Sanitation360, we convert waste (urine) into a valuable product (fertilizer).



Why urine?

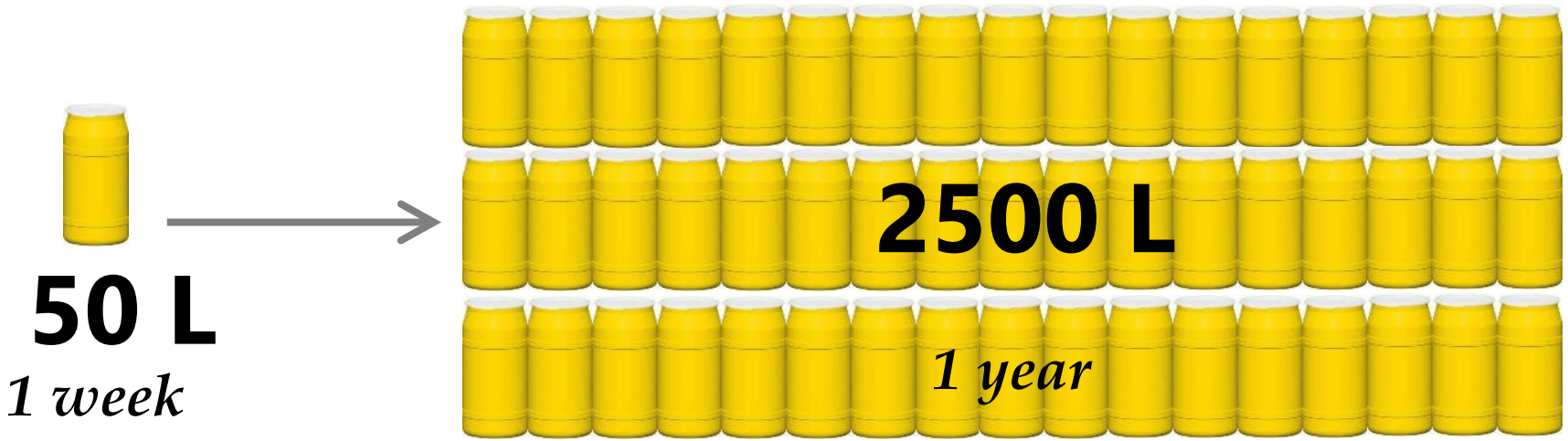


Global replacement potential of chemical fertilizer = 30%

Data from Jönsson et al., 2005

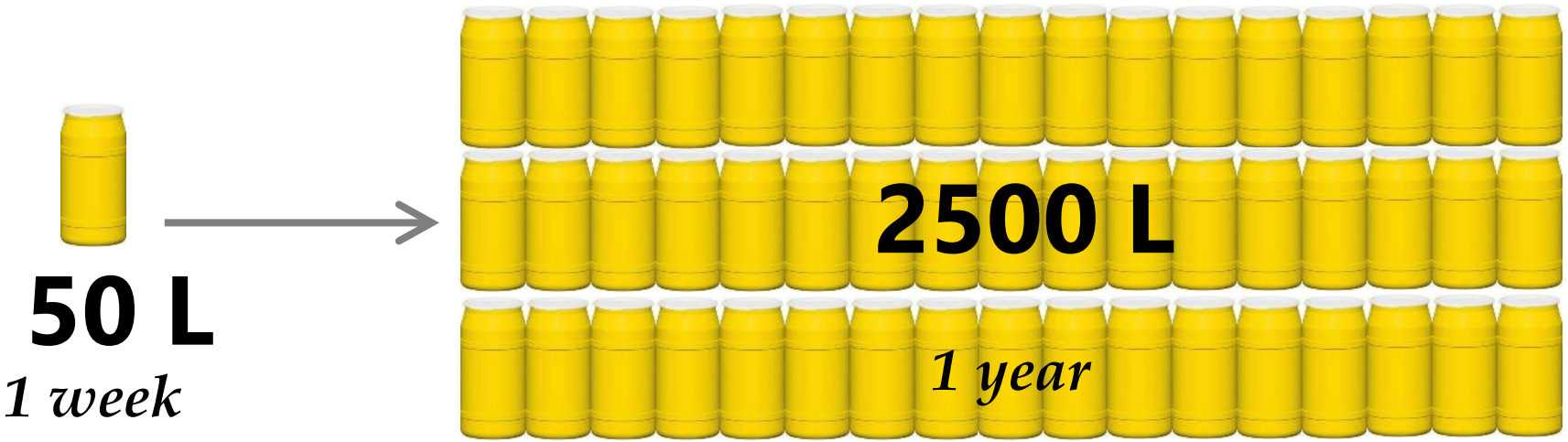
Toilet – urine system requirement

- Family of 4



Toilet – urine system requirement

- Family of 4



125kg Fertiliser
20kg N
10kg K
2kg P

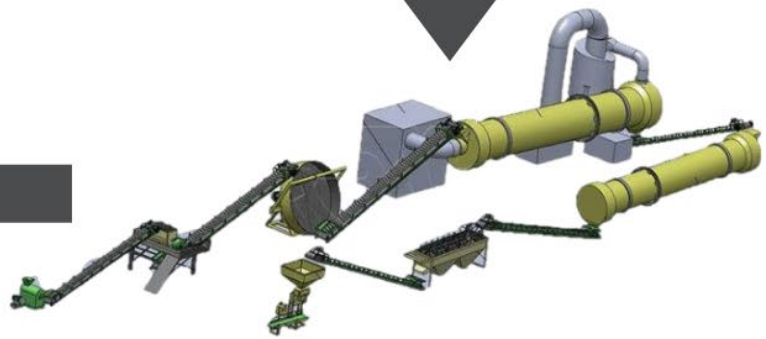
The Process

Stabilizer
(added to the toilet or urinal's urine collection tank)

Urine diverting toilet or urinal

Stabilized urine

Urine Drying System
(concentrates the urine x 25)



Production Facility
(Stabilizer blending and packaging,
In-house manufacturing; Fertiliser factory)

Dry Fertilizer Pellets
(achieved NPK = 15-2-4)

Applied on fields

Urine collection

- Urine diversion
  - Collects approx 70% of urine
- 1.5 L urine per person and day
  - 50-60g TS
  - 11g N
- System for
  - hourseholds
  - Buildings
- Major effect at wwtp

This toilet diverts and collects urine separately from rest of the wastewater

Manufactured by LAUFEN, Switzerland


Як правильно користуватися еко-туалетами
Малий отвір призначено для сечі, великий –для калу.
Після завершення туалету кал треба присипати землею/попелом, але нічого не кидайте в дірку для сечі!!!
Після туалету добре мийте руки милом!!!

Urine concentration

- Konvection drying
- Energy
  - 150 Wh per person and day
- Concentrate
  - 95% water removal
  - liquid
  - Fertiliser raw material

Nutrient peak flow

- Increases water emissions
- Increased N2O emissions
- Peak flows
  - Paus during football game
  - Valborg in Uppsala

Events and sport arenas

Kissamaja

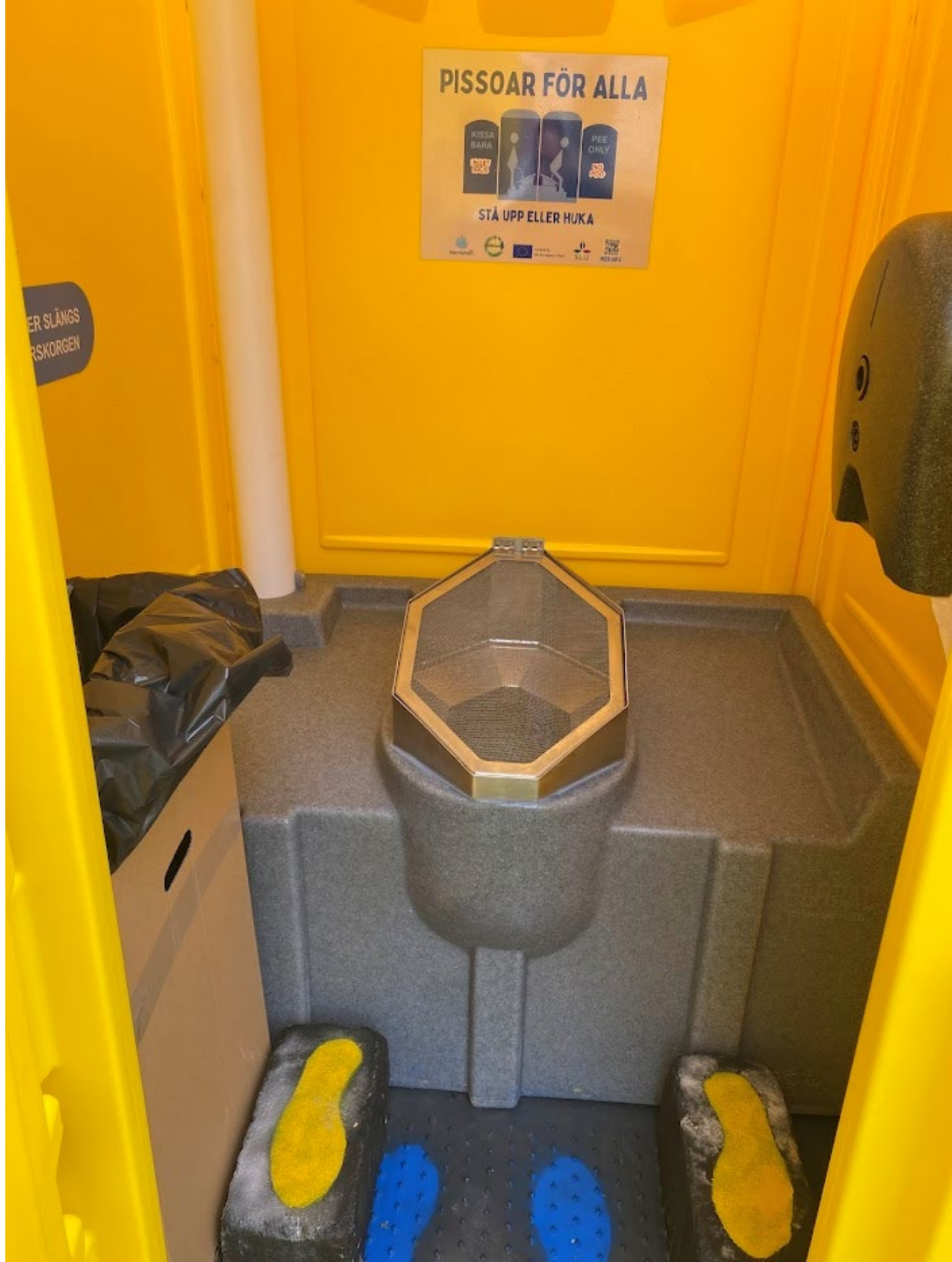
- Event toilet
- Unisex
- Possible to close door
- Nice user experience
  - cleaner
  - Less smell
- Introduction April 2025

Kissamaja

- Event toilet
- Unisex
- Possible to close door
- Nice user experience
  - cleaner
  - Less smell
- Introduction April 2025

Kissamaja

- Event toilet
- Unisex
- Possible to close door
- Nice user experience
  - cleaner
  - Less smell
- Introduction April 2025



Urine collection football arena

- Capacity 10 500
- Inaugurated September 2025
- Urine collection
  - All urinals
  - All handicap toilets
- Long term goal all toilets
- Local stabilisation
- Separate urine vacuum system
- Processing on arena

Collection toilet

- Laufen Save!
- Urine collection beside/behind toilet
- Vacuum transport after event

Collection urinals

- Local collection in tank
  - Tank in room or behind wall
- Stabilisation pH<3.
  - Block degradation of urea,
  - No ammonia formation
  - No smell
- Flushwater diverted
- Big signs
- Vacuum transport after event

Urine transport

- Vacuum system.
- Level sensors in collection
- Over flow safety

Urine transport

- Vacuum system.
- Level sensors in collection
- Overflow safety

Treatment

- Convective drying
- Producing a concentrate

Treatment unit in numbers

- Energy consumption
  - Max load 15-20kW
  - Annual use2000 kWh
- Collected urine 25 000L
- Produced fertiliser 1200 kg
- Fertiliser
  - N 170kg
  - P 20kg
  - K 70kg

The fertiliser

Fertiliser Treatment	N-P-K Content (%)	Mass fertilizer applied (kg/ha)	Barley Harvest (kg/ha)
S360 Fertilizer	15-2-4	567	6 500
NKP fertilizer	24-4-5	370	6 500
Fresh urine	0,6-0,07-0,2	14 167	5 500
Control	0-0-0	0	0 500

Conclusion

- Source separation improves
  - Hygiene
  - Resource recovery
  - Environment
- Urine dehydration
  - Low tech resource recovery
  - High quality fertiliser
  - Decreased environmental pollution
  - Potential replacement of 1/3 chemical fertiliser
- Triple gains
  - Decreased pollution
  - Local fertiliser
  - Improved resource recovery