The Urine Diversion Project at the GTZ Headquarters in Eschborn, Germany

name of the presenter
GTZ ecosan Programme

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partner of
sustainable sanitation alliance

HESSEN

gtz ecosan program recycling oriented wastewater management and sanitation systems

commissioned by
Federal Ministry for Economic Cooperation and Development

GTZ main building in Eschborn

- **office facilities for 650 employees, canteen, meeting rooms and auditorium**
- **built in 1976**
- **renovated between 2004 and 2006**
- **opportunity to promote an urban ecosan (ecological sanitation) system**

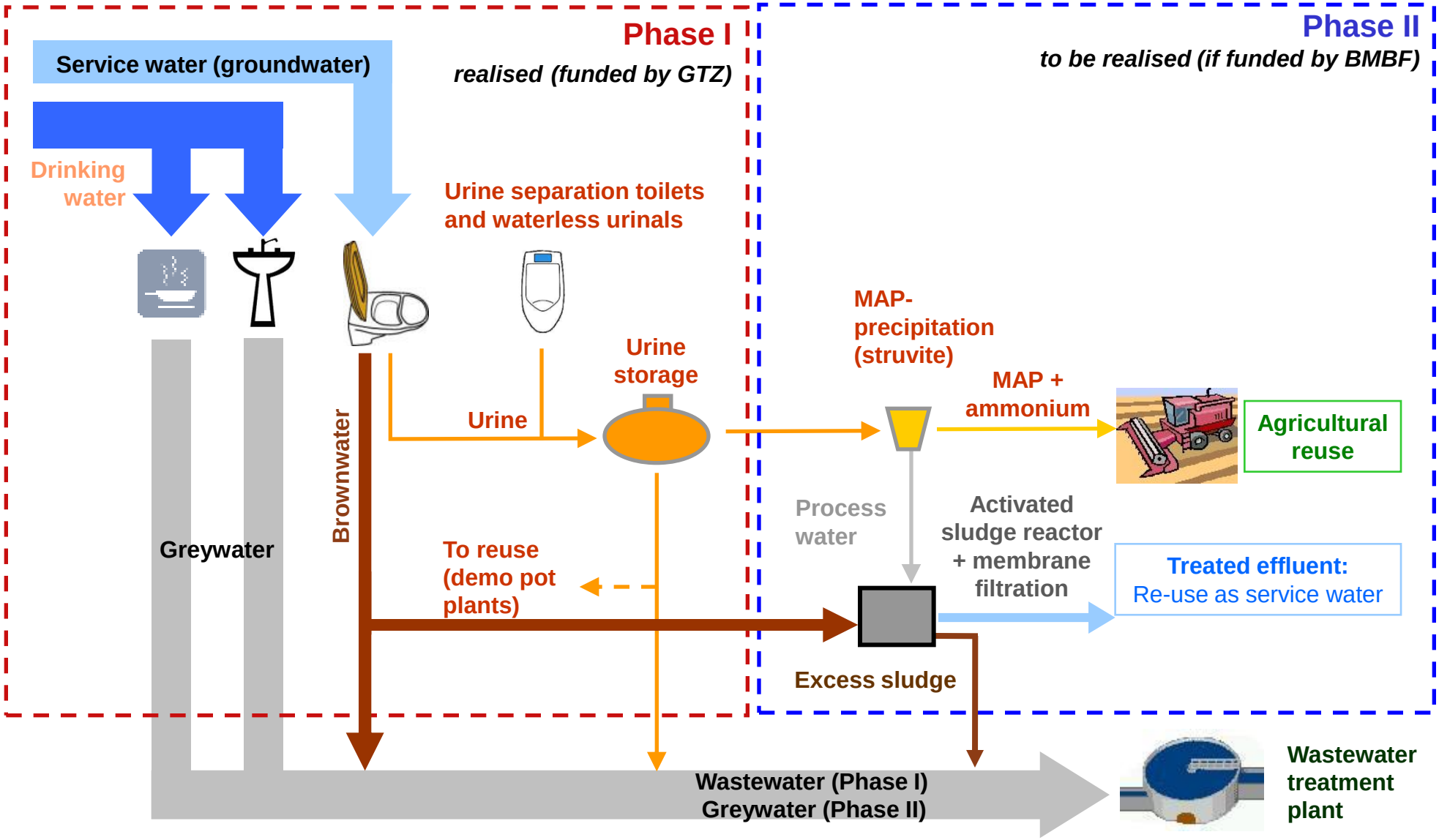
GTZ main office building during renovation

GTZ headquarters with Frankfurt skyline in the background

The renovated GTZ main building

Photos: GTZ

Ecosan Concept in GTZ Haus 1 (only phase I realised)



Phase I – Technical Implementation

Technical components installed (I)

50 low-flush urine diversion toilets (Roediger)
(1-3 L per urine flush, 6-9 L per faeces flush). Set during installation

Photos: GTZ

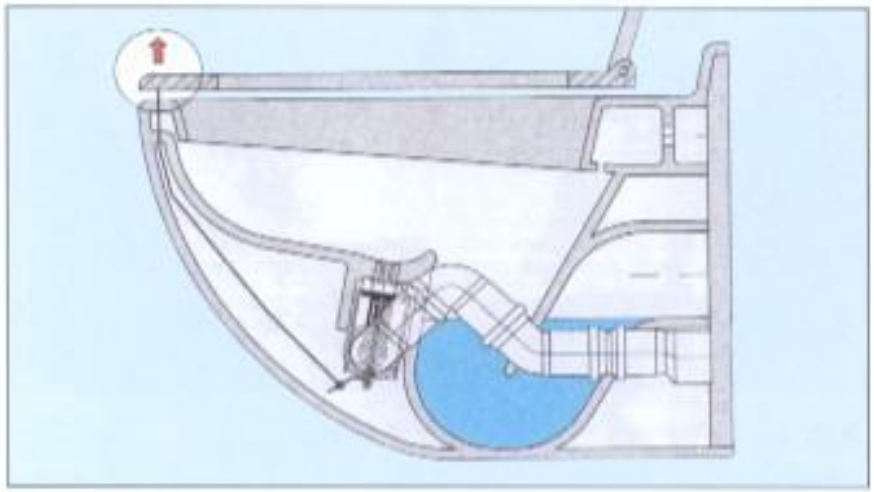
2nd generation

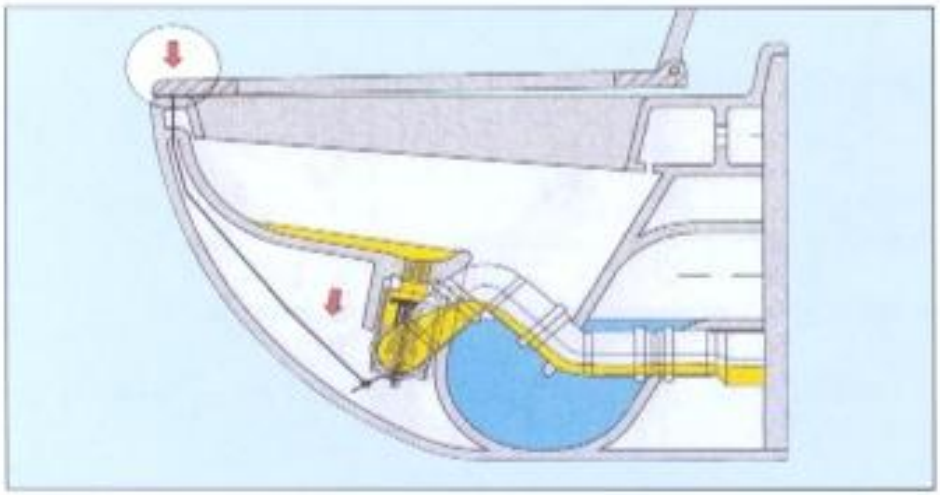
1st generation

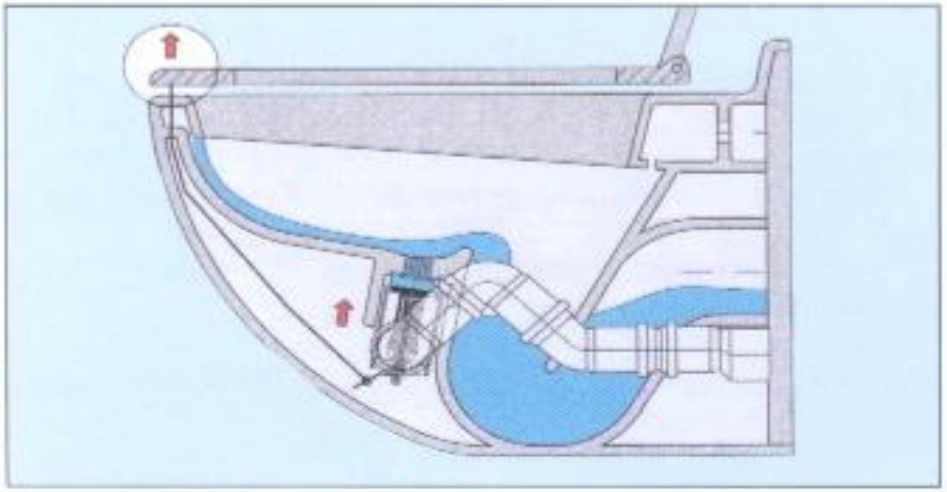
23 waterless urinals (Keramag)

Photos: GTZ

Technical components installed







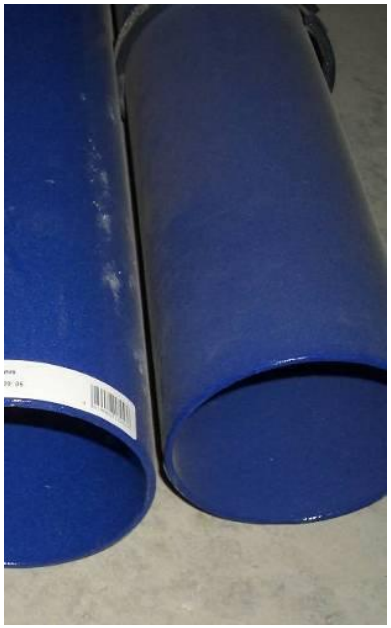
Functional scheme of the Roediger "No Mix Toilet"

(source: Roediger)

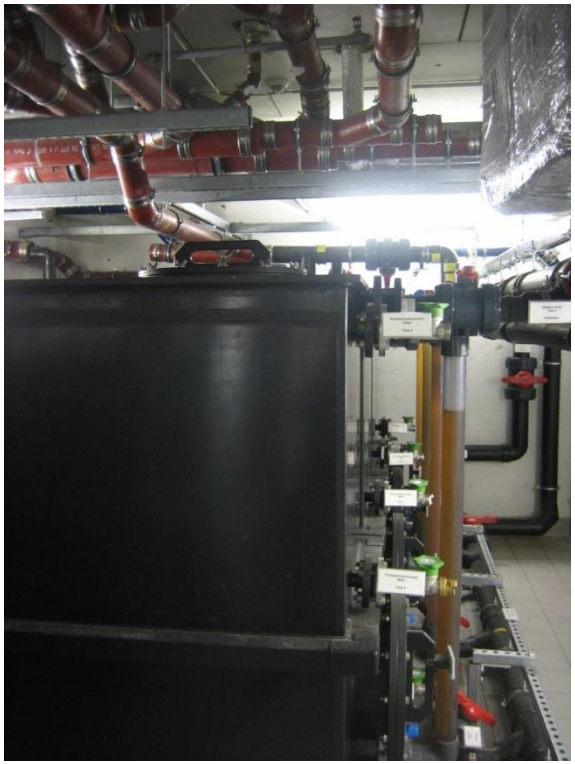
Phase I – Technical Implementation

Technical components installed (II)

Photos: GTZ



Urine collection pipes 50, 80 and 100 mm made of cast iron with enamel coating



PE urine storage tanks (4 x 2500 L)

Docking station for vacuum tanker

Urine Tank Emptying & Transport to uni Aachen for precipitation

Pump truck connection to docking station

Inside storage tank during urine evacuation

Photos: GTZ

From vacuum tanker Pumping into 1m³ plastic containers

Opportunities of this project

1. Users accept novel sanitary system and idea behind it (see survey results later)

2. Water savings(estimate:1000-2000m3/yr) (measurements not available)

3. Infrastructure for research of
   - Treatment technologies
   - User acceptance
   - Legal and economic aspects
   - Reuse practices

4. Demonstration object

5. Demonstration garden: urine is an excellent fertiliser

Photos: GTZ 2008

Challenges

1. Correct operation and maintenance
   - Daily cleaning of urinal rubber odour seal with rinsing water .
   - Regular (once every two months) use of urine scale removing chemicals in urine inlet valve of toilets

2. Urine diversion toilets not in full technical maturity
   - Urine inlet valve prone to struvite precipitation
   - Trade-off flushing strength ↔ water saving and avoiding drops on toilet seat
   - Flushing of toilet paper
   - Users have to sit etc.

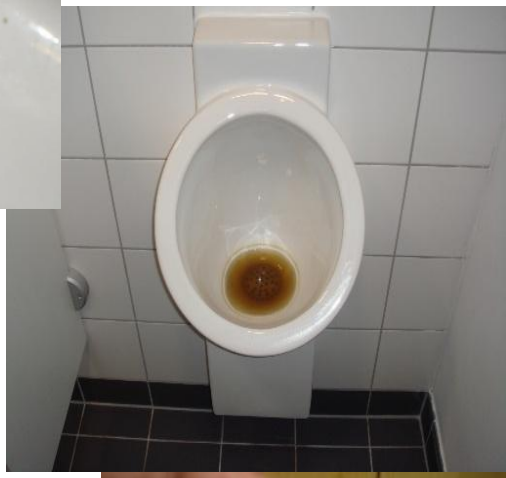
3. Cost-effectiveness not yet given (economy of scale)

4. Reuse of urine in agriculture not yet allowed in Germany
   - Micropollutants
   - Special permit required for urine application on fields

Photos: GTZ, 2009

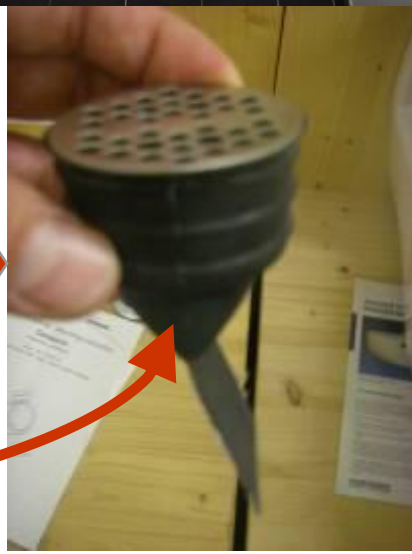
Problems with the waterless urinals

- if maintenance neglected: precipitations on rubber tube odour seal (not closing properly anymore)
- leakage of the drainage cylinder due to small vertical downwards movements of urinal on wall
- some pubic hairs in the urinal sticking to surface



...and how we solved them

- daily cleaning of urinals and of rubber tube seal
- exchange of the rubber tube seal after about 6 months
- micro-biological cleaning agent
- fresh air circulator
- 2nd version of rubber tube odour seal



…and how we solved (or will solve) them

- **in future: toilet seat covers for the ladies room, or disinfection spray in the cubicles**
- **“coffee test” to regularly check if urine valve is opening properly or not**
- **acid cleaning agent to dissolve precipitation on urine valve → contact time over night**
- **more collaboration with toilet maintenance crew**
- **user information poster in cubicles**

Problems with the toilets

- toilet paper or faeces do not always get flushed away with one flush
- some females do not sit down on public toilets
  → their urine not collected
- toilet maintenance neglected
  → urine valves clog due to precipitation (31 toilets in Aug. 2008)
  → urine drains off with flushing water

Tours and show room (“toilet museum”)

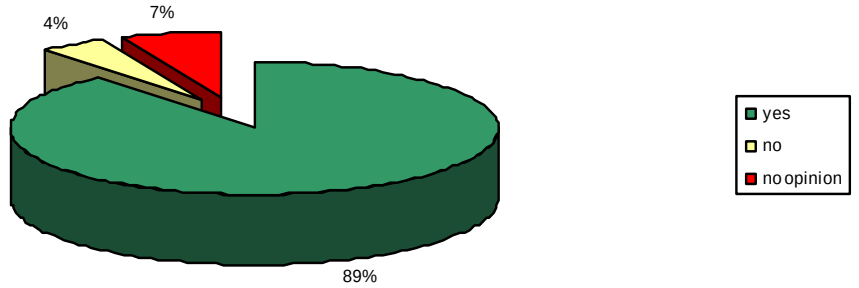
- **regular tours for visitors and students**
- **show room of different technologies**

Photos: GTZ

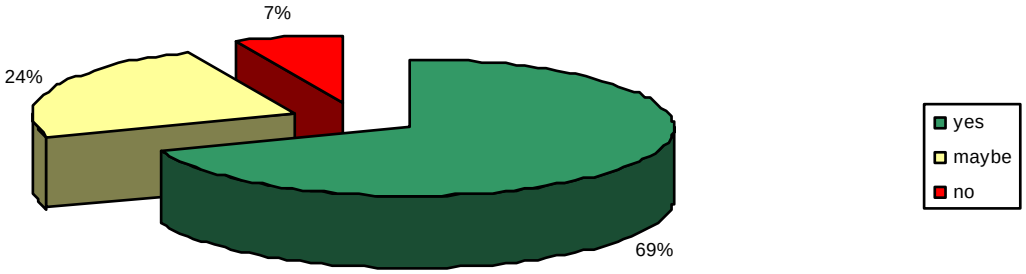
User survey in Sept. 2008

- 182 participants (gtz employees) in Eschborn
- majority (89%) think the separate collection of urine and usage as fertilizer is a good idea
- majority (69%) would buy fruits which are fertilized with urine
- 44% think it should be allowed to use urine as a fertilizer for organic farming

Do think the separate collection of urine and usage as fertilizer is a good idea?



Would you buy fruits which are fertized with urine following the WHO guidelines for the safe use of urine in agriculture?



Conclusions

1. **Possible to implement urine diversion systems in an urban office building in Germany**

2. **People accept waterless urinals and new toilet designs, and the idea of using urine as fertilizer**

3. **Room for improvement of design of UD flush toilets (valve and bowl design; ventilation system)**

4. **Urine-fertilized tomato plants have sparked even more interest from gtz colleagues than the UD toilets! (→ mainstreaming ecosan in gtz)**

Planned future work

- **More promotion and awareness raising: posters in toilets, more user online surveys and feedback**
- **Obtaining a permit for urine reuse on research fields**
- **Promoting installation of waterless urinals in gtz offices around the world**
- **Working on Phase 2 of the project (BMBF funded)**

Thank you for your attention!

Questions?

More Photos
www.flickr.com
Keyword: ecosan

Further information:
www.gtz.de/ecosan
www.susana.org

Photo: GTZ

Appendix

GTZ personnel in Eschborn (2008)

Einsatzort: Eschborn	Haus					
	?	Haus 1	Haus 2	Haus 3	Haus 4	Gesamt
Azubi	47,0	8,0	7,0	7,0	1,0	70,0
IMA	14,7	425,3	270,9	238,2	17,3	966,3
PMI	23,2	112,0	101,7	80,6	26,4	343,9
Praktikant	35,0	28,0	20,0	13,0	1,0	97,0
Gesamt	**119,9**	**573,3**	**399,6**	**338,8**	**45,7**	**1.477,2**

Source: Personalzahlen nach Häusern (preparative document for GTZ environmental report 2008)

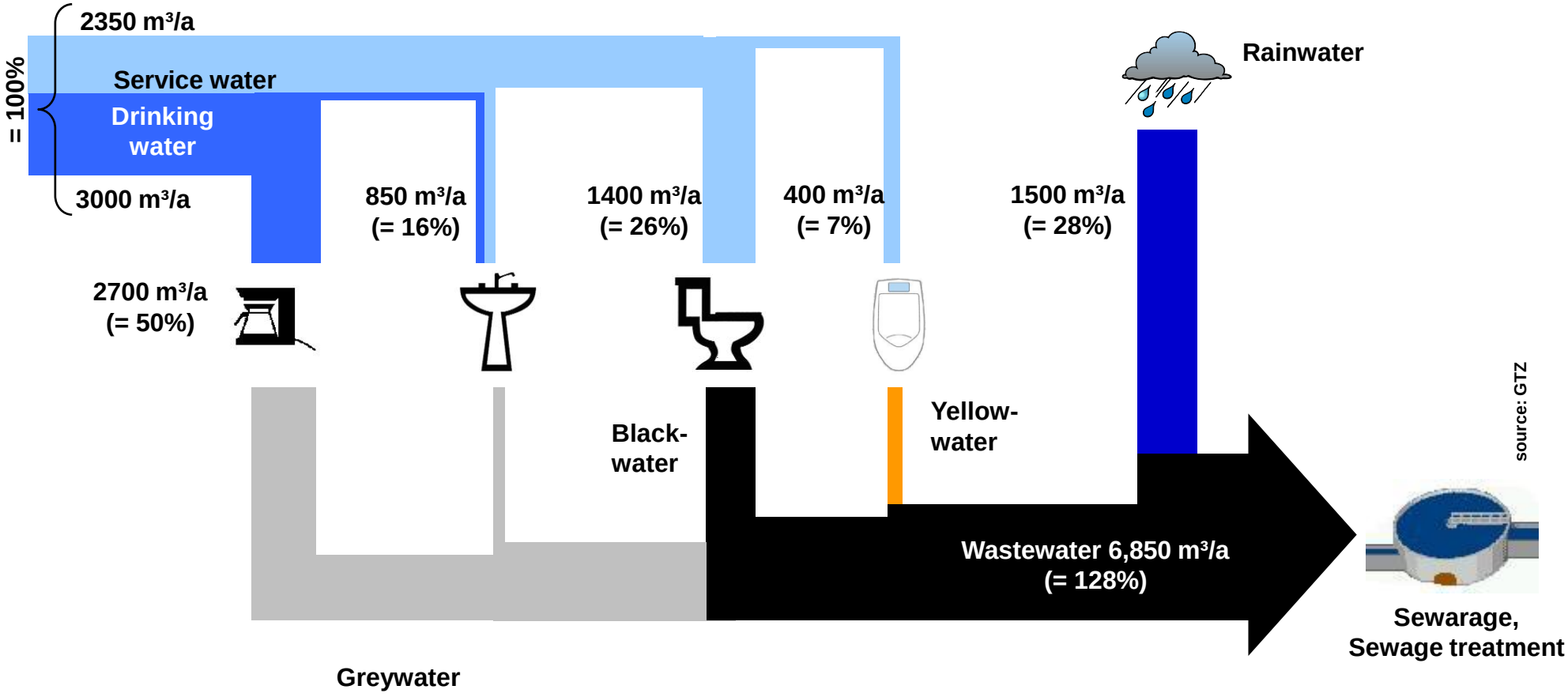
Legende

IMA: Mitarbeiter in Zentrale-Funktionen
PMI: Projektmitarbeiter Inland
Azubi: Auszubildende (für diese fehlt häufig eine Raum-Zuordnung)
Praktikant: In 2006 erstmals in die Übersicht aufgenommen, allerdings fehlt hier vielfach eine Raum-Zuordnung
Kann für Vergleichbarkeit mit Vorjahren ggf. unberücksichtigt bleiben.

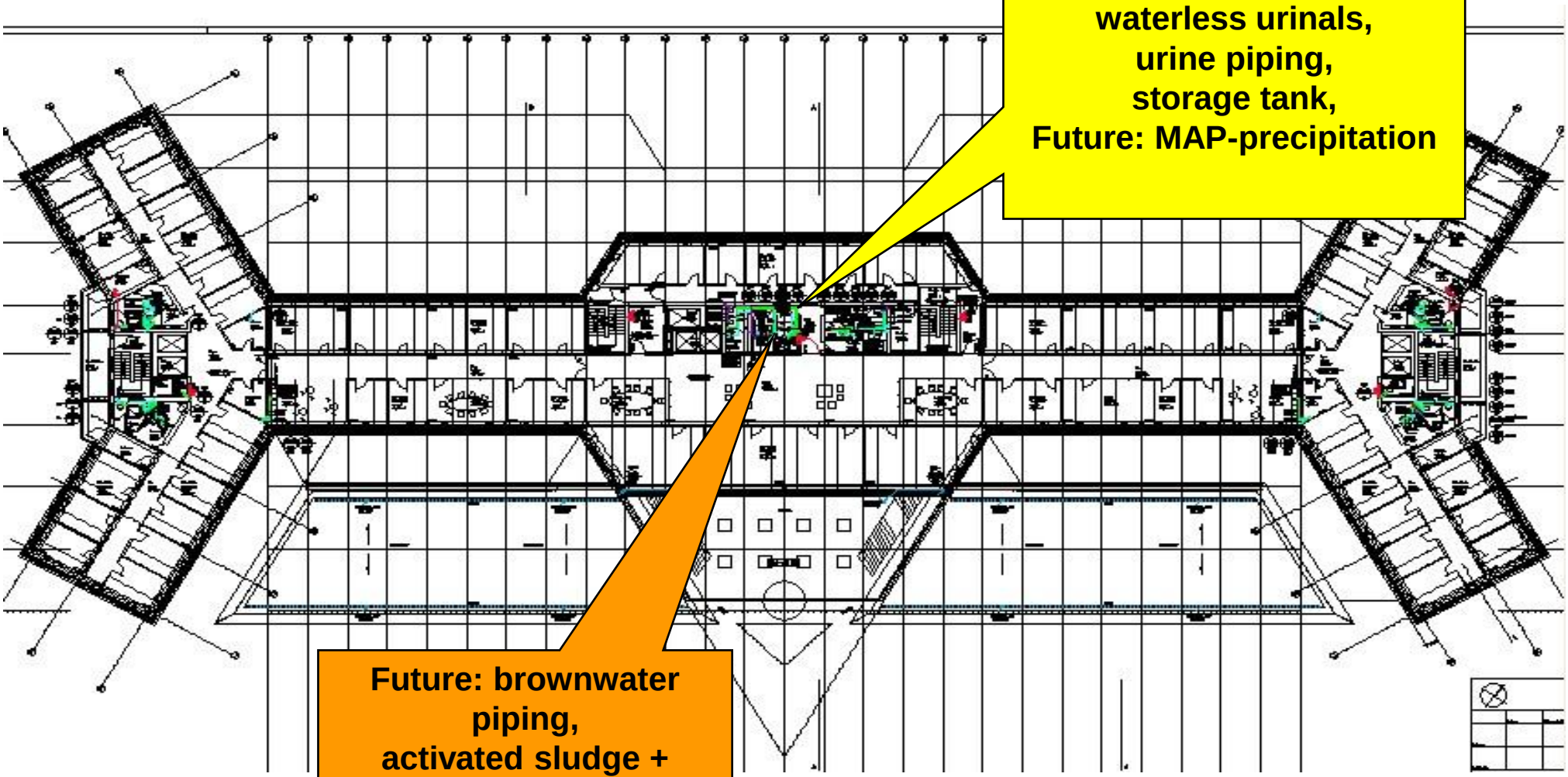
? Keine Raum-Zuordnung verfügbar.
Möglicherweise Einsatz in wechselnden Büros oder direkt in Ministerien (Berlin, Bonn)

Previous conventional system

Additionally ~ 68,000 m³/a of service water evacuated and discharged into a creek nearby!

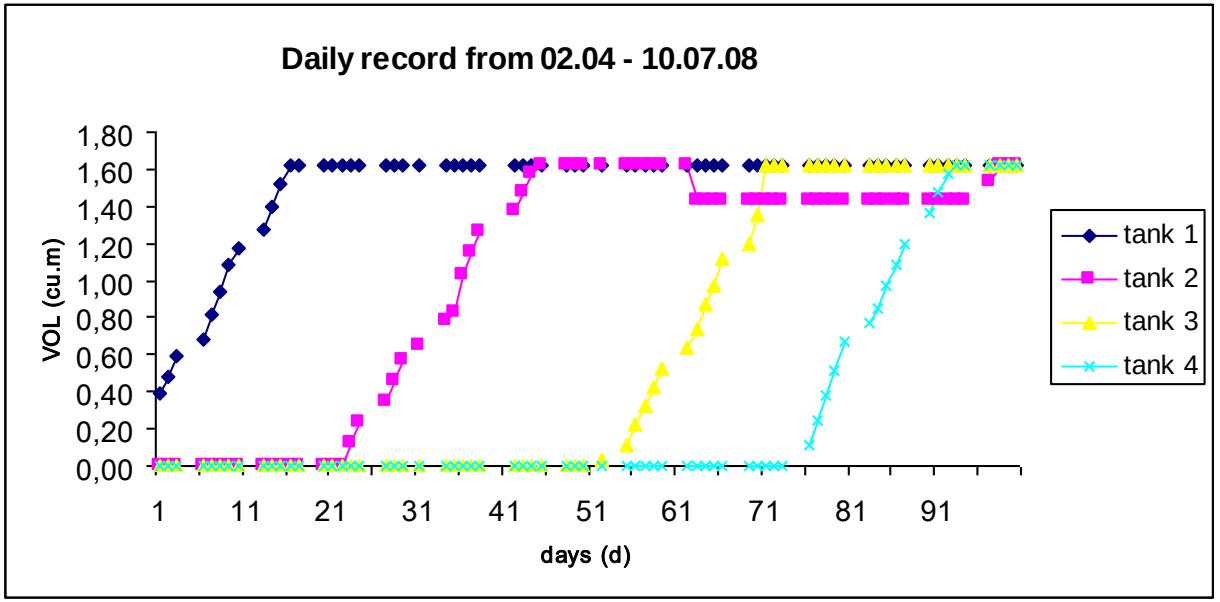


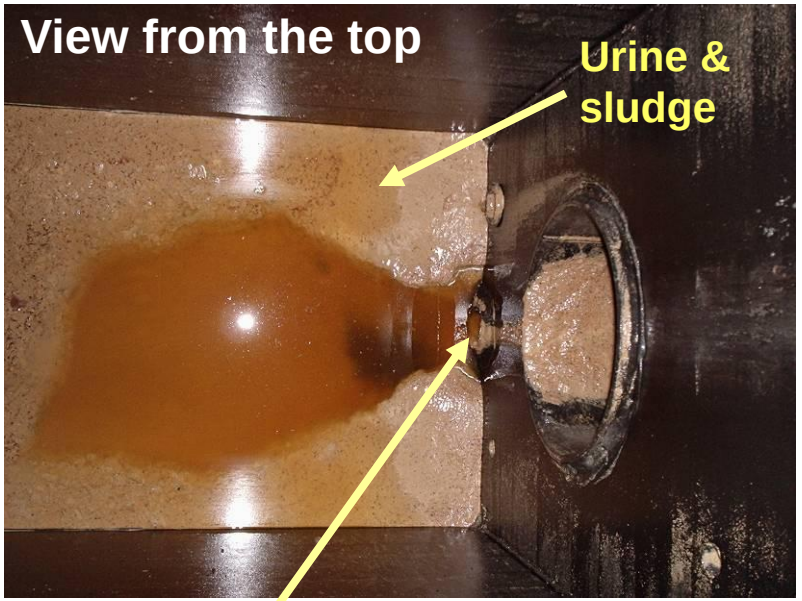
Overview - implementation

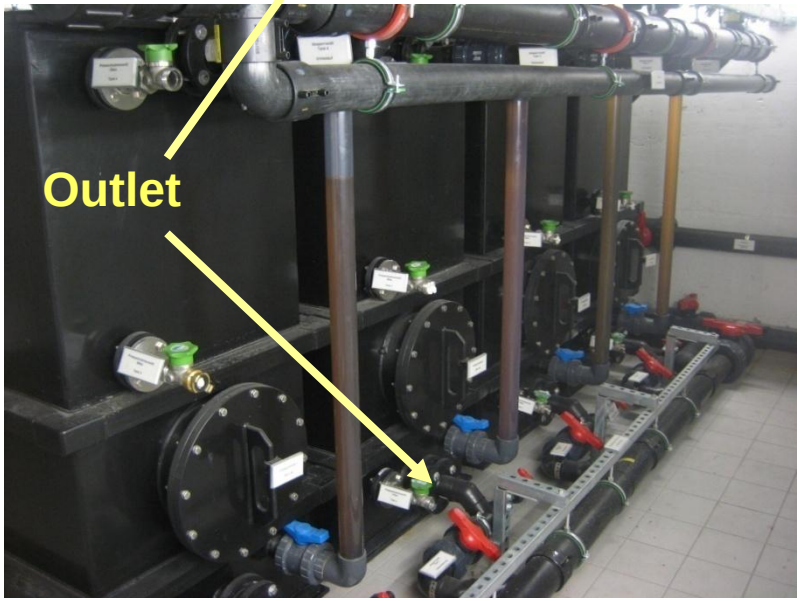


Urine production and uses

- **approx. 90 days filling time**
  → approx. 110 L/d urine
- **emptying by vacuum tanker**
- **precipitation inside of storage tank**
- **MAP production tests at Uni RWTH Aachen and treatment tests at FH Gießen**







Service water system in Haus 1

Source of service water

- **Groundwater is pumped on-site**
- **Goal: to keep the groundwater table low under the buildings (otherwise water would enter underground parking)**

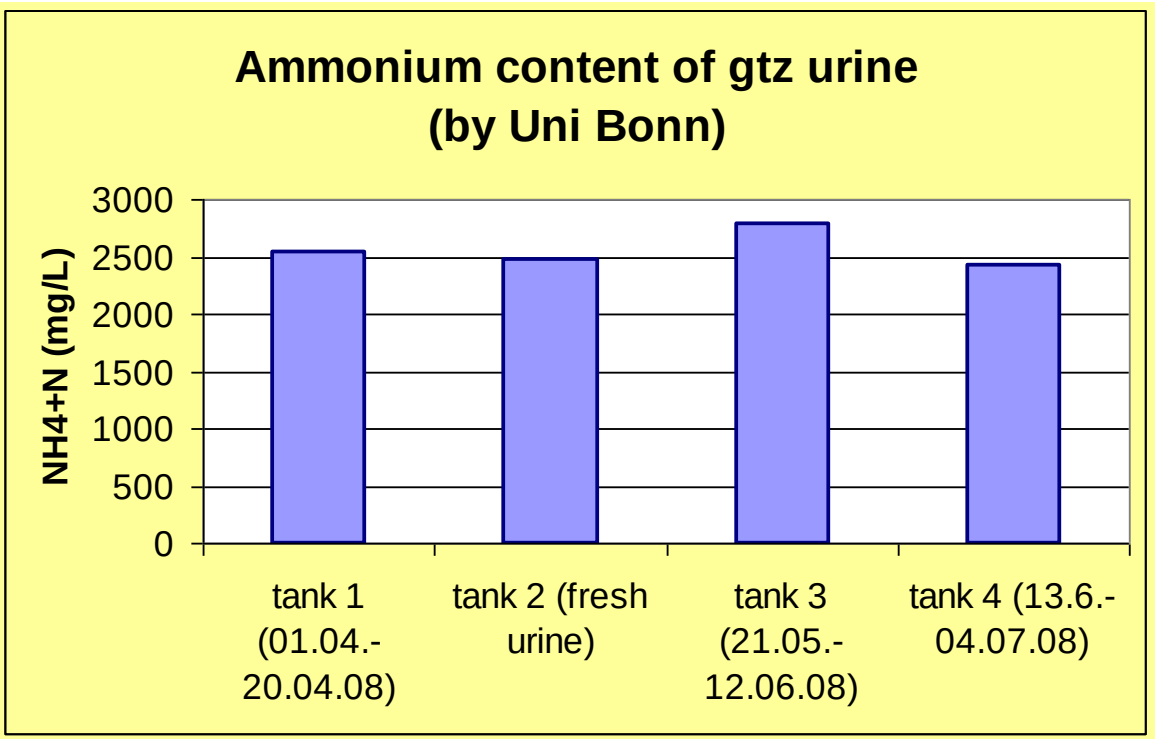
Use of service water

- **Toilet flush water**
- **Grease separator**
- **Cooling water for data processing center**
- **Air conditioning system**
- **Cleaning (separate water taps)**

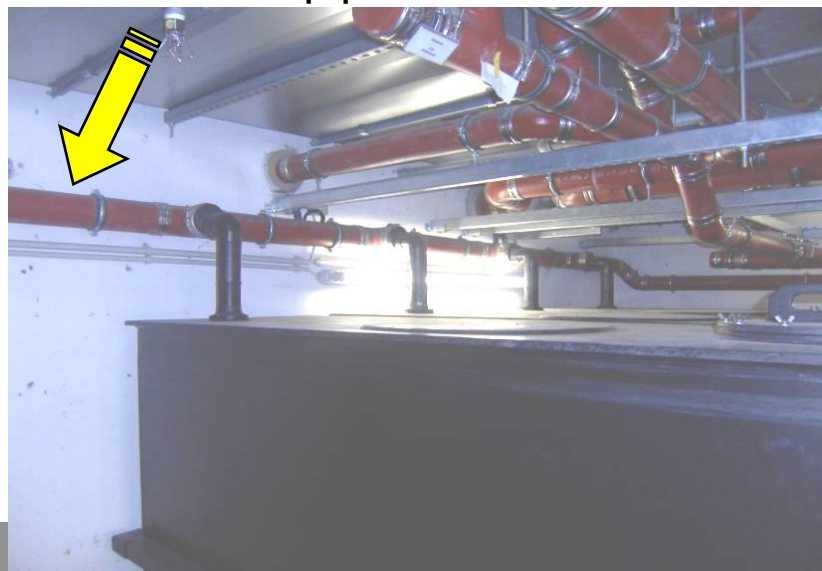
Even though it is clean the service water is not used as drinking water, because quality control would be too costly.

Problems with low ammonium content in urine (one third of expected)

- **ammonium content ca. 2800 mg/L**
- **literature value stored undiluted urine: 7000 - 9000 mg/L**

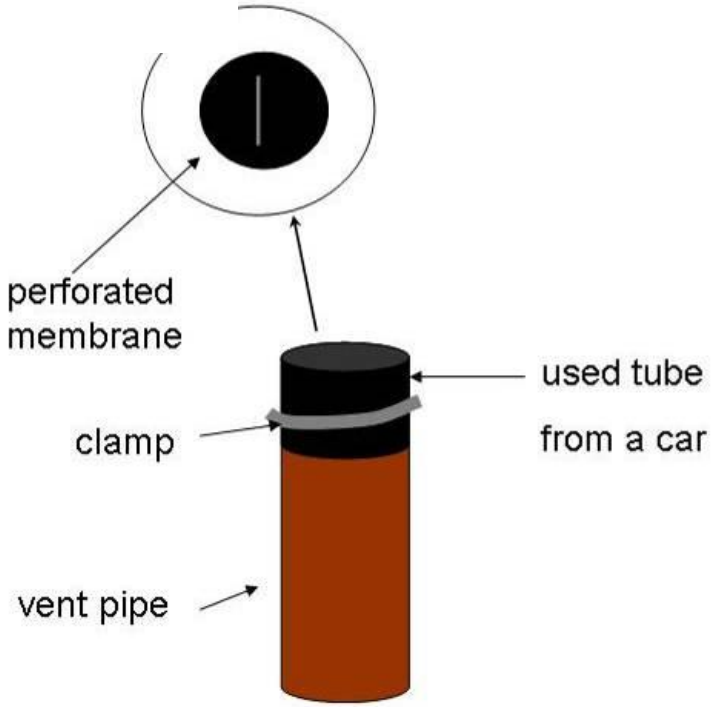


Vent pipe



…and how to reduce ammonium stripping

- **reduce the ventilation**
  - **cover the ventilation pipe from the urine storage tank on the roof**



other possible reasons for low ammonium content

- **no high concentrated morning urine**
- **diluted with flush water if user flushes toilet while sitting down**

Software and promotion

- user information on the toilets
- ecosan Information Poster at the canteen
- guided tours to the urine storage and show room
- demonstration garden
- promotion event on the world water day
- online survey

source: GTZ

source: GTZ

Feedback from the survey

- ***"…the approach is good, but the technical realization of the toilets could be done better"***
- ***"…solid matters stick in the toilet!"***
- ***"…I fear that hormones and drugs end up into the plants"***
- ***"…is water saving in Germany really necessary?"***
- ***"…gtz is probably the only company which asks their employees about their sanitation habits."***

Appendix – water saving calculations

Berechung der gesparten Wassermengen in Haus1

		ecosan System	konventionell	Ersparnis
Anzahl der Urinalbenutzung pro Tag		4,0	4,0	
Spülwassermenge Urinale	Liter [l]	0	3	
Handwaschmenge	Liter [l]			
männliche Nutzer (Mitarbeiter-+ Gäste)	[n]	80	80	
männliche Nutzer (Gäste)		0	0	
Mitarbeiterarbeitstage pro Jahr	d/a	250	250	
Summe	kbm/a	0	240	240
Anzahl der Toilettengänge pro Tag (urinieren) Frauen		4,0	4,0	
Spülwassermenge	Liter [l]	1	8	
weibliche Nutzerinnen (Mitarbeiterin)		80	80	
weibliche Nutzerinnen (Gäste)		0	0	
Mitarbeiterarbeitstage pro Jahr	d/a	250	250	
Summe	kbm/a	80	640	560
Anzahl der Toilettengänge pro Tag (defäkieren) Männer		1	1	
Toilettenspülwassermenge	l	6	8	
männliche Nutzer (Mitarbeiter-+ Gäste)	[n]	80	80	
männliche Nutzer (Gäste)		0	0	
Mitarbeiterarbeitstage pro Jahr	d/a	250	250	
Summe	kbm/a	120	160	40
Anzahl der Toilettengänge pro Tag (defäkieren) Frauen		1	1	
Toilettenspülwassermenge	l	6	8	
weibliche Nutzerinnen (Mitarbeiterin)		80	80	
weibliche Nutzerinnen (Gäste)		0	0	
Mitarbeiterarbeitstage pro Jahr	d/a	250	250	
Summe	kbm/a	120	160	40
Summe alle	kbm/a			880
	l/d			**3.520**
	l/(d*Pers)			22

Appendix - costs of the system

	Conventional system (€)	GTZ building prototype (€)	ecosan large-scale (€)
Sanitary infrastructure			
Conventional urinals	10.000	-	-
Waterless urinals		10.000	10.000
Conventional toilets	15.000	-	-
UD toilets		76.000	25.000
Blackwater pipe system	35.000	-	-
Urine pipe system	-	33.000	20.000
Brownwater pipe system	-	35.000	20.000
Greywater pipe system	-	20.000	20.000
Urine collection tank + pumps	-	45.000	20.000
Subtotal Sanitary Infrastructure	**60.000**	**219.000**	**115.000**
Treatment infrastructure			
Urine treatment	-	45.000	20.000
Brownwater treatment	-	60.000	30.000
Greywater treatment	-	-	30.000
Sewerage network (proportionately)	450.000	450.000	
Sewage treatment (proportionately)	45.000	23.000	-
Subtotal Treatment	**495.000**	**578.000**	**80.000**
Total	**555.000**	**797.000**	**195.000**
Difference (compared to conventional scenario)	**+ 0**	**+ 242.000**	**-360.000**

source: GTZ

Appendix - costs of the system

	Conventional system (€/year)	GTZ building prototype (€/year)	ecosan large-scale (€/year)
Water supply			
urinals	1100	0	0
toilets	4800	0	0
kitchenettes, sanitary sinks	1600	1600	1600
Wastewater fees	7500	1600	0
Onsite treatment + transport			
yellowwater	0	5000	2500
brownwater	0	7000	3500
greywater	0	0	3000
Income from products			
fertilizer value of urine and sludge	0	not considered	not considered
Total	**15000**	**15200**	**10600**
Difference (compared to conventional	**0**	**200**	**-4400**

source: GTZ

Appendix

ammonium concentrations

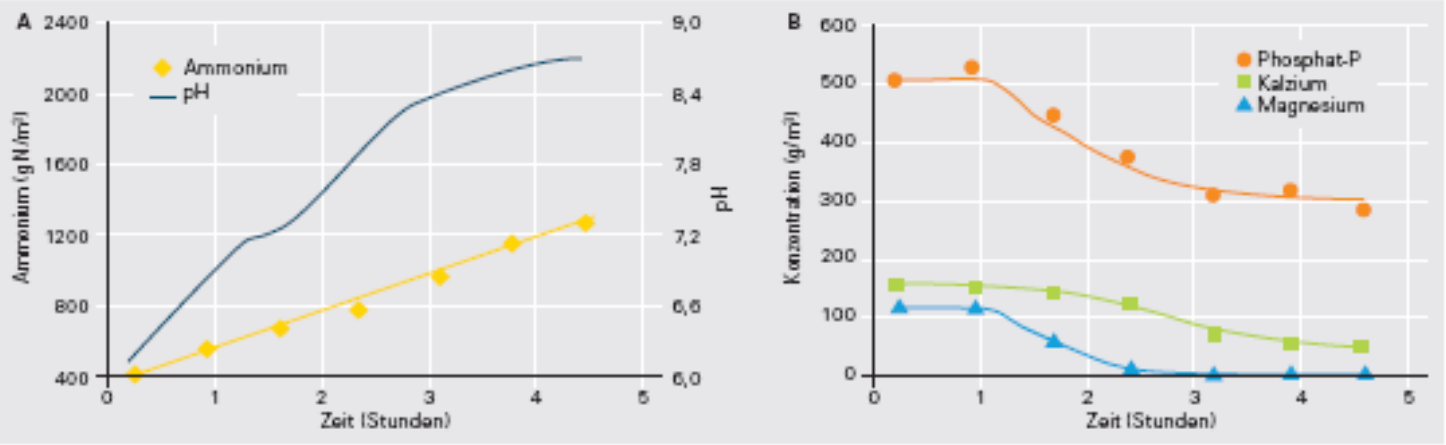
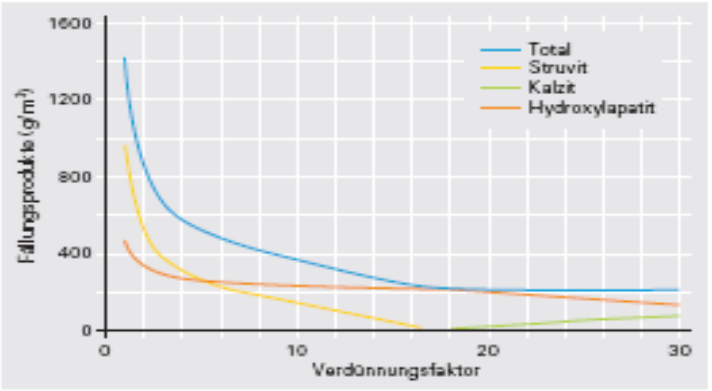


Abb. 1: Als Folge der Harnstoffhydrolyse im Urin steigen die Ammoniumkonzentration und der pH an (A), wogegen die Kalzium-, Magnesium- und Phosphatkonzentrationen im Urin abnehmen.

precipitation

Abb. 2: Die Ausfällung von Struvit, Hydroxylapatit und Kalzit ist abhängig von der Verdünnung des Urins.



Appendix

content of urine

Tab. 1: Chemische Zusammensetzung von gesammeltem, gelagertem Urin aus einem Haushalt mit gespülten Trenn-WCs [2] und dem Eawag-Bürogebäude mit wasserlosen Urinalen [3] im Vergleich zu frischem Urin [4]. CSB = Chemischer Sauerstoffbedarf, ein Mass für die organischen Bestandteile.

	Gelagerter Urin		Frischer Urin
	mit Spülwasser Haushalt	ohne Spülwasser, Bürogebäude	unverdünnt Literaturdaten
Verdünnung $V_{Urin}/(V_{Urin}+V_{Wasser})$	0,33	1	1
pH	9,0	9,1	6,2
N_{Gesamt} [g/m³]	1795	9200	8830
$NH_4^+ + NH_3$ [g N/m³]	1691	8100	463
$NO_3^- + NO_2^-$ [g N/m³]	0,06	0	–
P_{Gesamt} [g/m³]	210	540	800–2000
CSB [g O_2/m³]	–	10000	–
K [g/m3]	875	2200	2737
Na [g/m³]	982	2600	3450
Cl [g/m³]	2500	3800	4970
Ca [g/m³]	15,75	0	233
Mg [g/m³]	1,63	0	119

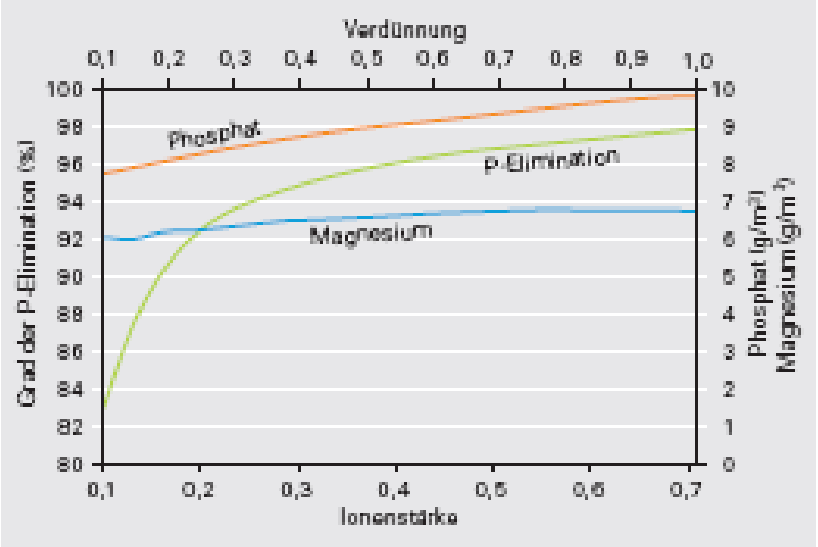
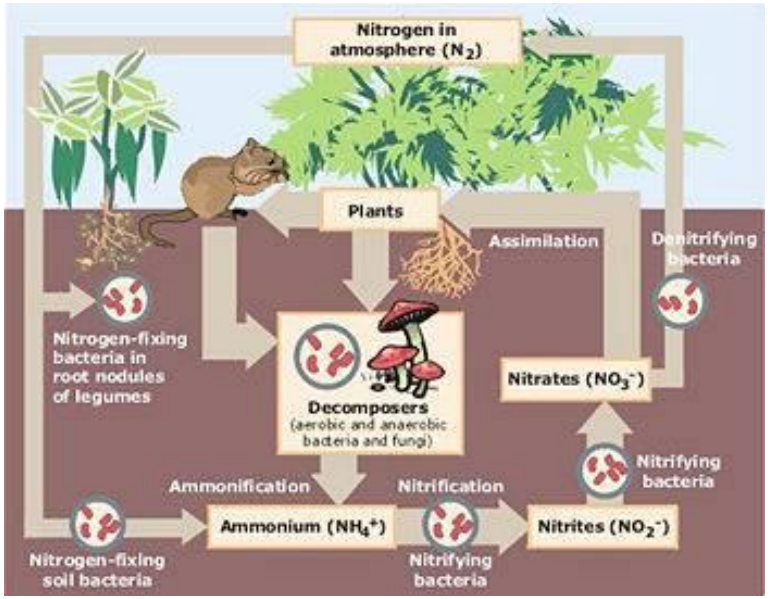


Abb. 1: Die gelösten Phosphat- und Magnesiumkonzentrationen nach der Struvit-Fällung sind abhängig von der Verdünnung des Urins mit Spülwasser (1 = unverdünnt, 0,1 = 10-fach verdünnt). Ausgangskonzentrationen der Nährstoffe im unverdünnten Urin: Phosphat = 440 g P/m³; Ammonium = 7850 g N/m³. Zugabe einer equimolaren Menge von Magnesiumchlorid (bezogen auf Phosphat).

Appendix

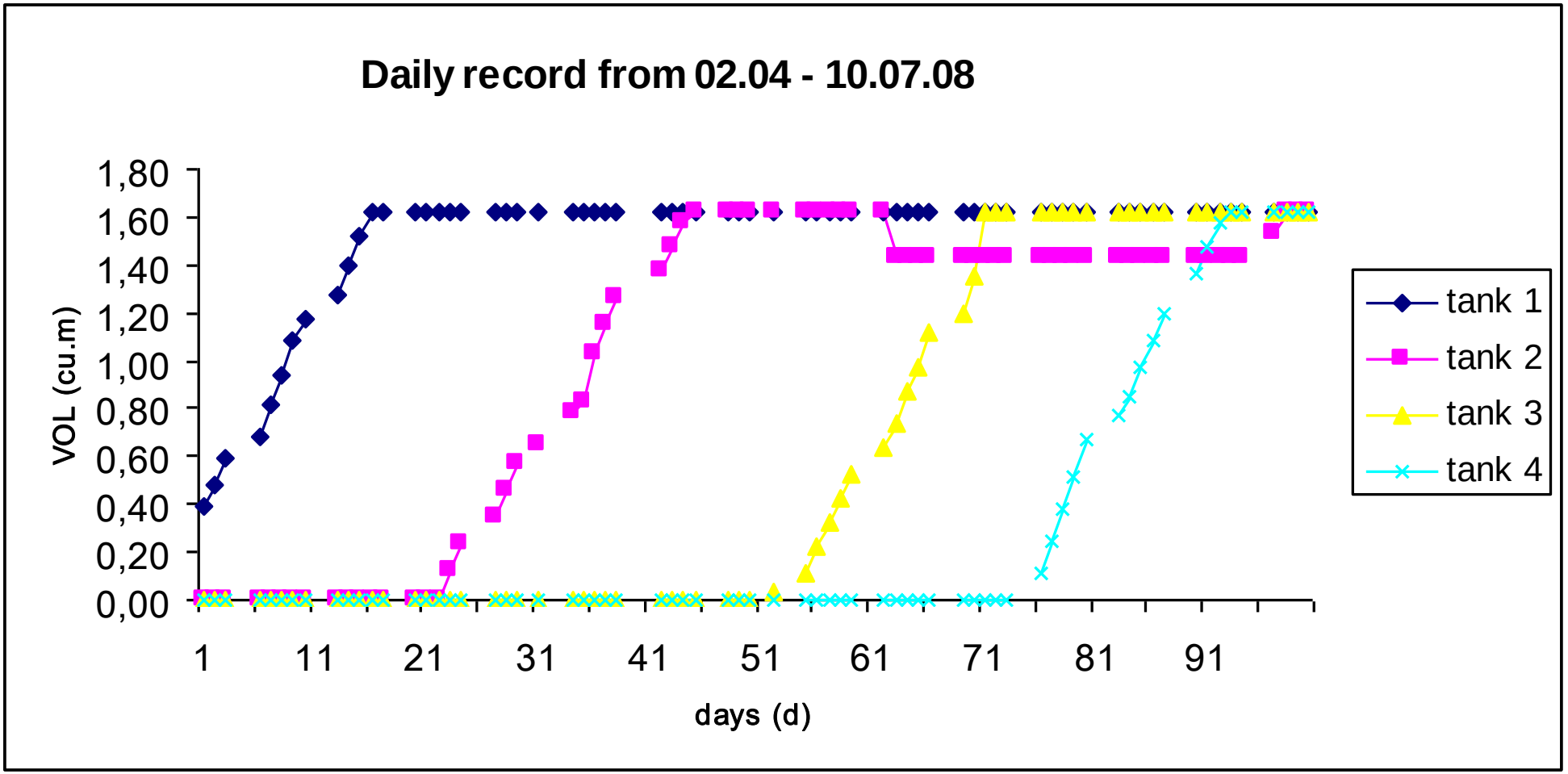
Nitrification is the biological oxidation of ammonia with oxygen into nitrite followed by the oxidation of these nitrites into nitrates. Degradation of ammonia to nitrite is usually the rate limiting step of nitrification. Nitrification is an important step in the nitrogen cycle in soil. This process was discovered by the Russian microbiologist, Sergei Winogradsky.



Chemistry

- Nitrification is a process of nitrogen compound oxidation (effectively, loss of electrons from the nitrogen atom to the oxygen atoms) :
- NH3 + CO2 + 1.5 O2 + Nitrosomonas → NO2- + H2O + H+
- NO2- + CO2 + 0.5 O2 + Nitrobacter → NO3-
- NH3 + O2 → NO2− + 3H+ + 2e−
- NO2− + H2O → NO3− + 2H+ + 2e−

[http://en.wikipedia.org/wiki/Nitrification]


Daily record from 02.04 - 10.07.08
VOL (cu.m)
1,80
1,60
1,40
1,20
1,00
0,80
0,60
0,40
0,20
0,00
1
11
21
31
41
51
61
71
81
91
days (d)
tank 1
tank 2
tank 3
tank 4