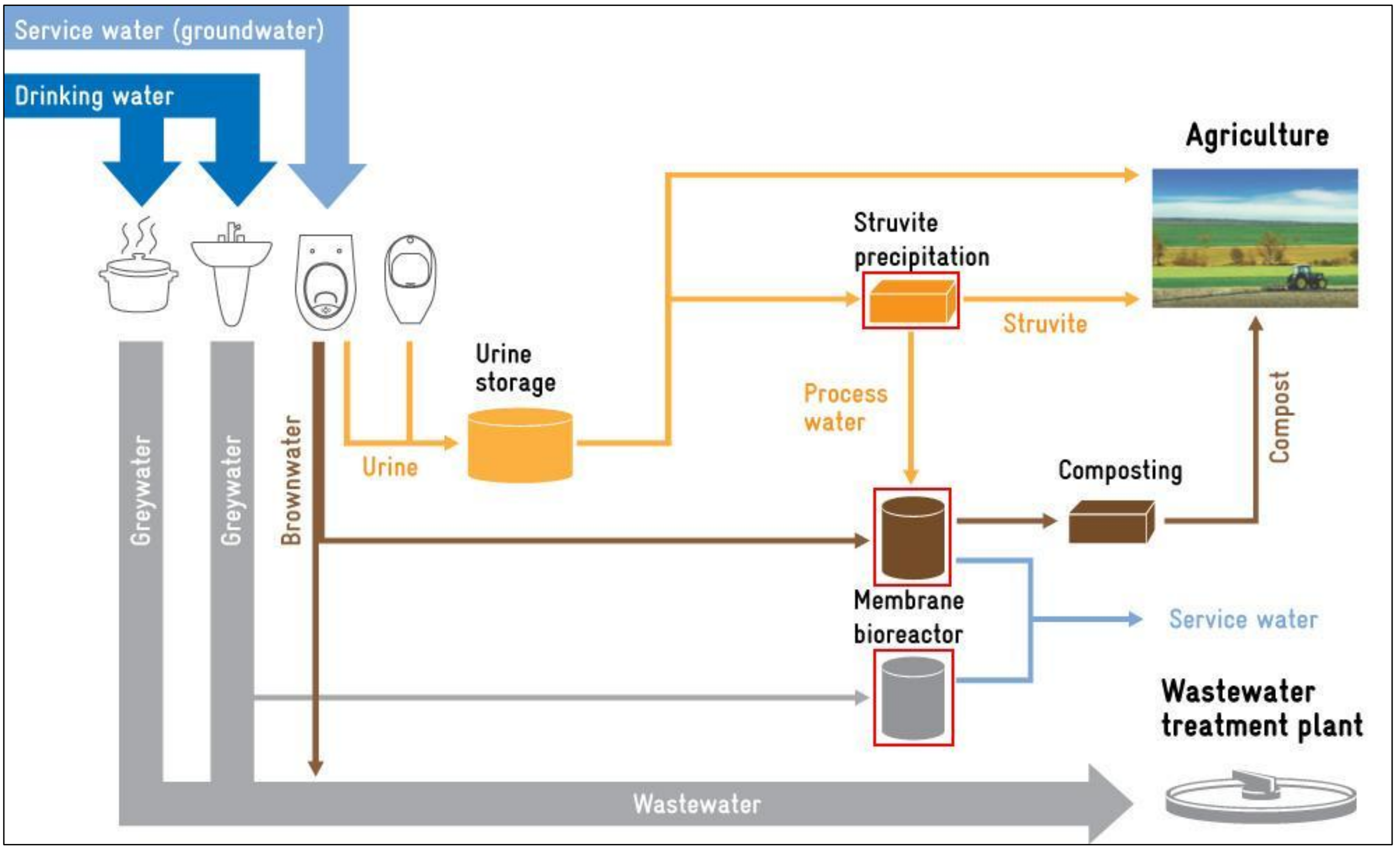
Compilation of the SANIRESCH-Factsheets

This compilation contains the factsheets of the MAP (struvite) reactor and the greywater as well as the brownwater treatment plant installed within the SANIRESCH project. The factsheets provide a detailed overview regarding technical aspects, analysis results and energy as well as investment costs.



This figure illustrates the SANIRESCH concept:
Urine is stored temporarily in tanks. Later, struvite is precipitated in the MAP reactor and both, urine and struvite can be used as a fertiliser in agriculture. A part of the brownwater is treated by the membrane bioreactor and can be used as service water. The solids could be used after composting as a fertiliser in agriculture. The greywater from tea kitchens and hand wash basins is treated in a MBR as well and the permeate is used as service water for the brownwater pretreatment plant.
The red boxes mark the plants which are presented in these factsheets.

Magnesium-Ammonium-Phosphate (MAP) reactor

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Magnesium-Ammonium-Phosphate (MAP) reactor

1 Process principle

Simplified equation:	$NH_4^+ + Mg^{2+} + PO_4^{3-} \rightarrow MgNH_4PO_4$
Ammonium (NH_4^+):	Ammonium ion, available in excess in urine
Magnesium (Mg^{2+}):	Magnesium ion, develops in the reaction chamber of the added MgO (magnesium oxide)
Phosphate (PO_4^{3-}):	Phosphate ion, present dissolved in urine
MAP ($MgNH_4PO_4$):	Reaction product (also known as struvite)

2 Process technology

2.1 Removal of nutrients

P_{total} in influent:	180 mg/l (average)
P_{total} in effluent:	36 - 72 mg/l
P removal:	60 - 80 %
N_{total} in influent:	2700 mg/l
N_{total} in effluent:	540 – 1080 mg/l
N removal:	60 - 80 % (Probably mainly due to ventilation)

2.2 Cycle data and amount of urine

10 cycles per day

Duration of one cycle:	135 min
Urine flow rate:	171 l/d
Per cycle:	40 l (theoretically possible: 50 l)
Amount treated:	400 l/d (theoretically possible: 500 l/d)
Usable urine storage:	7.5 m^3 (in 4 storage tanks)
Duration to process 7.5 m^3:	4 weeks if operating at 5 days per week and at full load

3 MAP recovery

MAP recovery:	
➢ with technical grade MgO	50 - 65 %
➢ with analytical grade MgO	90 - 95 % (only a few experiments in the laboratory)
Estimated recovery:	0.8 g MAP_{dried} / l urine
MAP production with technical MgO:	263 g MAP/d
	69 kg MAP/year

4 Operating costs

MgO bag:

- Total material costs — 0.31 €/bag
- Bag material — polyvinyl alcohol
- Bag content — 14 g MgO/bag (for cycle with 40 l urine)

Needle felt filter:

- Costs — 3 €/filter bag
- Life time — single use
- MAP loss — 37 - 12 % (remains in the filter)

Nylon filter (alternative option): (only a few experiments)

- Costs — 45 €/filter bag
- MAP loss — negligible loss

World market price MAP: approx. 300 €/t (conservative estimate)
Value of the produced MAP: 21 €/year

Theoretical costs (€) to fertilise 1 ha summer wheat for one year:[1]

Urine	**MAP (Pilot plant)**	**NPK (Mineral fertiliser)**
560	112,000,-	120

Reason for the high MAP costs: 1) at the moment there is a lot of manual labour necessary to produce MAP
2) MAP reactor was a new development, therefore very high investments cost

5 Field tests near Bonn

Soil: Supply level C (nutrient-rich soil)
Fertiliser: 100 - 140 kg N/ha for summer wheat, 40 kg N/ha for miscanthus
Urine application: 3-4 l/m² or 30-40 m³/ha (see table)

Date comparison:

	Data from Bonn	**Technology Review** [2]
N concentration in urine (gN/l)	2.3 – 3.9	maximum 7
Amount per area (l/m²)	3 – 4	1.5
N content per area (kgN/ha)	70 – 100	maximum 105

[1] Braum, C. (2011). Economical feasibility of using urine versus struvite as fertilizer. Using the example of GIZ in Eschborn. Bachelor thesis. Institute of Soil Sciences and Soil Conservation, Justus Liebig University Gießen, Germany
http://www.saniresch.de/images/stories/downloads/Bachelor%20Thesis%20Christina%20Braum.pdf

[2] von Muench, E., Winker, M. (2011). Technology review of urine diversion components - Overview on urine diversion components such as waterless urinals, urine diversion toilets, urine storage and reuse systems. Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, Germany.
http://www.susana.org/lang-en/library?view=ccbktypeitem&type=2&id=875

SANIRESCH – Brownwater treatment plant

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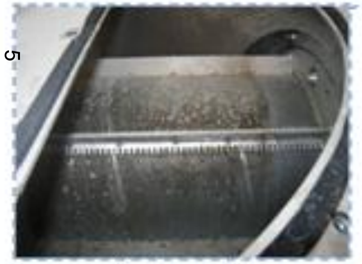
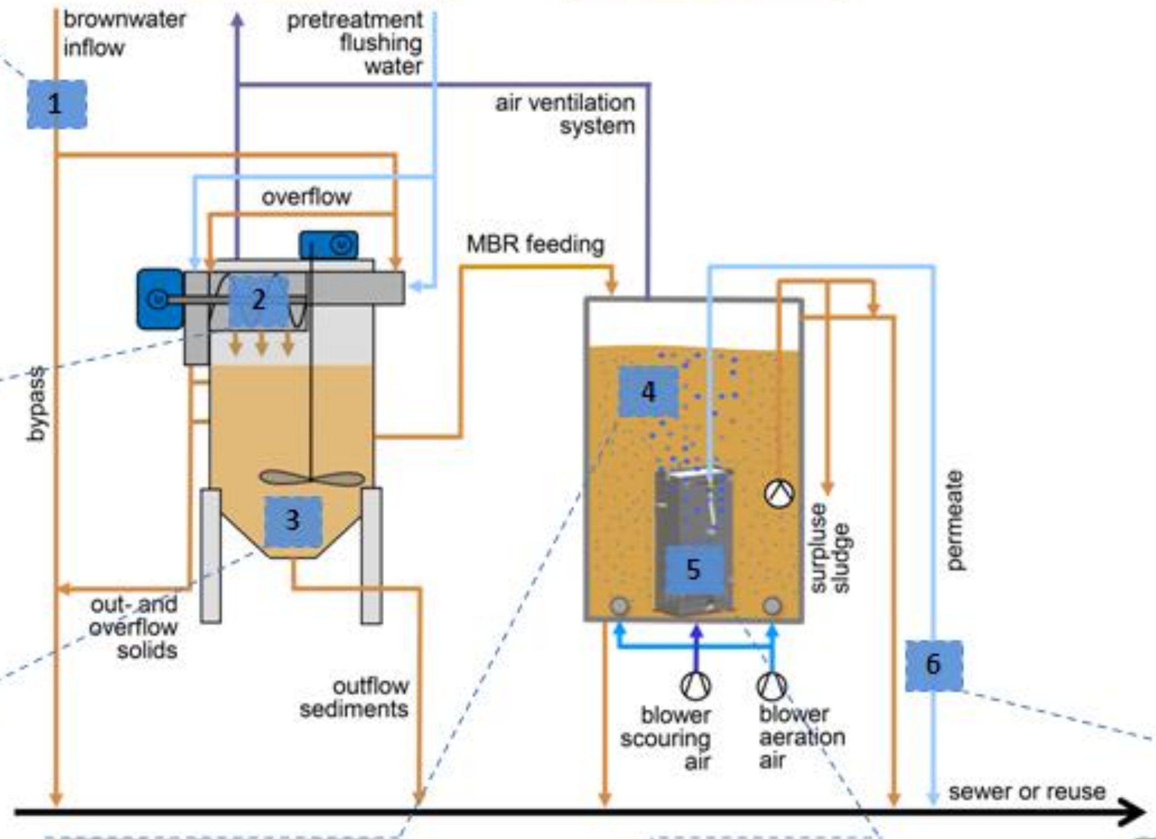
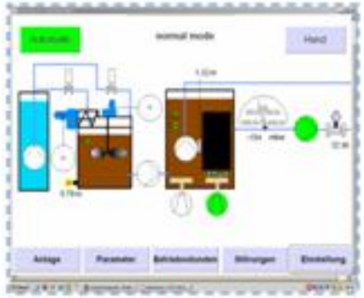
1 - Brownwater
From NoMix toilets: ~2000 l/d


2 - Screen basket with screw
For solids separation (hole size: 3 mm)


3 - Pretreatment tank
Volume of tank: ~400 l

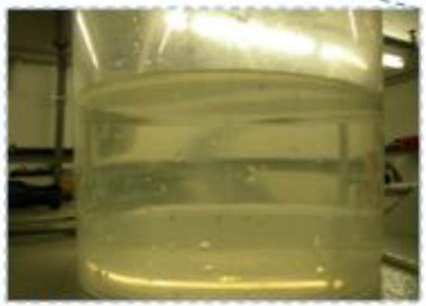


Remote control


Control panel touch screen


4 - Membrane bioreactor
Volume of tank: 710 l

5 - Ultrafiltration module
Plate membrane: 3.5 m², pore size: 38 nm


6 - Permeate
Treated brownwater, COD: ~18 mg/l

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Brownwater treatment (MBR)

1 Technology

Source of brownwater:	38 Urine diverting flush toilets (Model NoMix, Roediger Vacuum) and 14 conventional toilets (BW from 32 toilet is discharged via the sewer system)
Brownwater inflow$_{average}$:	2300 l/d
Flowrate of permeate$_{average}$:	725 l/d (Difference to the total daily brownwater inflow is discharged via the sewer system)

1.1 Volume

Pretreatment tank:	400 l
Membrane bioreactor$_{average}$:	670 l

1.2 Pretreatment

Hole size in the screenbasket:	3 mm
Screen rotation$_{day}$:	15 s operation, 60 s break
Screen rotation$_{night}$:	15 s operation, 3600 s break
Flushing of screen:	10 s inflow, 10 s break, 10 s outflow (10 times/24h)
SS in filtrate:	400 - 450 mg/l

1.3 Membrane filtration module

Type of membrane:	Plate membrane (MembranClearBox ®)
Membrane surface & pore size:	3.5 m^2, 38 nm
Material of membrane:	PES (Polyethylensulfone)
Scouring air$_{regular}$:	continuously
Scouring air$_{energy\ saving}$:	60 s operation, 60 s break
Oxygen concentration:	6.3 mg/l
MBR feeding pump:	Automatically regulated according to filling level of MBR
Permeate pump:	19 h/d filtration: 270 s operation, 30 s break 5 h/d relaxation (no operation)
Operation of permeate pump$_{net}$:	17 h/d (taking breaks into account)
Flowrate of permeate:	44 l/h; equivalent 725 l/d (19 h of operation)
Transmembrane pressure$_{net}$:	
➢ average	-50 mbar
➢ maximum possible	-350 mbar
Flux$_{net}$:	(Flow rate of permeate through membrane)
➢ average	12.6 l/(h x m²)
➢ maximum possible	30 l/(h x m²)
Concentration of activated sludge:	5 - 11 g/l TS
Removal of excess sludge:	15 l/week (automatically)

1.4 Differences in operation of grey- and brownwater treatment

Apart from the pretreatment, the grey- and brownwater plants are technically similar. However, due to different characteristics of the influent the operation differs accordingly:

	Permeate pump	Permeate flowrate
Greywater treatment	270 s operation; 120 s break	26 l/h
Brownwater treatment	270 s operation; 30 s break	44 l/h

2 Analyses*

	COD (mg/l)	N_{total} (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	P_{total} (mg/l)
$Inflow_{after\ pretreatment}$	829 ± 236	63 ± 23	2.2 ± 1.1	42 ± 14	23 ± 7
Permeate	22 ± 7	66 ± 21	65 ± 21	0.02 ± 0.02	19 ± 9

* Concentrations with 95% confidence intervals

	E. coli (n/100ml)	Intestinal enterococcus (n/100ml)	Coliform bacteria (n/100ml)
Permeate	16	23	219

COD- removal efficiency:
97 %

Nutrient ratios in inflow:
C : N : P = 100 : 8.6 : 1.3

3 Use of permeate

Possible areas of application: (Complying with quality standards e.g. EU Bathing water directive) — Process water for toilet flushing, heating, air conditioning, irrigation

Use in GIZ: — Due to technical reasons there is currently no reuse taking place.

4 Time spent on operation

The standard operation requires one scheduled maintenance event per year at which time an effluent sampling can also be analysed. Due to the research activities the time consumption is calculated as follows:

Maintenance: 2 days every six months
Analyses: 3 - 4 h/week
Checking the operation: 3 h (divided over two days per week)

5 Energy consumption

The energy consumption is mainly due to the plant component membrane bioreactor (see figure). These are design values, because no measures were done. The energy consumption can be higher than normal due to research activities.

Energy consumption: 1.74 kWh/d (equivalent to 637 kWh/a)
Specific energy consumption: 2.9 kWh/m³
Energy costs: 159 €/a (0.25 €/kWh)

6 Investment costs (without pretreatment)

Container, plant unit, control unit, membrane module	5,990 € (net, ex factory)

7 Project partners (all in Germany)

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SANIRESCH - Greywater treatment plant (MBR)

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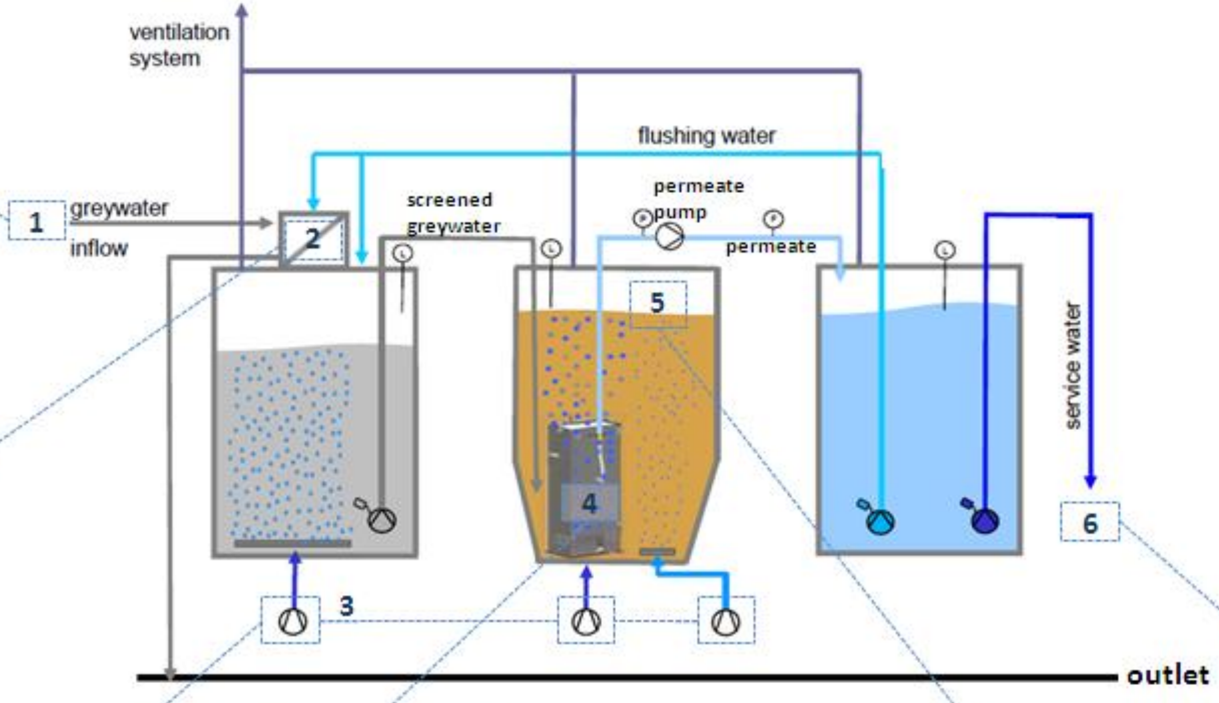
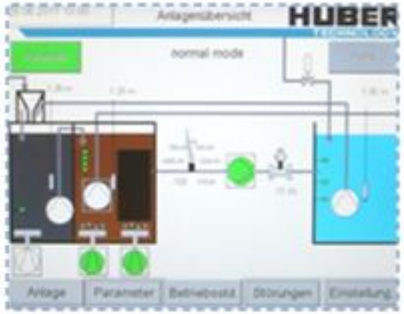
Collection tank | Membrane bioreactor | Storage tank | Remote control

1 - Raw greywater
COD 450 - 1000 mg/l

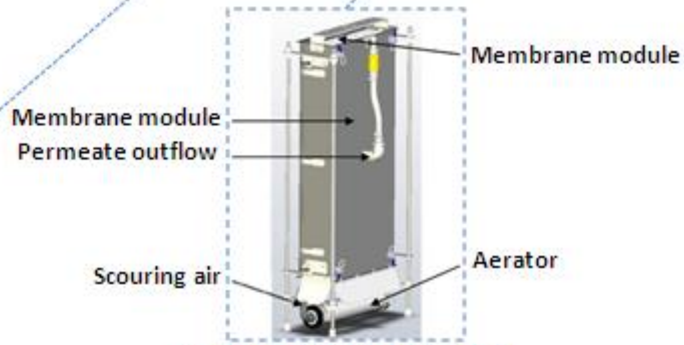
2 - Preceding screen (3 mm)

3 - Aeration blowers

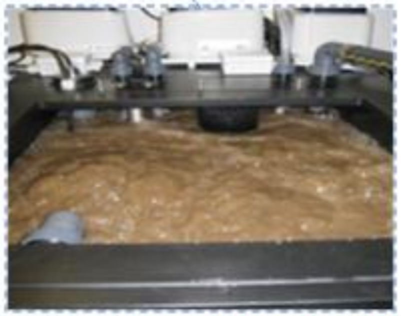




Control panel



4 - Ultrafiltration module
Plate membrane 3.5 m² / pore size 38 nm



5 - Membrane bioreactor (MBR)
Volume of tank 480 l

6 - Permeate
280 l/day
COD < 30 mg/l

Greywater treatment (MBR)

1. Technology

Source of greywater:	7 kitchenettes with sinks and dishwashers, 2 sinks, 19 hand washbasins in toilets rooms, 10 washbasins for cleaning purposes
Greywater inflow$_{average}$:	approx. 500 - 600 l/d
Flowrate of permeate$_{average}$:	approx. 480 l/d

1.1 Volume

Pretreatment tank:	480 l
Membrane bioreactor$_{average}$:	440 l (controlled by COD, TS and throughput)
Tank for service water:	480 l

1.2 Pretreatment

Mesh size of sieve:	3 mm
Cleaning of filter unit:	3 times per day for 10 s
Aeration of collection tank:	30 s/h (for mixing)
SS in filtrate:	120 - 220 mg/l

1.3 Membrane filtration module

Type of membrane:	Plate membrane (MembranClearBox ®)
Membrane surface & pore size:	3.5 m^2, 38 nm
Material of membrane:	PES (Polyethylensulfon)
Scouring air$_{regular}$:	continuously
Scouring air$_{energy\ saving}$:	60 s operation, 60 s break
Oxygen concentration:	8.1 mg/l
MBR feeding pump:	Automatically regulated according to filling level of MBR
Permeate pump:	16 h/d filtration: 270 s operation, 120 s break 8 h/d relaxation (no operation)
Operation of permeate pump$_{net}$:	11 h/d (taking breaks into account)
Flowrate of permeate:	26 l/h; equivalent 480 l/d (16 h of operation)
Transmembrane pressure$_{net}$:	
➢ average	-60 mbar
➢ maximum possible	-350 mbar
Flux$_{net}$:	(Flow rate of permeate through membrane)
➢ average	7 l/(h x m^2)
➢ maximum possible	30 l/(h x m^2)
Concentration of activated sludge:	5 g DM /l
Removal of surplus sludge:	40 l/week (automatically)

2. Analyses*

	COD (mg/l)	N_{total} (mg/l)	NO_3-N (mg/l)	NH4-N (mg/l)	P_{total} (mg/l)
Inflow	620 ± 190	14.6 ± 5.5	0.7 ± 0.3	0.6 ± 0.06	19 ± 10
Permeate	29 ± 7.8	11.9 ± 4.9	6.8 ± 4.4	0.02 ± 0.02	15 ± 5

* Concentrations with 95% confidence intervals.

COD-removal efficiency:
95 %

Nutrient ratios in inflow:
C : N : P = 100 : 2.3 : 1.2

Effect of dishwasher tabs:

P_{total} - content (mg/l)	Inflow	Permeate
Containing phosphate	35 ± 7.7	16 ± 3.3
Not containing phosphate	19 ± 10	15 ± 5

3. Use of permeate

Possible areas of application: (Complying with quality standards e.g. EU Bathing water directive) — Process water for toilet flushing, heating, air conditioning, wash machines, irrigation

Uses in GIZ: — Scouring for the pre-treatment of the brownwater plant

4. Time spent on operation

The standard operation requires one scheduled maintenance event per year at which time an effluent sampling can also be analysed. Due to the research activities the time consumption is calculated as follows:

Maintenance: 2 days every six months
Analysis: 3 - 4 h/week
Control of operation: 3 h (divided over 2 days per week)

5. Energy consumption

The energy consumption is related to the plant component membrane bioreactor (see figure). These are design values, because no measures were done. The energy consumption can be higher than normal due to research activities.

Energy consumption: 1.58 kWh/d (equivalent to 575 kWh/a)
Specific energy consumption: 5.3 kWh/m³
Energy costs: 145 €/a (0.25 €/kWh)

6. Investment costs (without pretreatment)

Container, plant unit, control unit, membrane module: 5,990 € (net, ex factory)

7. Project partners (all in Germany)

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Further project information

http://www.saniresch.de/en
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Imprint

MAP factsheet:	Martina Winker, Amel Saadoun Updated on: 31.07.2012
Greywater factsheet:	Martina Winker, Amel Saadoun, Fanny Kilian Updated on: 31.07.2012
Brownwater factsheet:	Enno Schröder, Martina Winker, Fanny Kilian Updated on: 31.07.2012