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D.T1.3.1 Technical Training Manual on Urban Circular Water Management for Municipalities

fbr, Association for Rainwater Harvesting and Water Utilisation

MODULE 6: CASE STUDIES

- Greywater recycling
  - Case study 1: ArabellaSheraton Hotel (RBCs)
  - Case study 2: Integrated water concept „Block 6“
  - Case study 3: Greywater and energy recycling using a moving-bed biofilm reactor (MBBR) in a passive residential building
  - Case study 4: Greywater recycling in a multi-storey building using a membrane bioreactor (MBR)
- Rainwater harvesting including street runoffs
  - Case study 5: Berlin-Lankwitz

CASE STUDY 1:
ARABELLA-SHERATON HOTEL

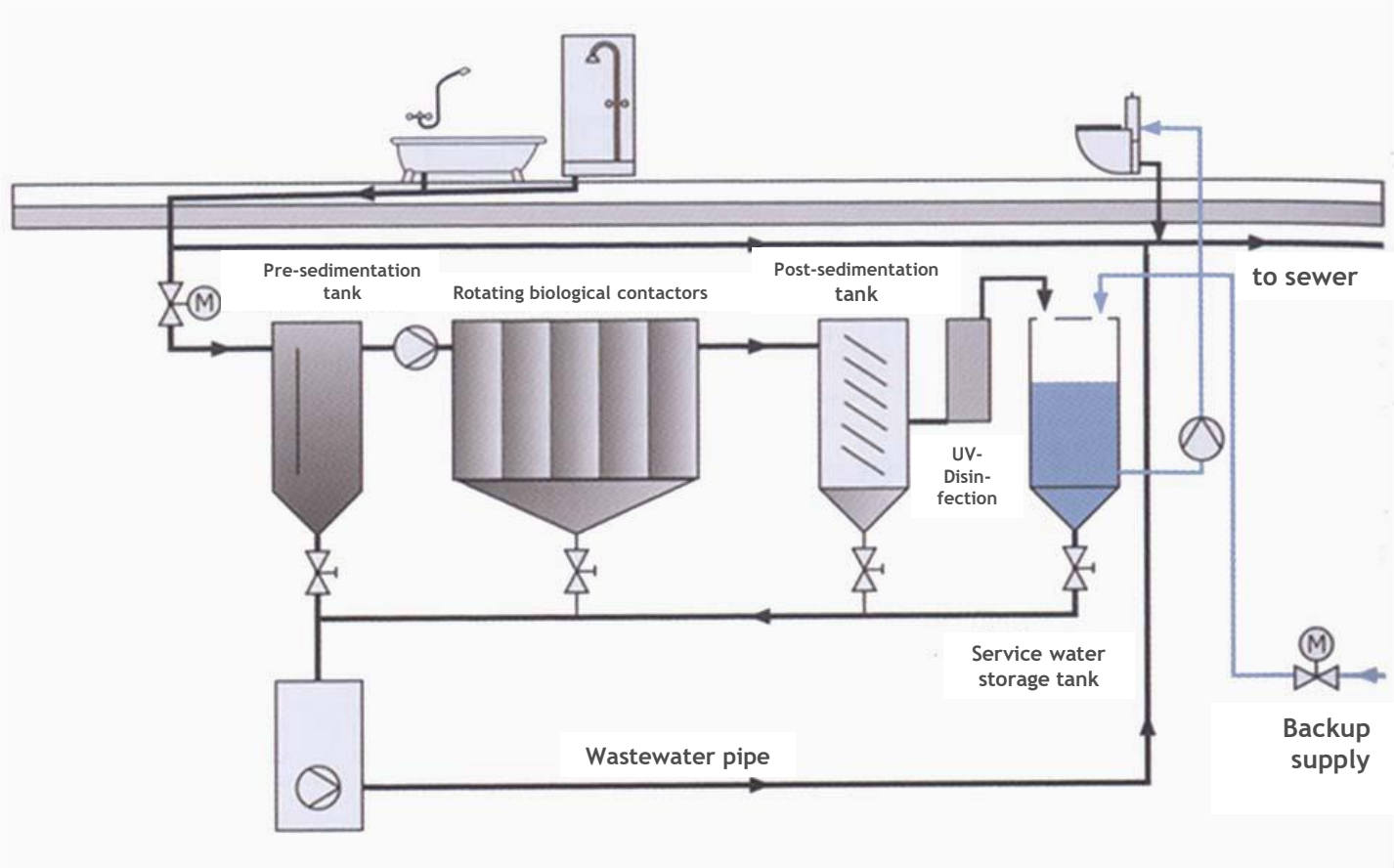
CASE STUDY 1: ARABELLA-SHERATON HOTEL

Greywater recycling system (multi-stage RBCs) in Arabella Hotel

(Source: Nolde & Partner)

CASE STUDY 1: ARABELLA-SHERATON HOTEL

Schematic diagram of the greywater treatment plant in ArabellaSheraton Hotel



Greywater recycling in a Hotel (1995)

Greywater recycling in 4-star hotel, ArabellaSheraton in Offenbach	
Description	The first generation of biological greywater recycling systems in Germany
Treatment system	Multi-stage rotating biological contactors (RBCs)
Start of operation	01/1996
Cleaning capacity	20 m^3/d (for 221 rooms, 380 beds)
Space requirement	2 parking lots, 5.7m x 6.7m = 38 m^2
Greywater sources	Showers and bath tubs
Reuse options	Toilet flushing, irrigation
Total energy demand	1.35 kWh/m^3 including service water distribution
Water savings	5,000 m^3/a, payback time less than 7 years

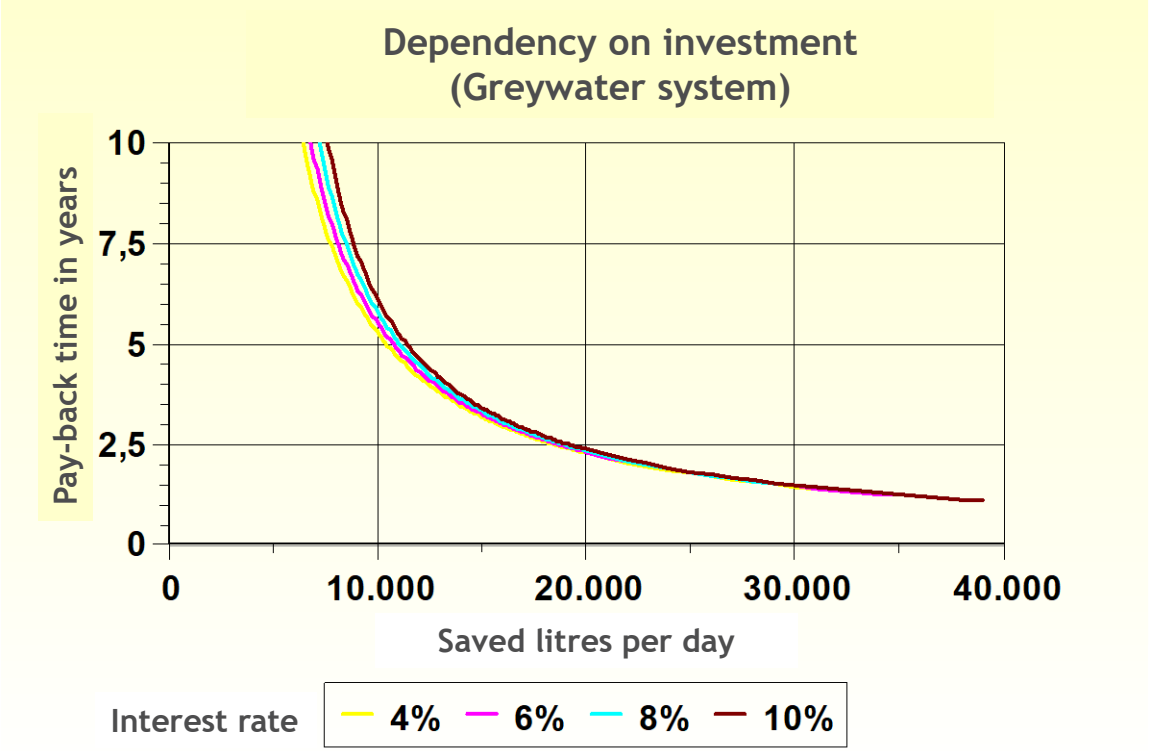
CASE STUDY 1:
ARABELLA-SHERATON HOTEL

Technical design specifications	
Greywater collection pipes	DN150 x 2
Collection and Pre-sedimentation tank	6.8 m^3 in total
Rotating biological contactors (6 RBC units)	6 x 1 m^3 Total HRT: 8 h
Sedimentation tank	2.4 m^3
UV-Disinfection unit	50 Watt
Service water tanks	6.8 m^3 in total
Booster pump station	3 x 1 kW pumps, 5 bar

CASE STUDY 1: ARABELLA-SHERATON HOTEL

		Annual costs (Euro/year)
Initial investment		
Treatment system incl. planning	72,000 €	
Dual piping system incl. planning	approx. 100,000 €	
Operational costs		5,680
Energy costs	Energy demand: 1.35 kWh/m^3 of treated greywater Electricity price: 0.3 €/kWh	2000
Internal maintenance costs		1,040
Maintenance by manufacturer		1,200
Repair costs		1,440
Cost savings		
Reduction in drinking water consumption	5,000 m^3 of drinking water saved per year (drinking water price: 6 €/m^3)	30,000

CASE STUDY 1:
ARABELLA-SHERATON HOTEL



CASE STUDY 2:
INTEGRATED WATER CONCEPT „BLOCK 6“

Phase I: Constructed wetland for greywater recycling (1987)

Constructed wetland

Reed bed

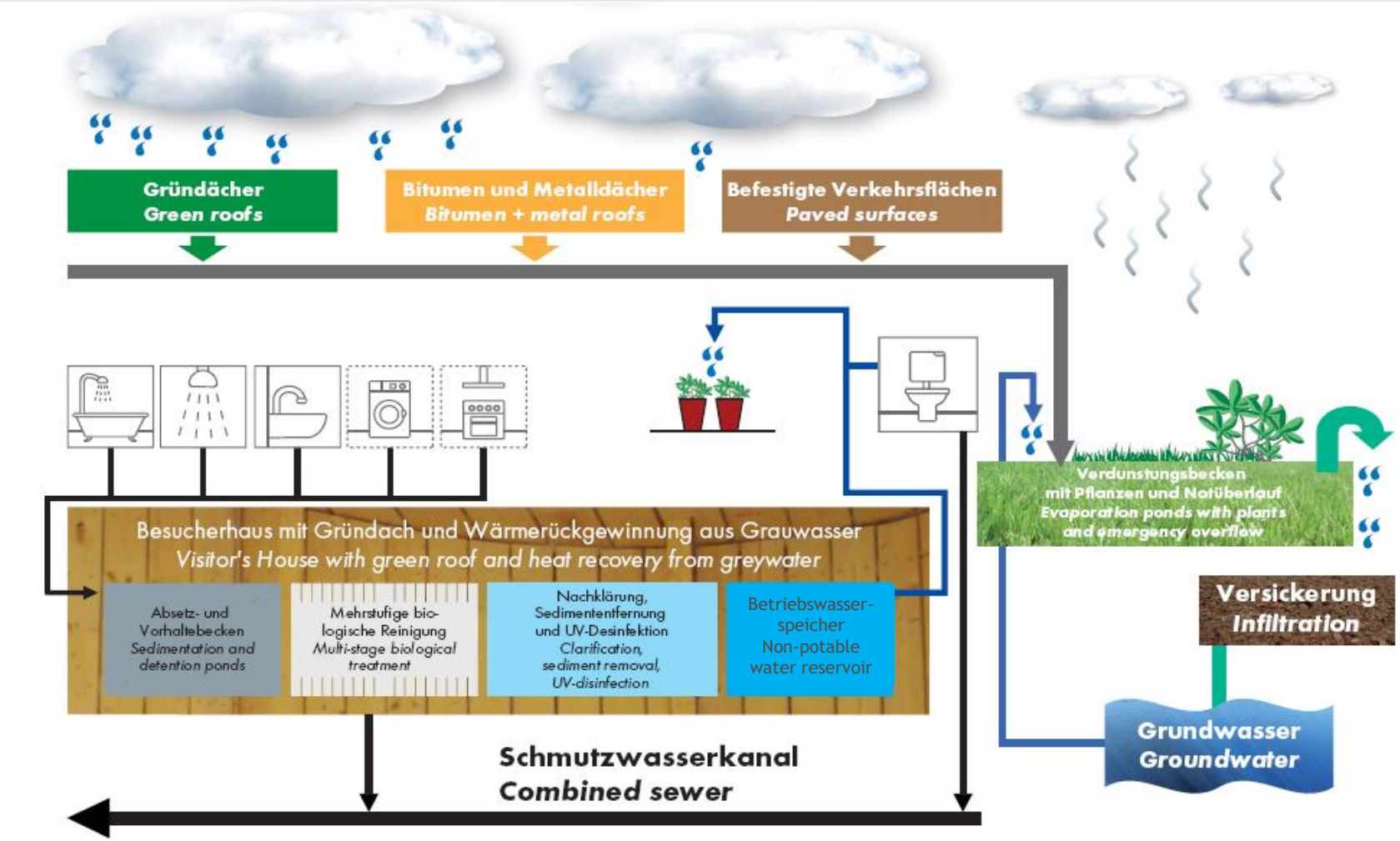
Maturation pond

CASE STUDY 2:
INTEGRATED WATER CONCEPT „BLOCK 6“

Integrated water concept „Block 6“ – Berlin until 2006

Phase I: 1987	Rainwater management	Greywater recycling
Site description	A block of 3 multi-storey residential buildings with approx. 250 persons in the centre of Berlin	
Infrastructure	Dual piping system and water-saving fittings and measures, water metres; Disconnection from municipal sewer (no rainwater user fees due)	
Space requirement	100 m^2 reed bed + rainwater pond	900 m^2 reed bed
System design	Rainwater pond bordering the constructed weltand; reed bed; evaporation	Constructed wetland (790 m^2 planted soil filter) + maturation pond (110 m^2)
Rainwater/greywater sources and reuses	2,350 m^2 roof surfaces 650 m^2 sealed surfaces	Hand washbasins, showers, bath tubs, **kitchen** and **washing machines** Reuse: toilet flushing and irrigation
Problems		High evaporation rates, massive algal growth, clogging of soil filter. Constructed wetland was shut down in 1993 due to high operating costs

CASE STUDY 2:
INTEGRATED WATER CONCEPT „BLOCK 6“



(Source: Nolde & Partner)

CASE STUDY 2:
INTEGRATED WATER CONCEPT „BLOCK 6“

Integrated water concept „Block 6“, Berlin, since 2006

Phase II*: 2006	Rainwater management	Greywater recycling
Site description	A block of 3 multi-storey residential buildings with approx. 250 persons in the centre of Berlin	
Infrastructure	Dual piping system, water-saving fittings and measures, water metres; Disconnection from municipal sewer (no rainwater user fees due)	
Space requirement	1,000 m^2	50 - 100 m^2 placed on former maturation pond site
System design	Rainwater pond and a vegetated swale; evaporation, reed beds	Biological-mechanical treatment using a multi-stage moving-bed biofilm reactor (MBBR) followed by UV disinfection Daily treatment capacity: 10 m^3
Rainwater/greywater sources and reuses	2,350 m^2 roof surfaces 650 m^2 sealed surfaces	Hand washbasins, showers, bath tubs, **kitchen** and **washing machines** Reuse: toilet flushing and irrigation
Advantages		Less space requirement, higher process stability, high service water quality, low maintenance; 3 Million litres of annual savings in drinking water; lower operating costs

* Following decommissioning of old plant and reconstruction

Rainwater management

All rainwater evaporates in rainwater ponds and infiltrates into the vegetated swale.

Advantages:

- Costs reduction in rainwater fees
  (no rainwater user fees due to disconnection to sewer)
- Release of burden on public sewer
- Improved microclimate
- Emergence of a new biotope with specific vegetation
- A habitat for birds and insects
- Open green space for the neighbourhood

(Source: Nolde & Partner)

CASE STUDY 2:
INTEGRATED WATER CONCEPT „BLOCK 6“

Interreg CENTRAL EUROPE
CWC
European Union
European Regional Development Fund

Rainwater evaporation in densely populated urban areas for cooling and improvement of the micro-climate

CASE STUDY 2:
INTEGRATED WATER CONCEPT „BLOCK 6“

Rainwater evaporation and infiltration

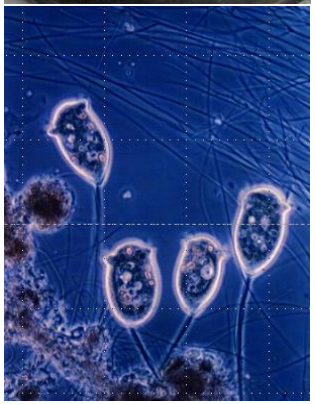
(Source: Nolde & Partner)

CASE STUDY 2:
INTEGRATED WATER CONCEPT „BLOCK 6“

Interreg CENTRAL EUROPE
CWC
European Union
European Regional Development Fund

Greywater treatment including wastewater from kitchen and laundry

Greywater from bath tubs, showers, washing machines and kitchen → Sieving and Sedimentation → Multi-stage biological treatment without chemicals → Particle removal (sedimentation) and UV disinfection → Service water use in buildings (WC) und for food production



Multi-stage moving-bed biofilm reactor (MBBR)

(Source: Nolde & Partner).

Greywater recycling

Low and high-load greywater from 71 apartments (250 persons) is treated and reused for toilet flushing and irrigation.

Advantages:

- Costs reduction in drinking water fees
- High quality service water for non-potable uses
- Contribute to fresh water conservation
- Environmental and sewer relief
- No use of chemicals for greywater treatment
- Annual savings in drinking water of approx. 3 million litres

CASE STUDY 2:
INTEGRATED WATER CONCEPT „BLOCK 6“

Technical design specifications	
Inflow COD concentrations	500 -1,000 mg/l
Pre-treatment	Grease/grit chamber and sieve
Moving-bed biofilm reactor (MBBR)	10 tanks with a capacity of 1.5 m^3 each
Post-treatment	Sand filter
UV disinfection unit	50 Watt
Other units	Booster pump, mains backup system
Service water price	3.50 €/m^3

CASE STUDY 3:
GREYWATER AND ENERGY RECYCLING

Interreg CENTRAL EUROPE
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Greywater and enrergy recycling in a passive residential house

CASE STUDY 3: GREYWATER AND ENERGY RECYCLING

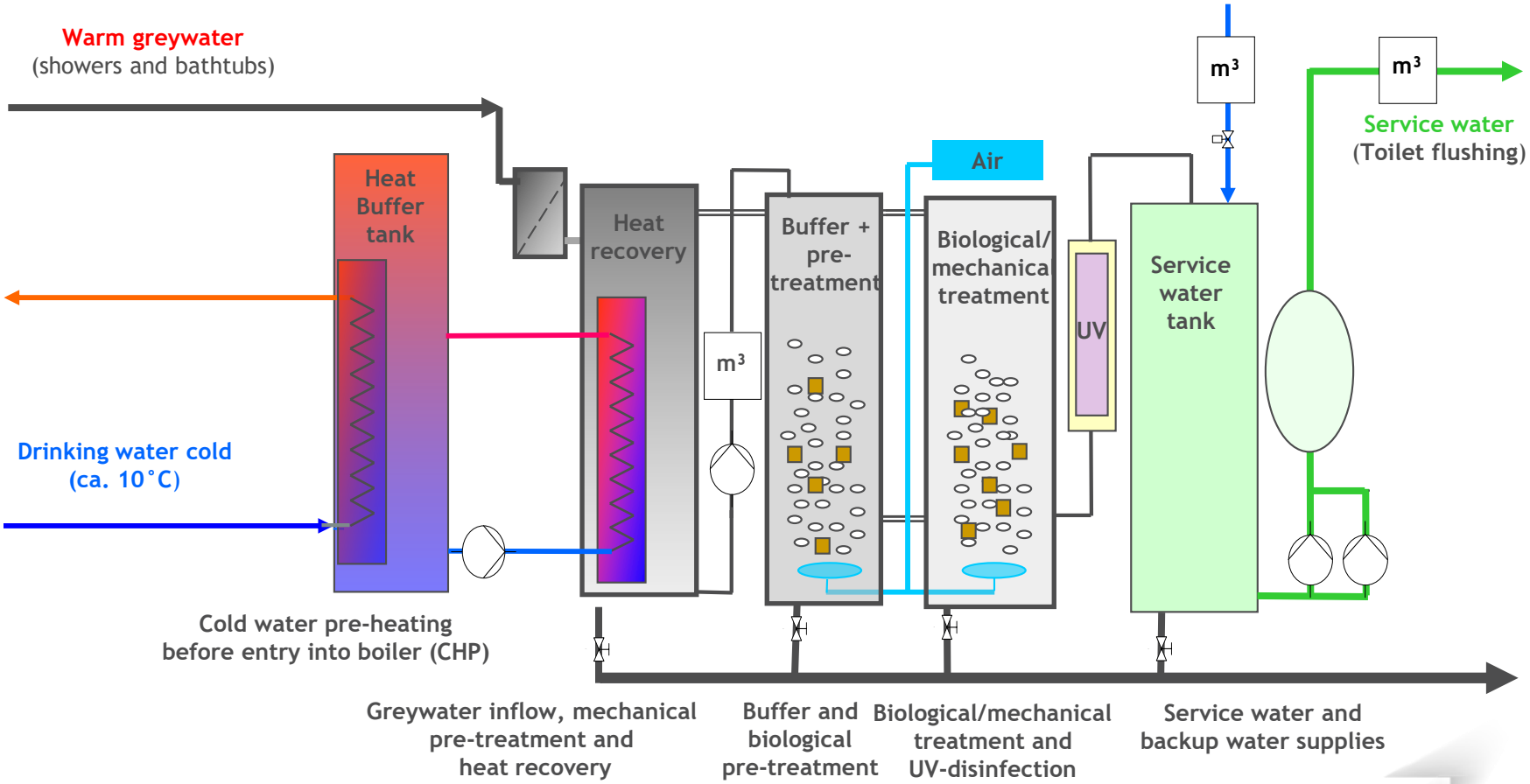
Project data of the passive residential house in Berlin			
Living space	4,600 m^2	Number of tenants	123
Number of flats	41	Commercial area	650 m^2
Underground car park	23	Number of commercial units	4
Land area	2,083 m^2	Gross floor space	6,620 m^2
Heat insulation	26 cm	Garden area	1,100 m^2
Space heating	73,400 kWh/a	Warm water heating	103,636 kWh/a (284 kWh/d)
Gas heating operated via CHP plant	16 $kW_{elec.}$ 35 $kW_{therm.}$	Photovoltaic: 92 Modules mit 20 kWp	18,000 kWh/a
Greywater recycling and heat recovery			
Greywater recycling	3 m^3/d (1,000 m^3/a)	Heat recovery from greywater	12.5 $kWh_{therm.}/m^3$ approx. 13,000 kWh/a
Water quality: BOD_7	< 3 mg/l	Water quality: turbidity	< 1- 2 NTU
Water quality: Hygiene	In accordance with the EU-Guidelines for Bathing Water		
Total area for greywater recycling and heat recovery plant	9 m^2	Total plant costs (incl. installation and taxes) per m^2 living space	11.30 €/m^2

CASE STUDY 3:
GREYWATER AND ENERGY RECYCLING

Technical design specifications	
Inflow COD concentrations	approx. 200 mg/l
Pre-treatment	Sieve
Moving-bed biofilm reactor (MBBR)	3 tanks with a capacity of 1 m^3 each
Post-treatment	Integrated sedimentation in the final bioreactor
UV disinfection unit	50 Watt
Other units	Booster pump, mains backup system
Service water price	3.50 €/m^3

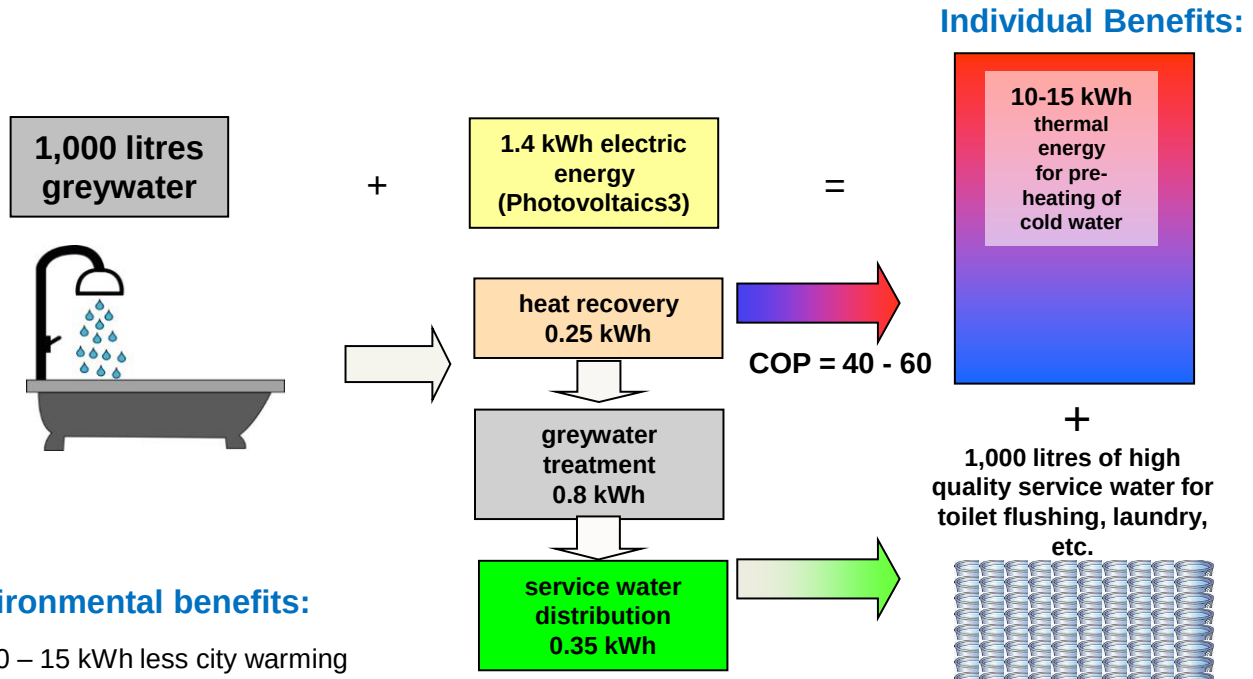
CASE STUDY 4: GREYWATER AND ENERGY RECYCLING

Greywater recycling and heat recovery from greywater



(Source: Nolde & Partner)

Benefits of greywater recycling combined to heat recovery

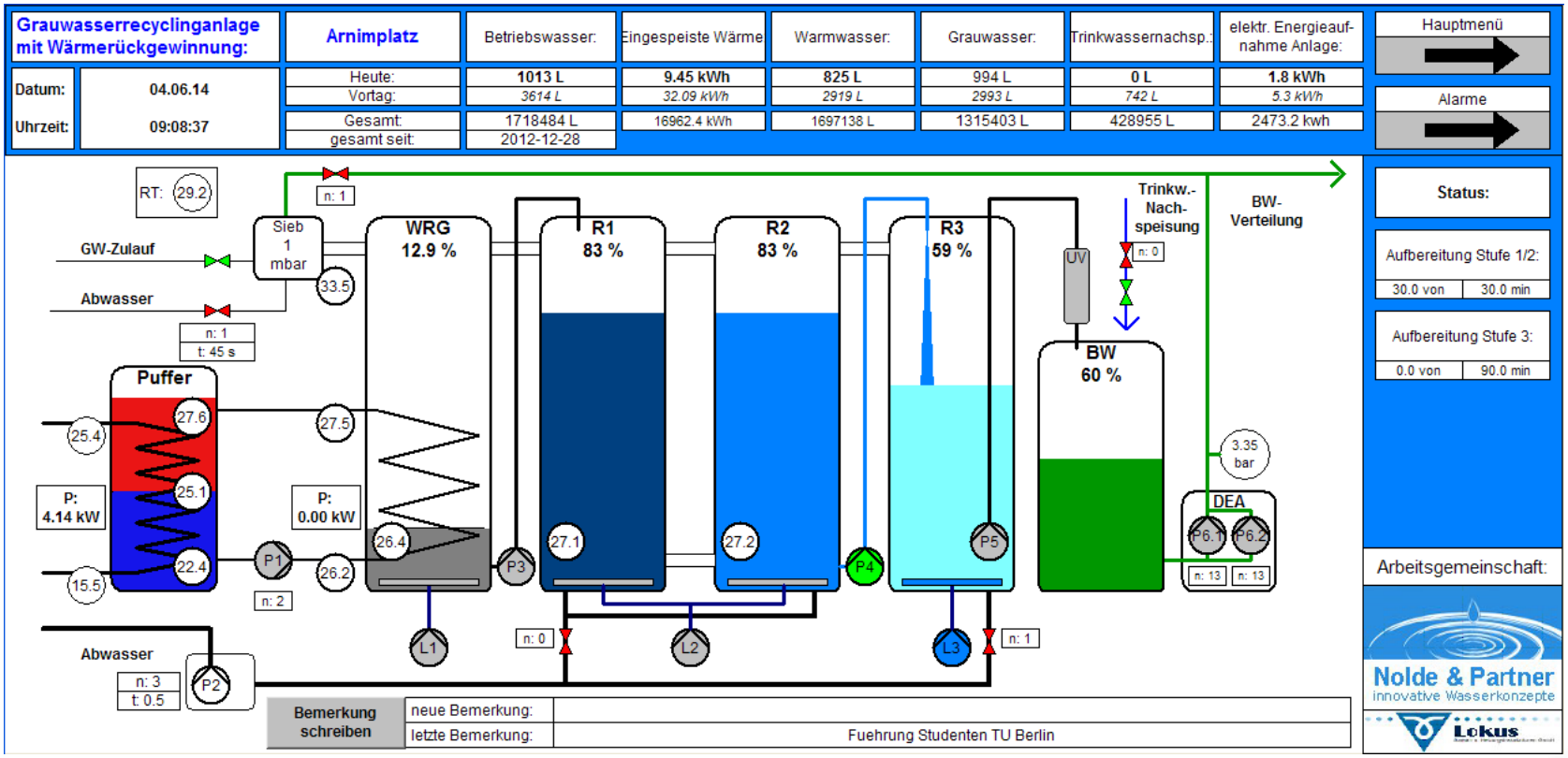


Environmental benefits:

(1) 10 – 15 kWh less city warming
(2) 1,000 litres of groundwater saved
(3) 1 - 3 kWh saved from drinking water and wastewater treatment including pumping
(4) saving on chemicals for drinking water and wastewater treatment
(5) less concrete corrosion in sewer
(6) CO_2 reduction (0.251 kg CO_2 per kWh recycled thermal energy **plus** 0.6 kg CO_2 per kWh saved electric energy for water service)

CASE STUDY 3:
GREYWATER AND ENERGY RECYCLING

System monitoring and control via internet



(Source: Nolde & Partner)

CASE STUDY 3:
GREYWATER AND ENERGY RECYCLING

Greywater recycling combined to heat recovery
(Results of a 2-year research and monitoring programme)

Space requirement (prototype):
9 m^2 = 0.1 m^2/P

Investment (prototype incl. additional costs for monitoring): 11.30 €/m^2 per living unit or 825 €/P incl. assembly and 19% VAT

Reduction in water costs:
5,000 €/a due to the production of 1,100 m^3/a of high quality service water

Energy savings due to heat recovery:
13,000 kWh/a, approx. 1,000 €/a

Maintenance and operation:
Electricity demand: 1,700 kWh/a, approx. 500 €/a
Consumables: < 50 €/a
Maintenance: < 1 day/a

CASE STUDY 4:
GREYWATER RECYCLING WITH MBR SYSTEM

Greywater recycling in a multi-storey building in Berlin

Photo: Nolde & Partner

Photo: Nolde & Partner

CASE STUDY 4:
GREYWATER RECYCLING WITH MBR SYSTEM

Outdoor greywater concrete cistern placed underground

Photo: Nolde & Partner

Greywater recycling system (MBR) placed in the cellar

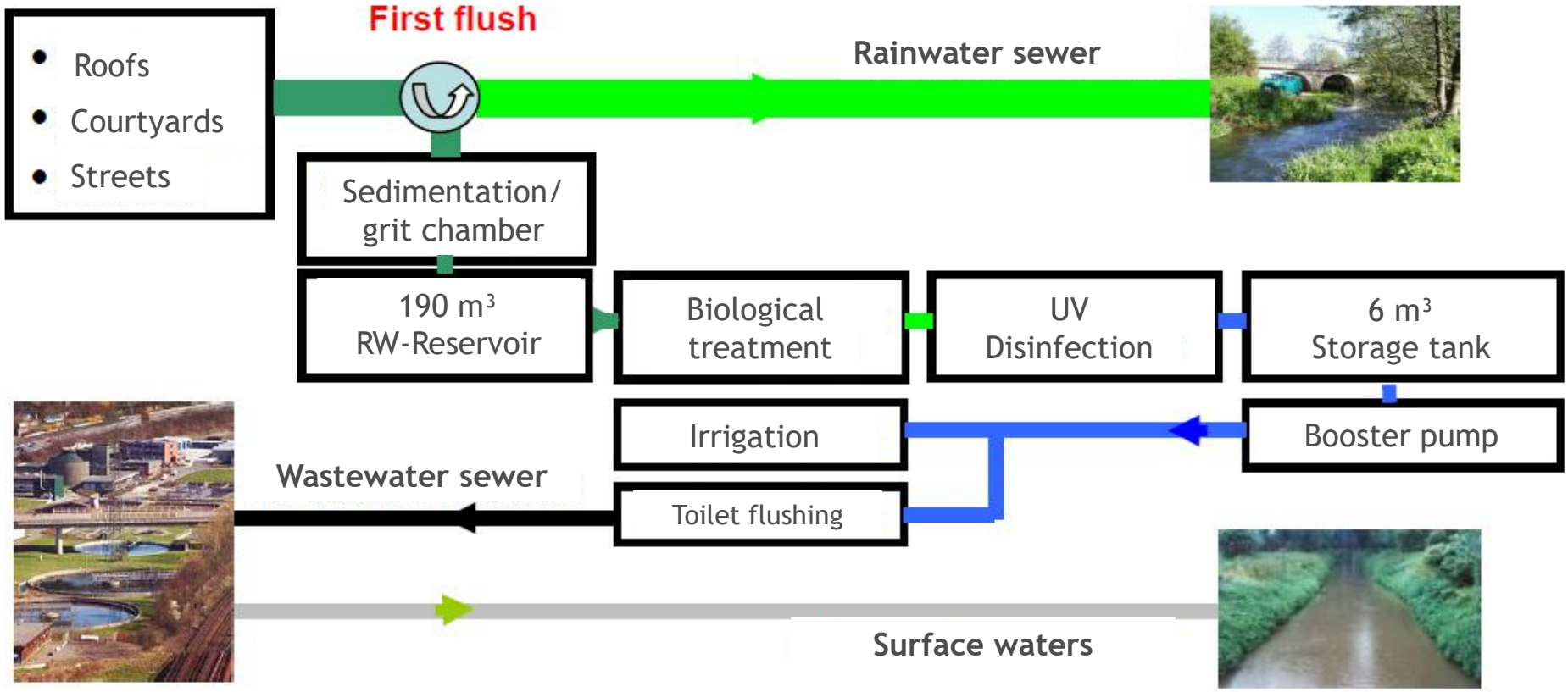
Photo: Nolde & Partner

CASE STUDY 4:
GREYWATER RECYCLING WITH MBR SYSTEM

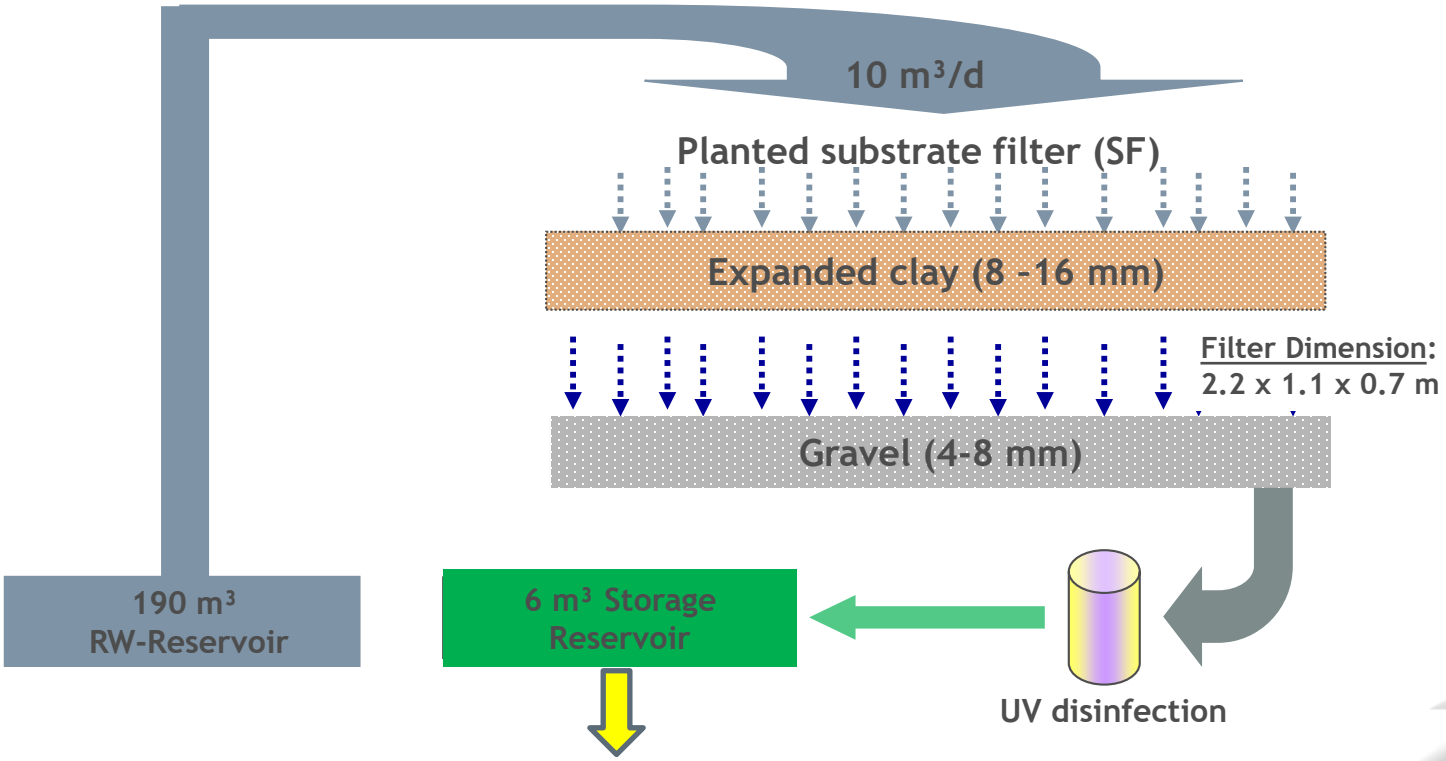
Greywater recycling with a membrane bioreator (MBR)	
Site description	○ A multi-storey building in Berlin ○ Greywater input from 55 apartments (123 persons) ○ Greywater sources: only showers and bath tubs ○ Use of recycled water in 63 apartments for toilet flushing
Start of operation	2018
Space requirement	3 m^2 (cellar)
Greywater collection	Outdoor greywater collection in a 5 m^3 concrete cistern
System design	Greywater treatment takes place indoors (cellar) by a membrane bioreactor (MBR) Booster pump unit also placed in the cellar
Treatment capacity	4 m^3/d
Energy consumption	1.5 kWh/m^3 for MBR 2.3 kWh/m^3 for total system operation
Operation	○ 2015-2018: Initial problems with membrane fouling and clogging ○ Restructuring and new membrane: since 05/2018 trouble-free operation and high water quality following membrane replacement and installation of a new electronic device. Also the greywater treatment system was moved from the outside to the inside of the building

Rainwater harvesting in Berlin-Lankwitz

A flow diagram of the rainwater treatment design scheme



System design



CASE STUDY 5:
RAINWATR HARVESTING (INCLUDING STREET RUNOFFS)

Rainwater sewer with switch diversion

Planted soil filter inside the building

Rainwater harvesting including street runoffs, Berlin	
Characteristics	The first project of its kind in Berlin including street runoffs for rainwater harvesting
Project start	2000
Collection area	Roof and courtyard surfaces including sealed street surfaces
Catchment area	12,000 m^2 sealed surfaces
Rainwater reservoir	190 m^3; rainwater is diverted from the rainwater sewer (including first flush)
Pre-treatment	Sedimentation and grit chamber (sand trap)
Biological treatment	Planted soil filter and UV disinfection
Treatment capacity	10 m^3/d
Reuse option	Toilet flushing (200 persons) and irrigation

Service water quality from the rainwater harvesting system compared to Berlin drinking water quality

Parameter		Ablauf Sandfilter Max	Min	Mittel	Berlin drinking water (typical concentrations)
LF [µS/cm]		199,00	60,00	103,38	Cond.: 813 µS/cm
Trans [%]		97,10	24,00	83,79	
TOC	[mg/l]	5,30	1,26	2,49	TOC: 4.5 mg/l
BSB_7	[mg/l]	3,00	0,59	0,86	
CSB	[mg/l]	15,80	4,56	6,82	
N_{ges}	[mg/l]	3,82	0,69	2,06	
P_{ges}	[mg/l]	0,174	0,014	0,089	
Cl	[mg/l]	17,22	0,81	4,05	
NO_2-N	[mg/l]	0,131	0,006	0,063	
NO_3-N	[mg/l]	3,512	0,364	1,726	
PO_4	[mg/l]	1,65	0,09	0,28	
SO_4	[mg/l]	19,51	2,72	7,09	SO_4: 180 mg/l
Na	[mg/l]	7,69	1,13	5,12	
Mg	[mg/l]	2,07	0,05	1,47	Mg: 13 mg/l
Ca	[mg/l]	19,76	6,68	15,74	Ca: 110 mg/l
HH_4-N	[mg/l]	6,61	0,47	3,54	

- **Drinking water saving potential:** 70% of the water demand for toilet flushing (80 apartments) = 2,500 m^3/a
- Hygiene requirements are met
- Only the unpolluted portion of the rainwater enters surface waters, ⟹ environmental relief