1) Grey Water

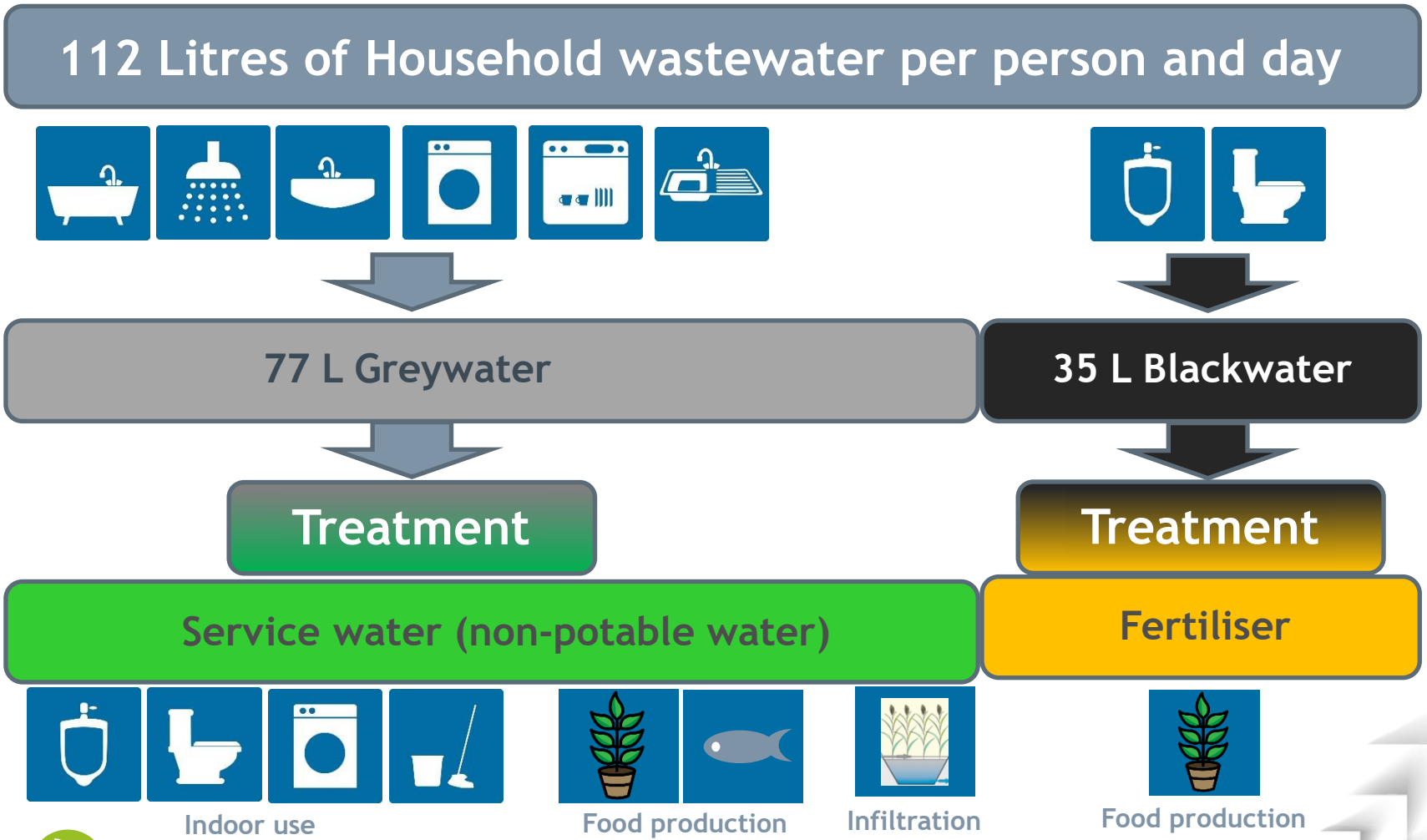
fbr, Association for Rainwater Harvesting and Water Utilization

GREYWATER RECYCLING

- Introduction
- Quality requirements for greywater recycling and reuse
- Technical and operational requirements
- Reuse options
- Treatment technologies
- Benefits of greywater recycling
- Annex

INTRODUCTION

Household wastewater



INTRODUCTION

What is greywater?

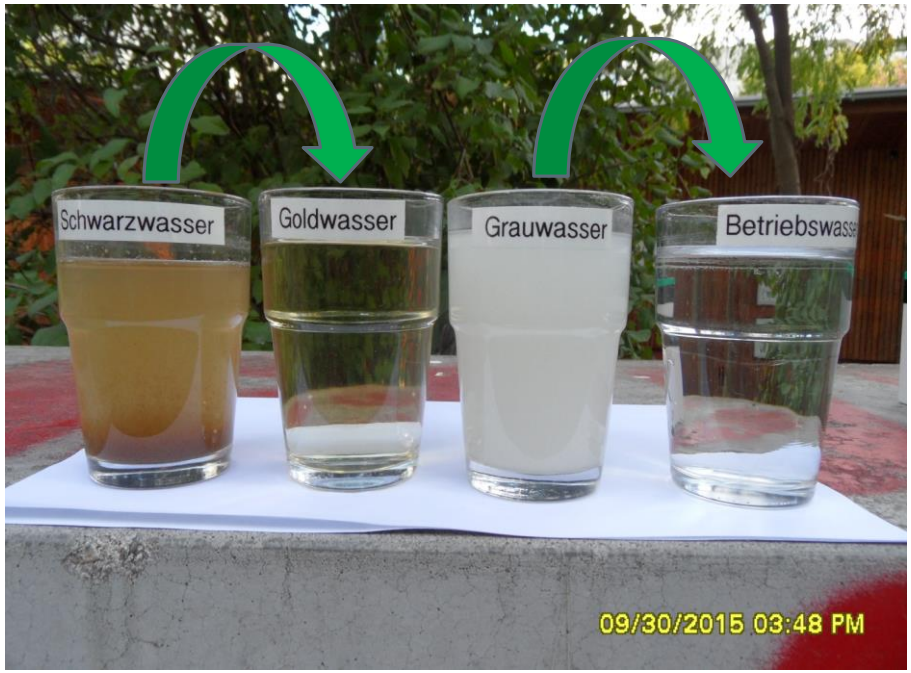
- Greywater can be defined as any domestic wastewater produced, excluding sewage
- It mainly originates from **low-load** sources (bath tubs, showers, hand washbasins) and **high-load** sources (laundry and kitchen)
- It constitutes the largest proportion of wastewater by volume (50 – 80 %) produced in an average household
- Typical volumes of greywater: 60 - 120 l/p/d depending on living standards, user behaviour, population structure, customs and habits, water installations and availability

Greywater characteristics

- Varies greatly in composition depending on type of building, user habits as well as on the use of chemicals in households for washing, cleaning and laundry (fats, oils, soap residues, detergents, …)
- Compared to blackwater it exhibits only half of the organic pollution load (can be higher, when water-saving measures and devices are applied in household)
- When high-load greywater, for example from kitchens and washing machines is used for recycling, high BOD (460 mg/l) and COD (850 mg/l) concentrations can be measured
- Greywater contains less faecal contamination than blackwater
- Greywater is generally poor in nutrients such as nitrogen and phosphorous (depending on greywater source)
- All types of greywater, including laundry water, show good biodegradability

INTRODUCTION

Wastewater is a resource for water, energy and nutrients



		Blackwater* Faeces + Urin + 30 Liter WC Spülwasser	Greywater	Total WW
		%	%	Sum
Volume	L/E/d	31,3%	**68,7%**	112,0
COD	g/E/d	59,8%	40,2%	117,0
N	g/E/d	**92,2%**	7,8%	12,9
P	g/E/d	**75,0%**	25,0%	2,0
K	g/E/d	**76,2%**	23,8%	4,2
S	g/E/d	23,7%	76,3%	3,8
Energy considerations				
Heat potential	Cooling of WW in K		20	2,0
	Wh/E/d		**1.768**	243
Biogas	Wh/E/d			118

*Blackwater: faeces + urine + 30 l flush toilet water

INTRODUCTION

Solid wastes management in Germany

1.27 kg/P/d of solid wastes originate from German households (2017: 462 kg/P/a)

In comparison:

112 kg/P/d of wastewater originate from German households (2017)

Paradigm change:

Separation of wastewater flows at the generation site should also become mandatory!

Solid wastes separation in Germany is mandatory

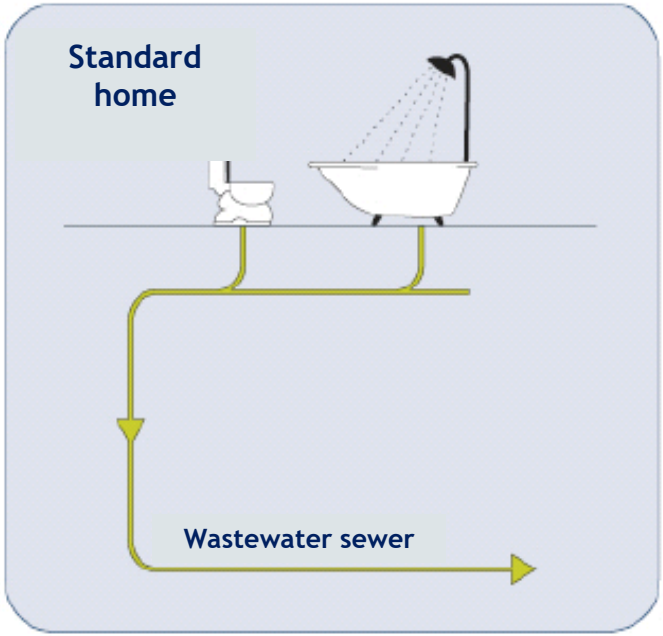
Target hierarchy for wastewater handling

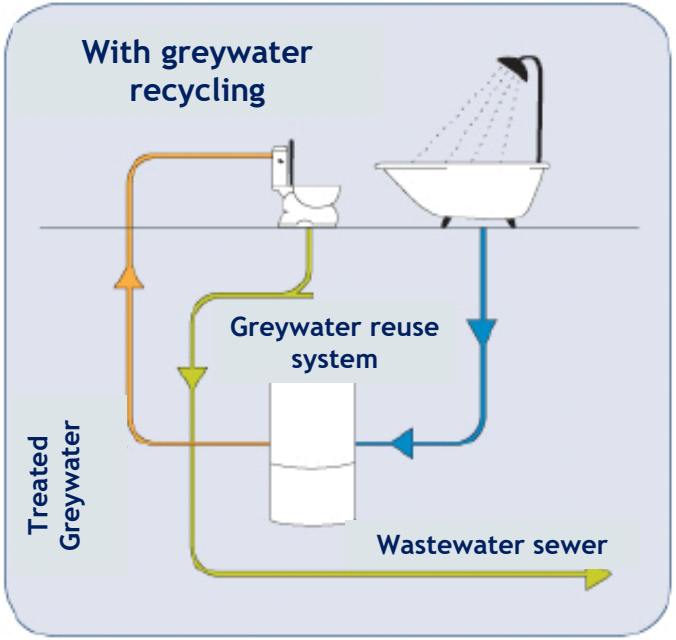
Based on the model of the Circular Economy Act:

- Avoid
- Reduce
- Recycle and Reuse
- Discharge following treatment

DUAL PIPING – A MUST FOR INDOOR REUSE OF RECYCLED WATER

- Separate pipes for greywater and blackwater (from toilets)
- Separate pipes for drinking water and service water (treated greywater)





Greywater collection

- Greywater is collected in separate sanitary pipework and allowed to flow from source (e.g. showers, bath tubs, washing machines, kitchen) to the greywater recycling system either by gravity or by using pumps
- A trouble-free operation is only secured in a frost-free installation
- Depending on the type of technology used, storage of the greywater should be provided for before and/or after treatment. It is recommended that the total buffer volume corresponds to less than one-day treatment capacity

Quality Requirements for greywater recycling and reuse

- Hygienic safety
- No comfort loss
- Environmental tolerance
- Economic feasibility

QUALITY REQUIREMENTS FOR GREYWATER RECYCLING AND REUSE

1. Hygienic safety

Microbiological parameters for **"service water"** (treated greywater) in accordance with the EU-Guidelines for Bathing Waters (2006/7/EC):

Total coliforms: < 100/ml
E. coli: < 10/ml
P. aeruginosa: < 1/ml

(Source: Berlin Senate Department for Urban Development and Housing, 1995)

- Orientated towards the EU Directive for Bathing Water (2006/7/EC)
- In setting guidelines for the EU Directive for Bathing Water, the legislator assumed that the bather, who has a full body contact in this water and who may occasionally swallow some of it and/or inhale aerosols, will have no health risk, if the limit values are complied with

In comparison:

E. coli in drinking water: 0/100 ml

E. coli in bathing water (limit value): 1,000/100ml

E. coli in recycled greywater (typical value): 0-10/100 ml

2. No comfort loss

Physical and chemical parameters which ensure an efficient treatment and storage of the treated greywater without any odours or clogging problems:

BOD_7:	< 5 mg/l
O_2 - Saturation:	> 50 %
UV-Transmission: $_{(254\ nm)}$	> 60 %
Turbidity:	< 2 NTU*

(Source: Berlin Senate Department for Urban Development and Housing, 1995)

The Biochemical Oxygen Demand (BOD) and the oxygen saturation level are the most important quality criteria for the “storage capability” of the treated service water. Low turbidity will cause less depositions in the service water network and a high oxygen saturation will prevent the development of odours.

*NTU: Nephlometric Turbidity unit

3. Environmental tolerance

- Low specific energy demand: ideally < 1.5 kWh/m^3
- No use of chemicals
- UV disinfection instead of chlorination

4. Economic feasibility

- Investment (including all operational costs) should pay off within a reasonable amortisation period
- The costs for the applied recycling technology should not exceed those for the conventional system
- Lower operating costs can be achieved if high-quality system components are used with low system maintenance and energy demand

Technical requirements

- A pre-treatment stage using self-cleaning sieves should be incorporated in all systems to remove coarse material (hair, lint, sand, metal and plastic parts). If kitchen greywater is included in the wastewater stream, it is recommended to install a combined grease and sediment trap
- The needed space requirement of about 0.1 m^2 per person is representative for biological systems used for greywater treatment. This is primarily dependent on the pollution load of the greywater (greywater sources), the needed buffer for greywater and service water peak flows as well as on the required service water quality
- Systems should be installed such that access to all system parts is possible at all times for maintenance

TECHNICAL REQUIREMENTS

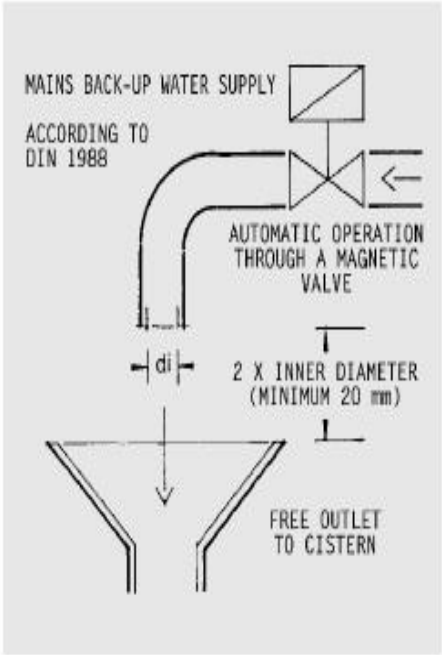
Installation requirements

- According to the Drinking Water Ordinance (TrinkwV) water recycling systems in Germany must be registered by the local health authority
- Installation work must be done by licensed installers/plumbers
- **Cross connection** between potable and non-potable water networks must be excluded! Cross connections must be checked prior to commissioning (dye test)
- **Labelling** of service water (non-potable) pipeworks and tapping points must be done to distinguish them from drinking water installations
- A **backflow prevention** arrangement which hinders the undesirable reversal flow of non-potable water into the drinking water network (open outlet) must be installed

Installation requirements (2)

- Greywater reuse systems must be provided with an automatic **backup system**, when used inside buildings to ensure continuous supply of service water. Drinking water, rainwater or other water source of suitable quality can be used

Diagram for backup water supply



Materials used to label pipework and tapping points of the service water network

(Source: fbr)

Operational requirements

- Energy input for the greywater recycling system should not exceed that for the conventional wastewater treatment system. This should be less than **2 kWh** for the treatment including distribution of one cubic metre of service water
- The use of chemicals for treatment, operation and maintenance should be prohibited
- Low operation and low maintenance expenditure should be sought
- System should be robust, insusceptible to fluctuations and system components long-lasting
- Skilled knowledge is needed for the planning process as well as for installation and maintenance of greywater recycling systems. Involving planers at the early planning phase contributes significantly to cost savings. End users should also ask for references and guarantees

Maintenance requirements

- When high-load greywater flows (from kitchen and washing machines) are also considered for treatment, the maintenance expenditure is expected to be slightly higher than when only low-load greywater is reused
- In general, automatic and periodic cleaning of sieves/filters would provide for a low-maintenance and trouble-free operation
- An internet-based control/monitoring unit helps optimise system operation and reduces the costs for maintenance and operation

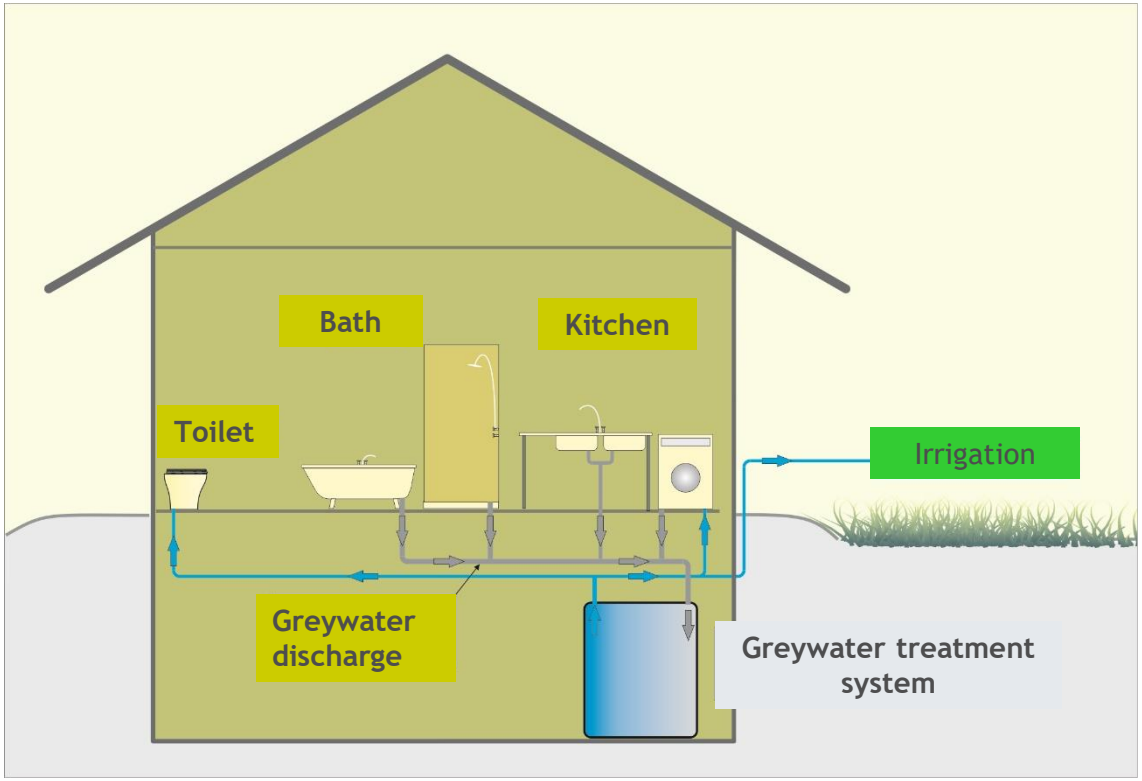
REUSE OPTIONS FOR RECYCLED GREYWATER

- **Indoor** reuse: urinal and toilet flushing, cleaning, laundry
- **Outoor** reuse: irrigation of lawns and domestic gardens, street cleaning, washing vehicles, cooling towers, irrigation of agricultural areas and groundwater recharge

Reuse option affects the choice of the treatment technology!

GREYWATER TREATMENT

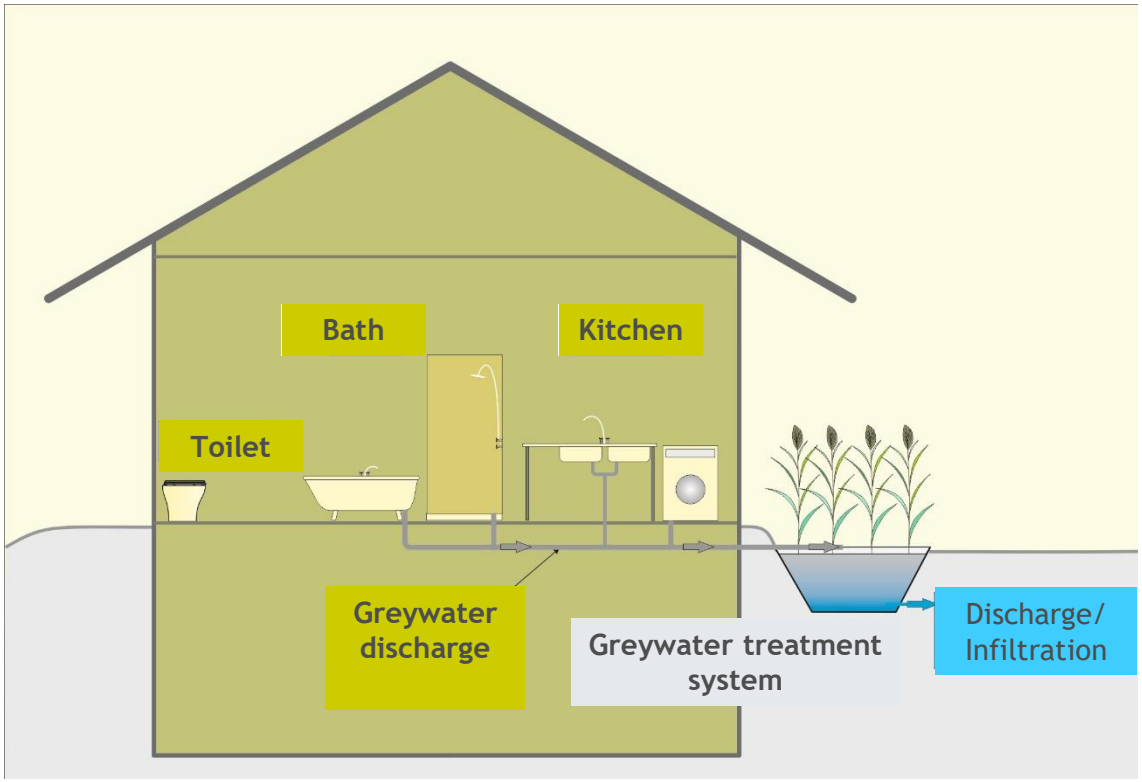
Greywater treatment in households for indoor and outdoor reuse



(Source: fbr)

GREYWATER TREATMENT

Treatment of overall greywater flow for discharge/infiltration



(Source: fbr)

Cost factors

The total costs for a greywater recycling system are usually allocated to the following:

- Dual piping system
- System technology
- Installation costs
- Operating costs (energy, personnel costs, monitoring)
- Maintenance and repair costs

As a rule, depending on the drinking water availability, water costs and the used recycling technology an amortisation period of less then 10 years can be achieved.

The investment costs of the applied technology amount to approx. 1- 2 monthly rents for one accommodation unit.

Greywater treatment

- Treatment and disinfection of greywater are **mandatory** to provide water that is both safe and aesthetically appropriate for reuse
- Treatment is mainly dependent on the pollution level of greywater, intended end use and the required (local) quality requirements for service water
- Good treatment results are possible with different technologies

Greywater treatment technologies

Include physical, chemical, and biological systems. Most of these technologies are preceded by a solid-liquid separation step as pre-treatment followed by a disinfection step as post-treatment.

Chemical treatments (e.g. coagulation, ion exchange systems, …) are usually associated with high energy and material consumption as well as waste by-products. Therefore, they are only recommended in exceptional cases.

- **Physical** treatment: coarse sand filtration, soil filtration, membrane filtration (MF, UF), UV disinfection
- **Biological** treatment: rotating biological contactors (RBC), moving –bed biofilm reactor (MBBR) sequencing batch reactor (SBR), constructed wetland (CW) and membrane bioreactors (MBR)

A combination of physical and biological treatment technologies is mostly applied in practice to achieve a high water quality for reuse.

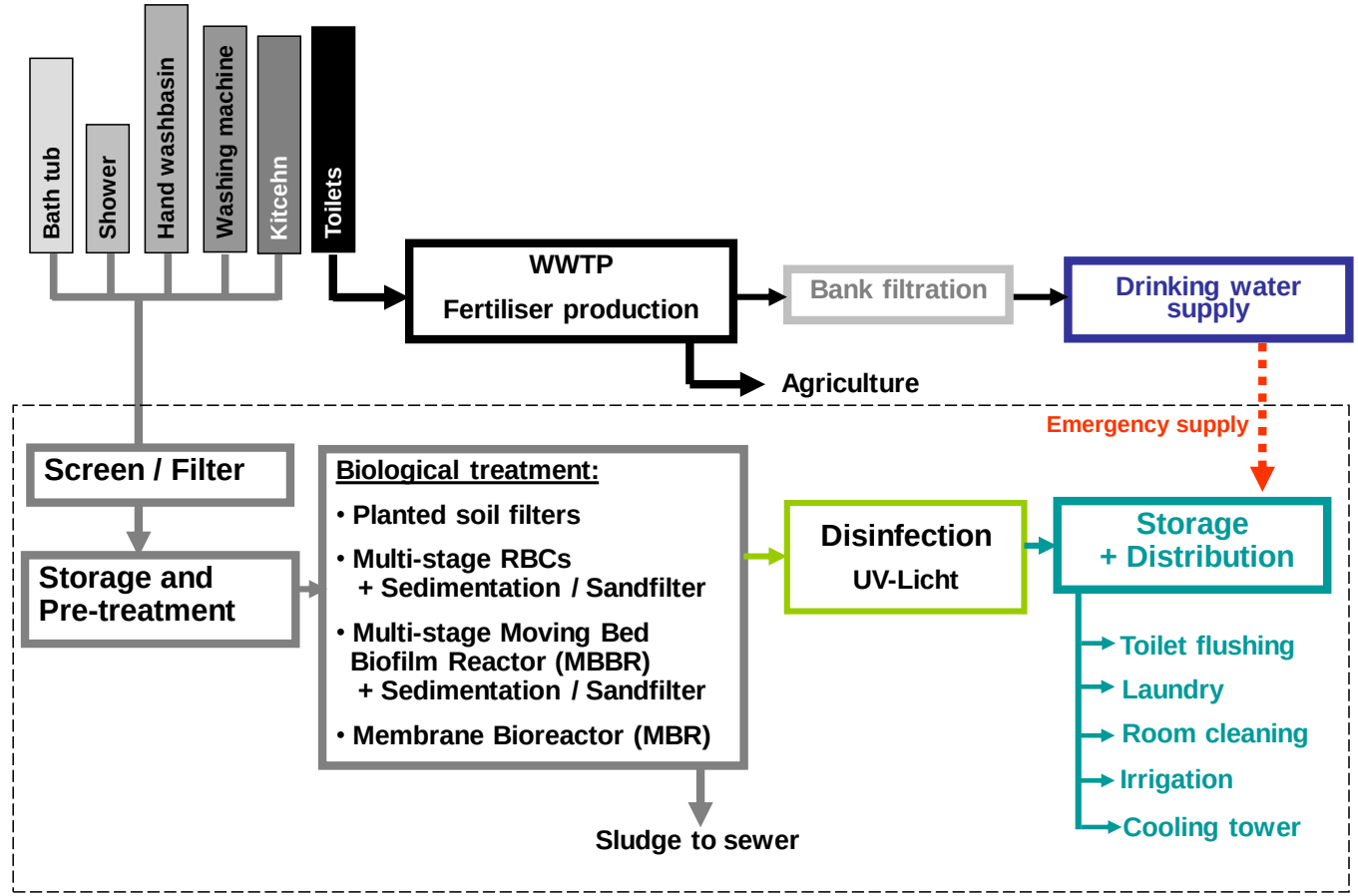
Biological treatment technologies

Examples:

- Rotating biological contactors (RBC)
- Moving-bed biofilm reactors (MBBR)
- Membrane bioreactors (MBR)

Except for the MBR process, most of the applied biological processes are followed by a filtration stage (e.g. sand filtration) and/or a disinfection stage to meet the non-potable reuse standards.

Biological treatment options for greywater recycling



(Source: Nolde & Partner)

Rotating Biological Contactors (RBCs)

(Source: Nolde & Partner)

Rotating Biological Contactors (RBCs)

- A fixed film, aerobic biological treatment system
- Consists of large plastic discs mounted on rotating shafts that slowly rotate half-submerged in the wastewater basin
- A sedimentatios stage is usually required as a post-treatment stage followed by disinfection
- High removal rate of biodegradable organic pollutants
- Low energy requirement
- RBCs produce high humidity and therefore proper ventilation should be provided for in the installation area

GREYWATER TREATMENT

A multi-stage moving-bed biofilm reactor (MBBR) for geywater recycling*

(Source: Nolde & Partner)

*For residential and industrial sectors

Moving-bed biofilm reactor (MBBR)

- An aerobic system which uses the immobilised activated sludge process
- It uses a bed of carrier material (foam cubes, HDPE, etc.) which provides a surface for biofilm growth
- Achieves a high biological activity in the reactor
- Less vulnerable to load fluctuations
- Has a low space requirement
- Compard to RBCs, it produces less humidity and odour problems
- Carrier material is long-lasting and need not be cleaned or replaced (a running time of over 15 years in practice)
- Low maintenance expenditure

GREYWATER TREATMENT

Aerated moving-bed biofilm reactor with foam cubes as carrier media

(Source: Nolde & Partner)

GREYWATER TREATMENT

Membrane systems for greywater recycling (low-load greywater)

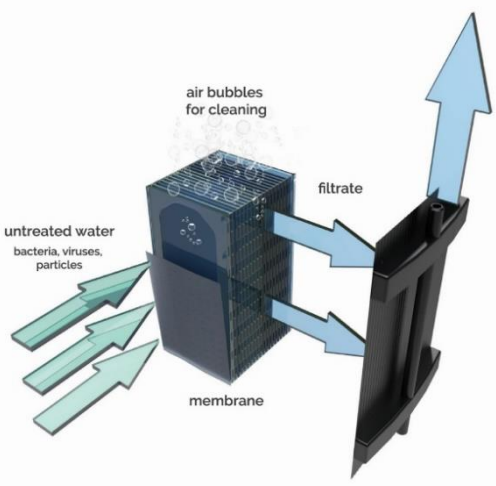
(Source: fbr, project examples)

GREYWATER TREATMENT

Membrane filter

(Source: Martin System GmbH)

Greywater recycling system
with membrane bioreactor (MBR)



(Source: GreenLife GmbH)

Membrane bioreactors (MBR)

- Are suspended-growth activated sludge systems which utilise micro-porous membranes (0.02 – 0.4 µm) for solid/liquid separation
- Require a pre-treatment sedimentation stage
- Treated wastewater passes through the membrane under a pressure of 0.1 – 0.3 bar, while sludge is held back by the submerged membrane
- Yields a good effluent quality
- Require little space
- Only suitable for low-load greywater
- Susceptible to chemicals found in greywater
- Prone to membrane fouling and clogging

BENEFITS OF GREYWATER RECYCLING

- Reduces freshwater demand up to 60%
- Significantly reduce household water bills
- Reduce the amount of wastewater entering sewers or on-site treatment systems
- Reduce dependency on public water supply
- Less sensitive to price variations
- Green building code certification

ANNEX

More on legal and technical framework for greywater recycling in Germany

Technical considerations for the operation and maintenance of greywater treatment and service water distribution systems

- For the installation of the drinking water backup system, the user is referred to **DIN 1989-1**: “Rainwater harvesting systems - Part 1: Planning, installation, operation and maintenance”. To carry out the network separation, reference is made to **DIN EN 1717**
- The switch-on point of the backup system and the required volume flow of the backup water should be dimensioned in such a way, that the service water pumps do not run dry, in case of a failure in the greywater treatment system
- For the dimensioning of the service water network, drinking water backup system, booster station and the service water meter, the guidelines in accordance with **DIN 1988-300** and the Working Sheet **DVGW W 406** should be taken into consideration
- For service water distribution, **DIN 1989-1** should be applied
- For a higher operational safety, it is recommended to install multi-pump systems. These should be installed according to **DIN EN 806-2** und **DIN 1988-200**

Technical considerations (2)

- Operation and start-up of a greywater reuse system should be reported to the responsible local authority in accordance with the guidelines of the Drinking Water Ordinance (TrinkwV)
- All technical parts, which have to be maintained or repaired, should be made easily accessible
- Following installation, the manufacturer or installation firm must hand over a user manual to the operator, who is instructed in all essential activities required for a normal operation
- A handover certificate must be handed over to the client by the installation firm, which documents that the user manual was handed over and a verbal instruction of the operator took place
- In the event of failure of the service water supply it is recommended to switch automatically to the water backup system. The system must be operated according to the manufacturer's specifications
- System maintenance should be made regularly by a skilled person according to the manufacturer's specifications. It is recommended to conclude a maintenance contract

Other installation requirements

For installations in a building, the following data is required on:

- Dimensions of the installation room
- Smallest clearance dimension (doors)
- Load-bearing capacity of the ground
- Other influencing factors, such as increased dust formation, increased room temperature, aeration and ventilation

For installations in the ground, the following data is required on:

- Built volume
- Soil conditions
- Groundwater table
- Distance to the building

Legal framework for greywater reuse in Germany

- legal requirements for the construction and operation of greywater reuse systems arise indirectly from the requirements of the German Infection Protection Act (Infektionsschutzgesetz – IfSG) and their subordinate ordinances such as the German Drinking Water Ordinance (TrinkwV) and the Ordinance about the General Conditions for Water Supplies (AVBWasserV). Further legal provisions arise from the Building Law and the legal requirements for the water supply and wastewater disposal sectors

- greywater is governed by the Water Law. According to the Federal Water Act (WHG), the discharge of treated greywater implies the use of a water body and therefore, it requires an official permit in compliance with §°8 of the WHG. This permit requires a revocable right and, if necessary, limited authority to use the water body (WHG 2009)

- greywater, which is undergoing treatment for reuse purpose, is not regarded as wastewater subject to the statutory duty of wastewater disposal

Legal framework (2)

- The Drinking Water Ordinance (TrinkwV) regulates the quality of water for human consumption. §°13 Para. 4 of the TrinkwV states that owners of rainwater and greywater treatment/reuse systems are obliged to notify the health authority upon commissioning. Also systems which supply water to the public are subject to monitoring by the health authority. The operator must ensure that the system has no repercussions on the drinking water network

- In order to safely and permanently exclude any contamination of the drinking water, the legal requirements in compliance with §°17 Para. 6 of the TrinkwV also apply to the pipework of rainwater and greywater reuse systems, inter alia. Service water reuse systems should have no connection with the drinking water supply systems and should be colour-coded. Service water collection points must be permanently labelled as such. It should be safeguarded through appropriate technical facilities, that no greywater from the greywater reuse system will enter the drinking water network (also not during a pressure drop in the drinking water pipe). The enforcement of the Drinking Water Ordinance is the responsibility of the Federal States, and therefore there is a regional difference with regard to the acceptance of water reuse concepts

Technical framework

Reference to the following standards are made for greywater recycling:

DIN EN 476:2011-04, General requirements for components used in drains and sewers; German version EN 476:2011

DIN EN 752:2017-07, Drain and sewer systems outside buildings - Sewer system management; German version EN 752:2017

DIN EN 1610:2015-12, Construction and testing of drains and sewers; German version EN 1610:2015

DIN EN 12050-1:2015-05, Wastewater lifting plants for buildings and sites - Part 1: Lifting plants for wastewater containing faecal matter; German version EN 12050-1:2015

DIN EN 12050-2:2015-05, Wastewater lifting plants for buildings and sites - Part 2: Lifting plants for faecal-free wastewater; German version EN 12050-2:2015

DIN EN 12050-3:2015-08, Wastewater lifting plants for buildings and sites - Part 3: Lifting plants for limited applications; German version EN 12050-3:2015

Technical framework (2)

DIN EN 12050-4:2015-05, Wastewater lifting plants for buildings and sites - Part 4: Non-return valves for faecal-free wastewater and wastewater containing faecal matter; German version EN 12050-4:2015

DIN EN 12056-1:2001-01, Gravity drainage systems inside buildings - Part 1: General and performance requirements; German version EN 12056-1:2000

DIN EN 12056-2:2001-01, Gravity drainage systems inside buildings - Part 2: Sanitary pipework, layout and calculation; German version EN 12056-2:2000

DIN EN 12056-4:2001-01, Gravity drainage systems inside buildings - Part 4: Wastewater lifting plants, layout and calculation; German version EN 12056-4:2000

DIN EN 12056-5:2001-01, Gravity drainage systems inside buildings - Part 5: Installation and testing, instructions for operation, maintenance and use; German version EN 12056-5:2000

DIN 1986-100:2016-12, Drainage systems on private ground - Part 100: Specifications in relation to DIN EN 752 and DIN EN 12056

DIN 1989-1:2002-04, Rainwater harvesting systems - Part 1: Planning, installation, operation and maintenance