fbr – Information Sheet H 201

Greywater Recycling

Planning fundamentals and operation information

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Content

Notice

The script at hand is a translation from the German of the fbr-Information Sheet H 201 which has been first published in May 2005. The script reflects the state-of-the-art in Germany regarding greywater reuse and therefore, at the present time it is focused upon the the guidelines of the German Drinking water Ordinance (TrinkwV) and the Norms of the German Institute for Standardisation (DIN).

The main objective of the English version of the Information Sheet H 201 is to open a platform for discussion and cooperation with international partners and establish the basis for an international framework regarding greywater recycling. The succeeding scripts will take into consideration the specific conditions and needs of the different countries in order to establish a commom and approved international framework for greywater-recycling.

Since the German translation for recycled greywater is “process” or “service” water, and since there is no specific term in the English language for recycled greywater or recycled and reused water in general, we chose the term “process water” in this information sheet to describe treated greywater which exhibits a high water quality for non potable use.

Preface

The Fachvereinigung Betriebs- und Regenwassernutzung e.V. (fbr) accompanies the topic “Greywater Recycling” since the foundation of the association in 1995.

Dealing with water ecologically and efficiently in the housing technology is becoming increasingly more important. Numerous research projects with long-term scientific investigations have led to industry products of greywater recycling plants which are now available on the market.

The present fbr Information Sheet H 201 documents the current standard of knowledge in this area and defines requirements for planning, execution, operation and maintenance of greywater recycling plants which have been proven in practice.

The fbr Information Sheet H 201 serves as a recommendation for manufacturers, planners and other interested persons. It does not replace, however, the technical instructions of the manufacturers, but serves as a planning basis and gives preliminary information on the operation of the plants.

The fbr Information Sheet H 201, the first in this series, has been developed by the fbr expert group “Greywater Use”. Special thanks go to its members for their work.

For the executive committee

Martin Bullermann

1 Definitions

Household wastewater (according to DIN EN 1085)
Wastewater from kitchens, washing machines, bathrooms, toilets and similarly used rooms.

Blackwater
Blackwater is part of the household wastewater. It is the drain from toilets and therefore, contains urine and/or faeces.

Greywater
Greywater is a part of the household wastewater without blackwater. It is the drain from bath tubs and shower trays, washbasins and washing machines and may also contain high-strength kitchen wastewater.

Water for greywater recycling
The least concentrated flows of the available household wastewater are especially appropriate for greywater recycling. For residential buildings, these are the drains from bath tubs and shower trays as well as washbasins.
Under certain conditions, the use of the washing machine drain or even kitchen wastewater may be of significance.

Greywater recycling plant
A plant which collects greywater and treats it to process water of sufficient quality for specific reuse purposes.

Process water
According to DIN 4046, process water is defined as “water with different quality characteristics serving commercial, industrial, agricultural or similar purposes”. In connection with greywater recycling, it also includes water which is used in households and trade and which does not have to be of a drinking water quality, such as water used for toilet flushing, irrigation, for cleaning purposes or for laundry.

2 Used signs / abbreviations

AOX	Adsorbable Organic Halogen compounds
ATV	Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V. (German Association for Water, Wastewater and Waste)
BODx	Biochemical Oxygen Demand used within x days
COD	Chemical Oxygen Demand
DIN	Deutsches Institut für Normung (German Institute for Standardisation)
E. coli	Escherichia coli
EU	European Union
fbr	Fachvereinigung Betriebs- und Regenwassernutzung (German Association for Water Reuse and Rainwater Harvesting)
HMUEJFG	Hessisches Ministerium für Umwelt, Energie, Jugend, Familie und Gesundheit (Ministry for the Environment, Energy, Youth, Family and Health in Hesse)
J	Joule
kWh	Kilowatt hour
L	Litres
L/(c*d)	Litres per capita per day
MLUR	Ministerium für Landwirtschaft, Umweltschutz und Raumordnung Brandenburg (Ministry for Agriculture, Environmental Protection and Regional Planning in Brandenburg)
n/a	Not applicable
N	Nitrogen
P	Phosphorous
pH	Concentration of hydrogen ions in pH units
RAL GZ	Deutsches Institut für Gütesicherung und Kennzeichnung e.V. (German Institute for Quality Assurance and Identification)
TrinkwV	Trinkwasserverordnung (German Drinking Water Ordinance)
UV	Ultraviolet radiation
WHO	World Health Organisation

3 Scope of the information sheet

The information sheet is valid for plants where a process water* supply is produced from greywater on a larger than single household scale, i.e., multiple-family dwellings, row houses or semi-detached houses and large housing estates with common collection and treatment of the greywater. Figure 1 shows an example of water flows for single households. Selection of partial flows for greywater recycling has to be decided upon for each individual case on the basis of a prediction of the water balance (refer to Chapter 5.1). Moreover, the information given in Figure 1 is also valid for commercial areas such as hotels, guest houses, schools and sports facilities, camping grounds and restaurants. For the above mentioned fields of application, an adequate water treatment is indispensable in order to achieve the respective quality aims defined in Chapter 6.

The information sheet H 201 is recommended for greywater recycling plants in detached houses or single apartments, where persons supplied with the process water are living in a commom household. Nonetheless, in single households, a more simple treatment technology may be employed at the owners' responsibility.

* Process water (according to DIN 4046): Water for use in trade, industry, agriculture or other similar purposes with different quality characteristics, whereby, drinking water quality may be included.

4 Water management and ecological aspects

Groundwater is the priority resource for drinking water in the Federal Republic of Germany and has to be protected according to the Water Resources Policy Act. Therefore, measures have to be taken to reduce the water consumption and to substitute drinking water in areas where drinking water quality is not required such as for toilet flushing, outdoor irrigation, washing of clothes or other cleaning purposes, e.g. car washing. The use of treated greywater as process water contributes to the protection of the water resources and exerts a positive influence on the water balance as well as on the environment.
Moreover, greywater recycling plants reduce the drinking water requirement. As a result, the negative effects of the drinking water extraction and distribution processes (e.g. energy and chemical requirement, drop in the groundwater level, consumption peaks) will also be reduced.

Greywater recycling plants reduce the amount of wastewater produced and consequently, the water pollution. By infiltrating the surplus treated greywater, the natural groundwater recharge process will be selectively increased and the amount of water discharged into the sewer decreased.

5 Greywater quantity and quality

Greywater originates from water burdened with pollutants. Greywater production and its degree of pollution are mainly determined by the habits of the consumers and is a result of products of personal hygiene, detergents, body dirt as well as soiled clothes. These pollutants are classified as easily bio-degradable.
Greywater is continuously available due to daily personal hygiene requirements and its production is independent from the weather conditions.

5.1 Greywater quantity

In Germany, the average drinking water requirement in households and small enterprises in 1998 amounted to 129 L/(c*d) [Stat. Bundesamt (Federal Office for Statistics) 2000], and this figure has not changed considerably since then. About 9% is required in small enterprises leaving an average water consumption of about 117 L/(c*d) for private households. The amounts of water consumed and greywater produced may vary considerably dependent on the sanitary standard in households and the user habits. In new buildings or buildings where sanitary equipment had been rehabilitated, an average water consumption of 100 L/(c*d) and greywater production of up to 70 L/(c*d) may be taken as a basis (Figure 1). In general, this greywater amount corresponds to a process water demand of about 40 L/(c*d), whereby, about 25 to 35 L/(c*d) are needed for toilet flushing. In general, process water demand in apartments lies clearly below the total available amounts of greywater.

5.2 Greywater composition

The easily degradable organic substances originate mainly from detergents, skin grease, hair and skin and dandruff particles. Due to its ready biodegradability, if greywater is not soon treated, decomposition processes in connection with sulfates will take place leading to unpleasant odour development.
The organic substances are measured by means of the parameters BOD or COD. The content of the organic substances is dependent on the origin of the partial flows of the collected greywater. Table 1 gives an overview on the expected concentrations.
Greywaters from showers and bath tubs are slightly polluted. When greywater from washing machines is additionally used, a considerably higher concentration of substances in the greywater is expected and as a consequence, a higher treatment expenditure. The additional use of kitchen wastewater (sink, dishwasher) will further increase the load.

Moreover, the values listed in Table 1 may vary depending on the regional drinking water quality, e.g., higher nitrate concentration or the addition of phosphates to prevent pipe corrosion. Additional significant phosphate concentrations may result from dishwashing soap.

Compared with household wastewater, greywater contains considerably less nutrients (phosphorous / nitrogen). A possible limitation of biological treatment due to insufficient nutrient supply was not detected in investigations carried out on greywater recycling plants.

The vast number of microbiological studies which have been performed in the past years on greywater from bath tubs, showers and washbasins have shown a 100-fold decrease in the numbers of total and faecal coliforms (E. coli) compared to the total household wastewater (Table 2). When greywater from washing machines is also collected, higher bacterial concentrations are measured in the greywater dependent on the washing temperature.

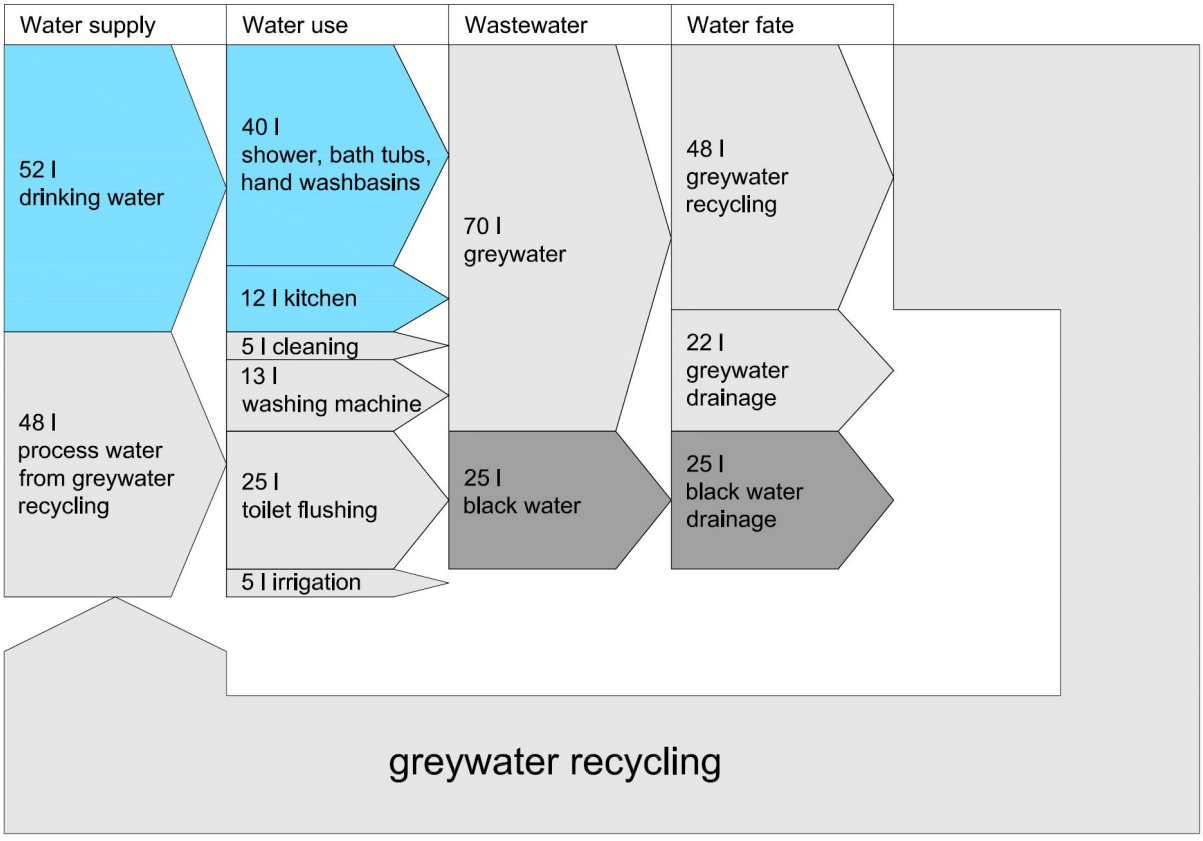

Figure 1: Average partial water flows (litres per inhabitant and day) for private households in new buildings and sanitary rehabilitated buildings [Mehlhart, 2001].

Table 1: Composition of untreated greywater of different origins. The values are based on experience from measurements of between 10 and 100 each [from: Nolde, 1995 and Bullermann et. al., 2001].

		from bath tubs, showers and hand washbasins (measured after the sendimentation tank	from bath tubs, showers, hand washbasins **and** washing machine (including baby diapers)	from bathtubs, showers, hand washbasins, washing machine **and** kitchen
COD	[mg/l]	150 – 400 Ø 225	250 – 430	400 – 700 Ø 535
BOD_5	[mg/l]	85 – 200 Ø 111	125 – 250	250 – 550 Ø 360
AFS	[mg/l]	30 – 70 Ø 40	n/a	n/a
P_{total} A)	[mg/l]	0,5 – 4 Ø 1,5	n/a	3 – 8 Ø 5,4
N_{total} A)	[mg/l]	4 – 16 Ø 10	n/a	10 – 17 Ø 13
pH	[-]	7,5 – 8,2	n/a	6,9 – 8

A) Values may vary depending on the regional drinking water quality, e.g. higher nitrate content or addition of phosphate to prevent corrosion of pipes. Additional significant phosphate concentrations may result from dishwashers.

Table 2: Total coliforms and E. coli in untreated greywater and sewage from households: The values are based on experience from measurements of between 10 and 100 each. [from: Nolde, 1995 and Bullermann et. al., 2001].

Parameter	Unit	Greywater from bath tubs, showers and hand washbasins	Greywater from bath tubs, showers, hand washbasins **and** washing machine (including baby diapers)	Greywater from bath tubs, showers, hand washbasins, washing machine **and** kitchen	Household wastewater including faeces
Total coliform bacteria	1/ml	$10^1 – 10^5$ median: 10^5	$10^2 – 10^6$	$10^2 – 10^6$	$10^4 – 10^7$
Faecal coliform bacteria (*E. coli*)	1/ml	$10^1 – 10^5$ median: 10^4	$10^1 – 10^5$	$10^2 – 10^6$	$10^4 – 10^7$

6 Application range and quality requirements for process water

In public/commercial buildings and where several households are connected to a greywater recycling plant, treatment of the greywater is dependent on the intended use and the respective quality requirements. These quality requirements for process water should be oriented towards the intended use. In general, process water from greywater recycling plants should be hygienically / microbiologically safe, colourless and almost free from suspended matter. Even following several days of storage, no odour emissions from the process water should occur. Since no statutory regulations for plant operation and process water quality exist, it is recommended to request written guarantees from the respective supplier concerning the quality requirements for greywater recycling for the specified intended use.

Based on current scientific investigations, the following quality aims have been tested and proved and are thus recommended for application in the areas of toilet flushing, laundry, irrigation, infiltration and direct discharge into surface waters.

6.1 Toilet flushing

The requirements listed in Table 3 have been developed on behalf of the Berlin Senate Office. The hygiene requirements for total coliform and faecal coliform bacteria are oriented towards the EU Guidelines for Bathing Water (76/160/EEC). This was based on the assumption that persons having body contact with this water and moreover, those who even occasionally swallow some of it will not be subjected to a health risk if the limit values are held.

The most strict requirements are valid for Pseudomonas aeruginosa, the so-called wet-germ pathogen, which is health-relevant. BOD_7 and oxygen saturation are quality criteria for the „shelf life“ of the treated water.

Table 3: Quality requirements for toilet flush water [SenStadt, 2003].

BOD_7	< 5 mg/l
Oxygen saturation	> 50%
Total coliform bacteria [A)]	< 100/ml
Faecel coliform bacteria [A)]	< 10/ml
Pseudomonas aeruginosa [B)]	< 1/ml

[A)] Analysis according to EU Guideline 76/160/EEC.
[B)] Analysis according to the German Drinking Water Ordinance (TrinkwV 200).

6.2 Laundry

The quality requirements for process water listed in Table 3 are recommended for laundry activities.

From scientific investigations on clothes washing with rainwater, it is well known that from a hygienic / microbiological aspect, there is no difference between clothes washed with rainwater and those washed with drinking water [Holländer et. al., 1993].

Studies made with treated greywater, which fulfill the quality aims listed in Table 3, have also shown that from a hygienic / microbiological aspect, there is no difference between clothes washed with treated greywater and those washed with drinking water following drying [Töpfer et.al., 2003].

In individual households, the user is free to wash clothes with process water. In an apartment house, process water may be provided for the washing of clothes if, alternatively, a drinking water connection for the washing machine is made available to the tenant according to the German Drinking Water Ordinance [TrinkwV, 2001].

The RAL GZ 992 gives additional hints on the cleaning of clothes in certified business establishments.

6.3 Water for irrigation

The quality requirements for irrigation water are regulated by the DIN 19650. These quality requirements refer to the hygienic / microbiological aspects of irrigation water in agriculture, gardening, landscaping as well as in parks and sport facilities.

The hygienic safety of irrigation water is divided into 4 qualification classes which has to be verified for each intended use (refer to the excerpt of the DIN 19650 in Table 4).

Table 4: Hygienic / microbiological qualification classes of irrigation water and their application [according to DIN 19650, 1999].

Qualification class	Application	Faecel streptococci number of colonies/ 100 ml (according to the German Drinking Water Ordinance TrinkwV or EU Guidelines for Bathing Water [1])	E. coli number of colonies/ 100 ml (according to the German Drinking Water Ordinance TrinkwV or EU Guidelines for Bathing Water [1])	Salmonellae/ 1000 ml (according to DIN 38414-13)	Potentially infectious stages of human and pet parasites [2] in 1000 ml
1 (Drinking water)	All crops in greenhouses and on open land without restriction	Not detectable	Not detectable	Not detectable	Not detectable
2[3]	Crops on open land and in greenhouses for raw consumption, schools sport fields, public parks	≤ 100 [4]	≤ 200 [4]	Not detectable	Not detectable
3[3]	Crops in greenhouses not intended for consumption Crops on open land for raw consumption up to the fruiting stage or for vegetables up to 2 weeks prior to harvesting Fruits and vegetables for conservation Greenland or forage plants up to 2 weeks before cut or grazing All other crops on open land without restriction Other sport fields [5]	≤ 400	≤ 2000	Not detectable	Not detectable
4 [3], [5]	Wine and fruit cultures for protection against frost Forest, polder and wetlands Sugar-beets, starch potatoes, oil fruits and non-food plants for industrial processing and seeds up to two weeks prior to harvesting Grain up to the germination phase (not intended for raw consumption) Feed for conservation up to 2 weeks prior to harvesting	Wastewater which has undergone at least one biological treatment			For intestinal nematodes, no standard recommend-ations are possible for Taenia stages: not detectable

[1] Microbiological surveys according to the methods applied for bathing water.

[2] As far as it is necessary for the protection of the health of humans and animals, an examination of the irrigation water for intestinal nematodes (Ascaris and Trichuris species as well as hookworms) and/or life stages of tapeworms (especially Taenia) may be accommodated according to WHO recommendation.

[3] If a wetting of the parts of the crop products which are appropriate for consumption is excluded, a restriction according to the hygienic / microbiological qualification classes may be dropped.

[4] Guide value, below which measured values should lie, according to the German Drinking Water Ordinance TrinkwV § 2 Para 3 “as far as the state-of-the-art and a justifiable expenditure allow, taking into consideration each individual case”.

[5] In case of spray irrigation, it has to be ensured through protective measures that employees and the public are not at risk.

According to the requirements established by the DIN 19650, one can indirectly deduce that the quality requirements for irrigation water for most applications are more strict than those for toilet flush water.
Treatment of the greywater with an appropriate technology is required. According to DIN 19650, it is unacceptable to achieve these requirements by disinfection such as addition of chemicals or irradiation.

6.4 Infiltration of treated greywater

The infiltration of treated wastewater in a technical infiltration plant, e.g. an infiltration trough or infiltration ditch, is to be approved by the responsible water authority. In certain cases, such permissions have already been granted. It is however of significance that the nutrients (phosphorous and nitrogen) in the greywater constitute only about 2 to 5% of the total nutrients in the household wastewater.
For the off-site disposal of biologically treated wastewater into the subsurface, the DIN 4261-1 (Small wastewater plants – Part 1: Plants for wastewater pre-treatment) has to be taken into consideration [DIN 4261-1, 2002].

For the infiltration of treated wastewater, country-specific guidelines have been published. Examples of requirements from the Federal States Hesse [HMUEJFG, 1996] and Brandenburg [MLUR, 2001] are included in Table 5. During infiltration, the corresponding state-specific requirements regarding passage through the soil layer and proximity of the infiltration plant to the groundwater, have to be taken into consideration.

6.5 Direct discharge of treated greywater into surface waters

The direct discharge of treated greywater into surface waters requires appropriate authorisation. Generally, the regional regulations concerning the discharge of wastewater have to be followed.

Table 5: Requirements for treated household and municipal wastewater from sewage plants for infiltration purposes.

		Control value	Source
Suspended solids(SS)	For connection values up to 15 inhabitants	0.1 ml/l	HMUEJFG, 1996
BOD_5		20 mg/l	HMUEJFG, 1996
COD		100 mg/l	HMUEJFG, 1996
Suspended solids (SS)	For connection values of more than 15 inhabitants	0.1 ml/l	HMUEJFG, 1996
BOD_5		15 mg/l	HMUEJFG, 1996
COD		80 mg/l	HMUEJFG, 1996
$N_{inorg, total}$		24 mg/l	MLUR, 2001
AOX		0.025 mg/l	MLUR, 2001

7 Plant design

A greywater recycling plant has to collect, store and reduce the organic and hygienic load of the greywater in order to meet the quality requirements listed in Chapter 6 and to ensure a continuous supply of high-quality process water. Different technologies are available from a number of manufacturers.

Based on the predictions made for the water balance and the overall water concept, it has to be determined for each individual case, which partial flows (shower, bath tub, washbasin, washing machine) have to be harvested for greywater recycling and whether dishwashers and kitchen sinks have to be also connected.

7.1 Plant dimensioning

Greywater availability as well as greywater composition are strongly dependent on the consumer's habits.

As a general rule, process water demand in apartments is considerably lower than the totally available quantity of greywater.

Usually, it is not necessary to treat the total amount of available greywater. For greywater recycling, it is more advantageous to admit only the less polluted partial flows from the shower, bath tub and washbasin to the greywater recycling plant.

For the dimensioning of greywater recycling plants in public and commercial areas such as in a hotel, the specific ancillary conditions for greywater availability and consumption have to be identified and included in the planning process since these may deviate considerably from the consumption in households (refer also to Figure 3).

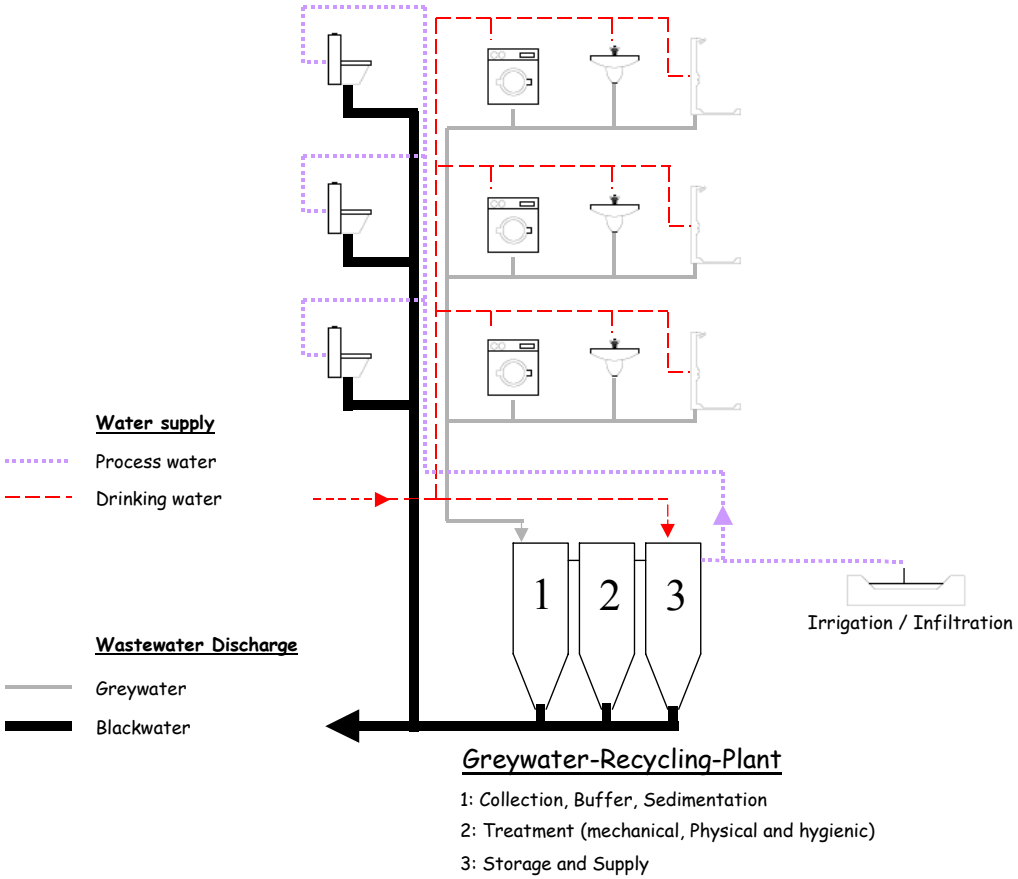

Figure 2: Typical application of greywater recycling from several households (Note: As an alternative, a drinking water connection to the washing machine is offered to the tenant).

7.2 Connection to the building services, drainage and room ventilation

A cross connection between the drinking water and process water networks should not exist. The process water pipes should be permanently colour-coded according to the specifications of the German Drinking Water Ordinance.
The drinking water feed system should follow DIN EN 1717. The tap connections should be completed according to the German Drinking Water Ordinance (TrinkwV 2001 § 17 Para. 2 Phrase 3).
All reservoirs or pipeworks in which greywater is stored without aeration / treatment or otherwise retained, have to be designed odour-tight and if possible, aerated separately from the roof top air vent of the house drainage. Emergency overflows have to be equipped with an odour trap and, if required, protected against rodents. The backwater level of the sewer has to be taken into consideration. Dependent on the plant site, one has to bear in mind that in case of a backwater event, no wastewater from the municipal sewer should enter the greywater recycling plant.
In technologies with a high open water surface area and / or high temperature gradients, a high air humidity is generated in the room where the greywater plant is installed. Condensation water is expected on construction and plant components and pipes where the temperature is below the ambient temperature. For this reason, all cold water pipes should be equipped with heat insulation. In contrast, a heat insulation of the pipes which convey the (warm) greywater is not required. On the cooled construction components (thermal bridges and corners), condensation water formation is also possible. An appropriate positioning of an air suction exhaust or a corresponding heat insulation may act as a corrective measure.
For larger open water surface area, an active air vent in the operation room is necessary.

7.3 Fittings, pipe system and pumps

Some material contained in greywater, such as hair may cause operational failures. Pipes and fittings which are in contact with the untreated greywater have to be designed in such a way that, no sharp edges or other forms are available on which hair, for example, may preferentially deposit. All mechanical equipment such as pumps, motorised valves, filters and other units have to be easily accessible and removable in order to perform repair, maintenance and cleaning works. This applies particularly when high-load (greasy) kitchen wastewater is introduced into the greywater recycling plant and suitable pumps and fittings have to be used for this purpose.

7.4 Buffer and storage reservoirs

Buffer and storage reservoirs serve to compensate between the temporally delayed introduction of greywater into the recycling system and the process water demand. The storage volume is dependent on the user habits (daily course of process water supply and consumption) as well as the process requirements (rapid or time-consuming treatment). Therefore, storage reservoirs are an integral part of the treatment plant and they may be supplied by the manufacturer analogous to the process requirements. From the user's behaviour pattern, there is usually a consistency between greywater production and process water demand (refer to the example in Figure 3). For this reason, the buffer and storage capacities (these may be regulated before or after the treatment) should under no circumstance be larger than the process water demand for one day.

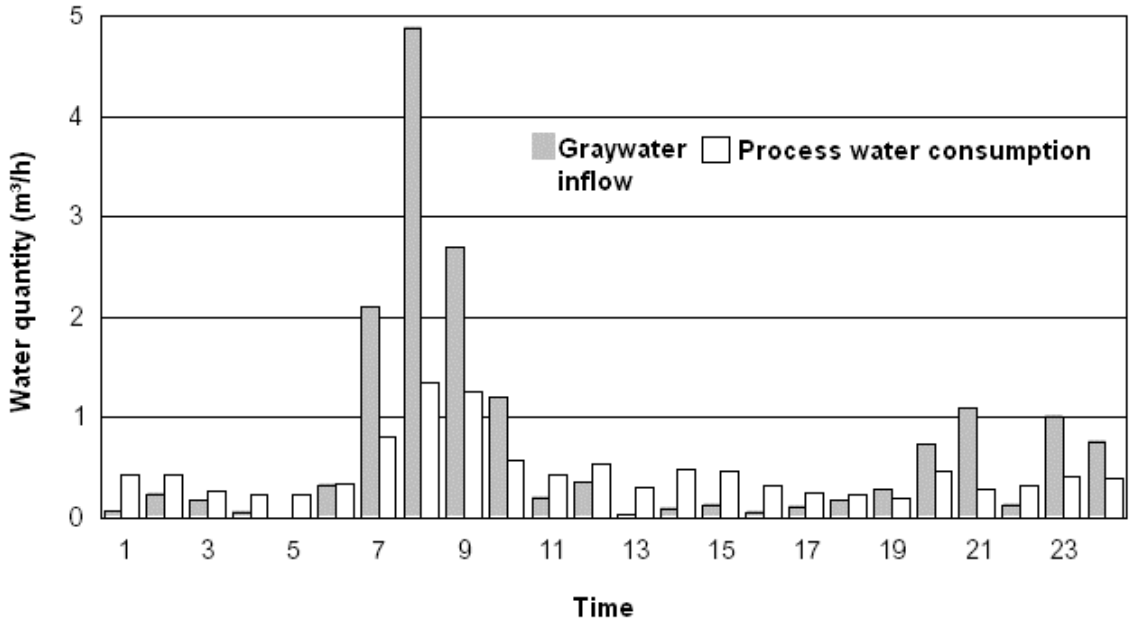

Figure 3: Daily greywater inflow (bath tubs, showers and hand washbasins) from hotel guest rooms and process water demand for toilet flushing [Nolde, 2000].

For larger plants or well defined ancillary conditions, the size of the storage reservoir may be considerably reduced.
Storage reservoirs have to be protected against direct sunlight (e.g. in the cellar without windows) or manufactured from an opaque material in order to avoid the possible growth of algae.

7.5 Treatment

Basically, various technologies which are well-established in the water treatment sector may be applied for the treatment of greywater.
Technologies which do not require the addition of chemicals and which need little energy and maintenance are preferable. These are

- Biological systems (processes which use microorganisms on carrier material for water treatment have proved their high efficiency)
- Membrane technology
- Combined technology

7.6 Reduction of microorganisms

If the necessary reduction of microbes occurs parallel to the reduction of the organic load, one can do without a disinfection step. Microbial reduction may take place, for example, in planted soil filters or in membrane installations.
If a technical disinfection is required as a stage in the greywater treatment, UV-lamps have been used for this purpose. According to the wastewater disinfection procedures [ATV-M 205], a radiation efficiency of 250 J/m^2 is usually sufficient following a biological treatment and a solid separation stage, in order to ensure the hygienic quality requirements according to Table 3. Upon determining the radiation efficiency, other factors such as the expected transmission, maximum flow-rate at the radiation site, ageing of the lamp, a contamination in the radiation area with biofilms, lime or other material, have to be taken into consideration.

Other techniques may be also considered for disinfection as alternatives to the technical disinfection with UV light.

A chemical disinfection of the greywater with chlorine according to ATV M 205, is to be rejected as a standard solution since the introduction of additional chemicals may lead to uncontrolled reactions (e.g. formation of organic chlorine compounds) with adverse effects on the ecology of waterbodies.

Regarding the use of other technologies in greywater recycling, no investigation results are available so far.

In order to ensure the operational safety, it is recommended to provide technical installations for disinfection with an automatic operation control unit. In case of a breakdown of the disinfection unit, an automatic barrier to the inlet of the process water reservoir is necessary which ensures that non-disinfected process water is not fed into the pipework.

7.7 Mains back-up system

Although the process water demand in apartments is generally considerably less than the total available greywater quantity, this may not always be the case on certain days. In this case, an automatic mains back-up system should be provided to guarantee a continuous water supply. This is preferentially installed in the last stage in the greywater recycling plant.
The quality of the back-up water must be adequate for the corresponding application.
If feeding takes place with drinking water, this should be perfomed according to DIN EN 1717.

When the minimum water volume in the process water storage reservoir is reached, the mains back-up system has to be automatically controlled in such a way that, only small amount of drinking water is fed. Operational disturbances have to be indicated by error messages. Depending on the area of application, a floating output should be available to deliver the error message.

With all systems in which a mains back-up system in combination with an emergency overflow is built, there exists a potential hazard of accidental back-up water leading to an overflow and discharge of drinking water into the sewer. The possibility of flooding, e.g. in case of backwater, must be ruled out. The overflow due to back-up water has to be installed in such a way, so that its function is always guaranteed and the overflow process is obvious.

7.8 Miscellaneous

- Power supply:
  The greywater recycling plant has to be protected by an earth leakage circuit breaker.
- Sensors for measuring the water level:
  If possible, motionless sensors (e.g. conductivity, pressure) are preferred for control.

8 Operation information

The local health authority has to be informed on the operation and start-up of a greywater recycling plant according to the requirements of the German Drinking Water Ordinance [TrinkwV, 2001] (refer to Annex 1).
The start-up of operation has to be documented in a protocol following manufacturer's instructions. In this context, the following aspects have to be verified:

- No cross-connection to the drinking water network
- Documentation of the pipework material and colour of the pipes
- Drinking water feed according to DIN EN 1717
- Tap connections according to the German Drinking Water Ordinance (TrinkwV 2001, § 17 Para. 2 Phrase 3).

For the proper operation of a greywater recycling plant, the following documents have to be enclosed in the delivery:

- Information concerning the manufacturer / supplier, addresses, service phone numbers
- Description of the complete mode of operation of the plant, possible disturbances as well as possible trouble-shooting (by operator, specialised technician or manufacturer)
- Description of the required inspections / visual inspection by the operator
- Description of a checklist for inspections / visual inspection
- Description of the required maintenance works (by operator, specialist company or manufacturer)
- Where required, documents on main components (e.g. pumps/pressure increase, engine ball valves, water level measurements, control) with an exact product designation (including serial number, manufacturing date), manufacturer, addresses, service phone number, information on maintenance intervals of required wearing parts
- Documentation of the electrical equipment.

The state-of-the-art greywater recycling plants guarantee a continuously high process water quality without comfort loss for the user, as long as plants are being inspected and maintained according to the instructions of the manufacturer. In case of infiltration or discharge of the treated greywater into surface waters, the requirements of the local authorities have to be taken into consideration.
During plant operation, no disturbances should occur such as odour or noise generation.
Greywater recycling plants are preferentially equipped with a fully automatic control system in order to guarantee a low-maintenance and failure-free operation. The possibility of integration into the central building control system (alarm monitoring) could be arranged.

8.1 Inspection

Inspections of the plant by the operator / user have to be performed according to the instructions of the manufacturer of the greywater recycling plant. Besides testing the functioning of the plant and the relevant plant parts, a testing concerning the clarity (visual turbidity) and odour of the process water has to be completed. This inspection should be easily and rapidly performed without appreciable cost.

8.2 Maintenance

Regular maintenance according to the instructions of the manufacturer of the greywater recycling plant contributes considerably to its operational safety. Additionally, it increases the service life and energy efficiency. Typical maintenance intervals should be about one year.

8.3 Specific operation conditions

For biological treatment processes following a longer shutdown periods / service interruptions, special attention should be given to sufficient re-establishment of the active biomass before the process water supply is used.

In case of doubt and as long as no guarantees have been made by the manufacturer that following a certain period of time a sufficient cleaning capacity is ensured, a hygienic inspection according to the quality requirements mentioned under 6.1 is recommended.

9 Costs

The ecological aspects of greywater use are not yet accounted for in conventional economical considerations. The effects of high drinking water consumption on water resources and wetlands, in addition to the effects of high amounts of discharged wastewater on waterbody load, have not been monetarily measured. For holistic assessment, these aspects must to taken into account. Currently, sufficient data does not exist to carry out this overall consideration.

Moreover, when comparing the costs of the conventional water supply and disposal systems with those of other water systems such as the use of greywater, subsidies delivered for the infrastructure of the conventional water supply and wastewater treatment systems are generally not taken into consideration. Particularly in rural areas, high investment subsidies are delivered by the Federal States for the conventional systems.

Also, it has not been monetarily considered, that the separation of the household wastewater into a high-load blackwater and a low-load greywater part, water, nutrient and energy recycling can be practised with justifiable costs.

The following paragraphs describe available parameters for the evaluation of the investment and operation costs. By establishing a water management concept for each individual case, economical optimisation usually occurs.

9.1 Investment costs

In the framework of a survey completed in December 1999, the costs for greywater recycling plants, including the required storage and pressure increase, have been requested from the manufacturers [Mehlhart / Bullermann, 2001]. At that time, the specific investment cost was determined by the size of the plant. Nowadays, this dependancy has become considerably lower due to new products. For small plants for about 15 persons, the specific investment costs are currently around 300 € per capita. The additional costs for separate greywater and process water pipeworks have to be calculated according to the local conditions.

9.2 Operation costs

Operation costs include costs for repair, maintenance, upkeep, inspection, utilities such as electricity and drinking water feed as well as the costs for the calculation of the process water consumption.

9.2.1 Repair and maintenance

The costs for repair, maintenance and upkeep depend on the selected technology. For simply constructed plants, generally 1% of the investment costs is sufficient per year; for machines / technical facilities, up to 4% of the investment amount are required per year.

9.2.2 Inspection

Inspections are regular, visual surveying of the plant, keeping inspection books and similar tasks without the need for immediate maintenance or upkeep measures.

The costs for inspections can be minimised by automation and remote monitoring, as long as these costs are not the responsibility of the user.

9.2.3 Energy consumption

The energy consumption for greywater treatment, including pressure increase / drinking water feed into the process water network, lies between 1.5 and 3 kWh per cubic meter of process water dependent on the applied technology.

9.2.4 Mains back-up system

As long as longer shutdown periods can be avoided, the demand for drinking water feed in commom residential buildings amounts to maximally about 2% of the process water demand. In other buildings with different uses for the greywater (restaurants, sport facilities, hotels, homes for the elderly, schools, etc.), other values may result which have to be calculated individually.

9.2.5 Billing of metered process water

Billing of metered process water to individual households should be avoided as the operation of a metering and billing system (water meters, reading services) would generate excessive costs. A flat rate per capita is advisable, since the variable, consumption related costs for the plant operation claim only 20% of the total costs whereas 80% are fixed costs.

10 Applied and further literature

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Consignor (contractor / owner):
Surname, Name
Company
Address
Postcode / City
(Code) Phone / Fax / e-mail

To

_____
- Health Authority -

_____
Street,number

_____
Postcode

1. I herewith notify the following

θ Operation of an already existing plant
θ Commissioning of a plant
θ Recommissioning of a plant
θ Closedown of a plant

on _____
Date

Volumetric capacity of the cistern is about _____m³

2. Plant site

_____
Address

_____
Postcode

_____
Building / part of the building

_____
Type of use of building

3. Origin of the process water
θ House well
θ Roof storm water
θ Surface water
θ Greywater
(bath, shower, hand washbasin, washing machine)
θ Other:

_____

4. Origin of mains back-up water
θ Central drinking water supply
θ Other:

_____

.

5. Drainage of the surplus
process water takes place through:
θ Separate sewage system
θ Combined sewage system
θ Infiltration
θ Other:

Notification according to § 13 Para. 3 of the German Drinking Water Ordinance
- Utilisation of a process water plant -

6. Contact on site

_____
Surname, Name

_____
Address

_____
Postcode, City

_____
Phone / Fax

7. General

a) How many apartments are supplied with process water? _____ number

b) How many users are supplied with process water? _____ ca. number

c) What is the estimated amount of process water produced yearly? _____ ca. m^2

d) Did you conclude a maintenance contract? θ yes θ no

e) What is being supplied with process water?
θ Toilet
θ Washing machine
θ Garden irrigation
θ Others:

_____

8. Did you consider the following requirements?
a) Did you have the plant installed by a specialised company?
(if so, please enclose receipt)
θ yes θ no

b) Are pipes clearly colour-coded and the water taps labelled with the inscription
"Process Water – No Drinking Water "!
(§ 17 para. 2 TrinkwV 2001)
θ yes θ no

c) Is back-up water from drinking water provided exclusively by an open outlet?
θ yes θ no

d) Is a maintenance plan available?
θ yes θ no
(if so, please enclose receipt)

_____
Place, Date Signature

fbr
Fachvereinigung Betriebs- und Regenwassernutzung e.V.

What is fbr ?

fbr is a nation-wide professional association of people, companies, local authorities, offices, specialized trading companies and institutions interested or already actively involved in water recycling and rainwater utilization. The association is a registered non-profit-making organisation with headquarters in Darmstadt, Germany. fbr is a non governmental organisation.

Objective
fbr has set itself the objective of promoting water recycling and rainwater utilization and bringing together everyone activily involved and interested in this sector.

Purpose and responsibilities
The purpose of fbr is to promote water recycling and rainwater utilization, save drinking water and reduce sewage. Its responsibility lies in the creation of a provision against future contingencies, while at the same time taking into account all aspects of environmental protection, science and research. Within the association, members are active in work groups dealing with all topics water recycling and rainwater utilization.

Members
People, companies, local authorities, offices, specialist trade and institutions interested or already actively involved in the use of water recycling and rainwater utilization.

What are the advantages of membership?
- Representation of interests for water recycling and rainwater utilization
- Contacts and exchange of experience with experts actively involved in the use of service and rainwater
- Reduced rate for trade events, exhibitions and fairs
- Possibility of active participation in various work groups
- Access to consultants and experts
- Entry in members´ directory with company profile
- Subscription to „fbr-wasserspiegel“
- Subscription to fbr serial publications

Activities
Conferences, Members´ newspaper, fbr serial publications, Trade fair presentations, Work groups, Research aid, Representation of interests, Member counselling, Press work, Info data base, Saving drinking water, Technical Regulations, Water quality, Eco-balances, Rainwater management, Water recycling, Rainwater utilization

Contact:
Fachvereinigung Betriebs- und Regenwassernutzung e.V.(fbr),

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