Greywater Reuse: Concept, Benefits, Risks and Treatment Technologies

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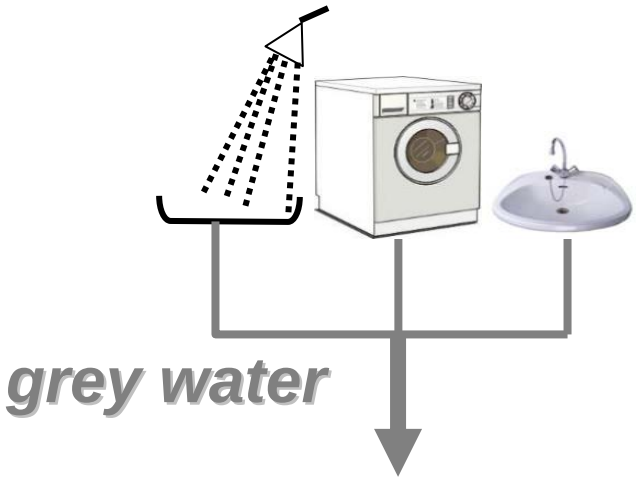
What is greywater?

Greywater is that part of domestic wastewater which is not passing toilets:



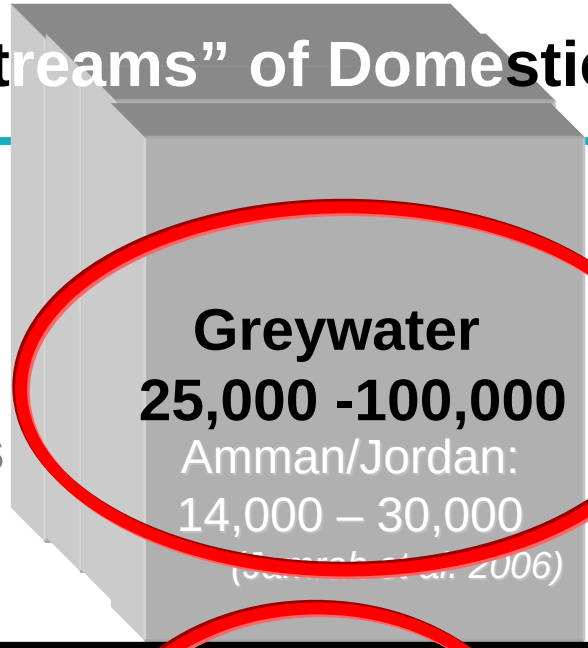
i.e. originating from

bath tubs
showers
hand-wash basins
washing machines
automatic dish washers
kitchen sinks
floor drains

Slightly different definition in Australia:

Sustainable Earth Technologies: “Some people also categorise kitchen wastewater as blackwater because it has quite a high organic loading relative to other sources of wastewater such as bathwater.”

The Three "Streams" of Domestic Wastewater



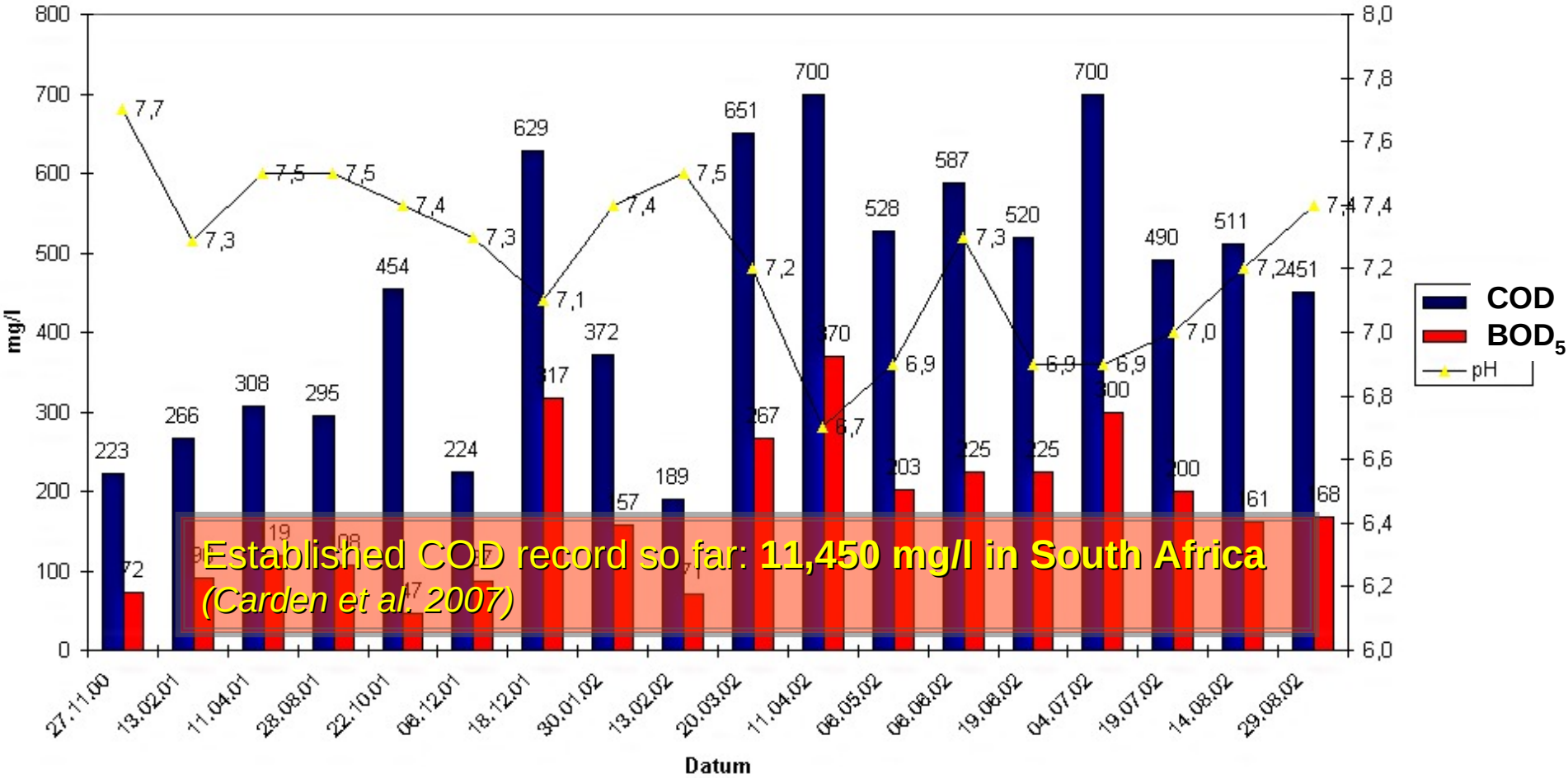
Volume flows
l/(P*year)

Specific mass flows
kg/(P*year)

		Greywater	Yellow Water	Brown Water
		25,000 -100,000 Amman/Jordan: 14,000 – 30,000 (Jamrah et al. 2006)	**500**	**~ 50**
N	~ 4-5	~ 3 %	~ 87 %	~ 10 %
P	~ 0.75	~ 10 %	~50 %	~ 40 %
K	~ 1.8	~ 34 %	~ 54 %	~ 12%
COD	~ 30	~ 41 %	~ 12 %	~ 47 %

MOST PATHOGENS!

Raw greywater of the eco-settlement Luebeck-Flintenbreite, Germany

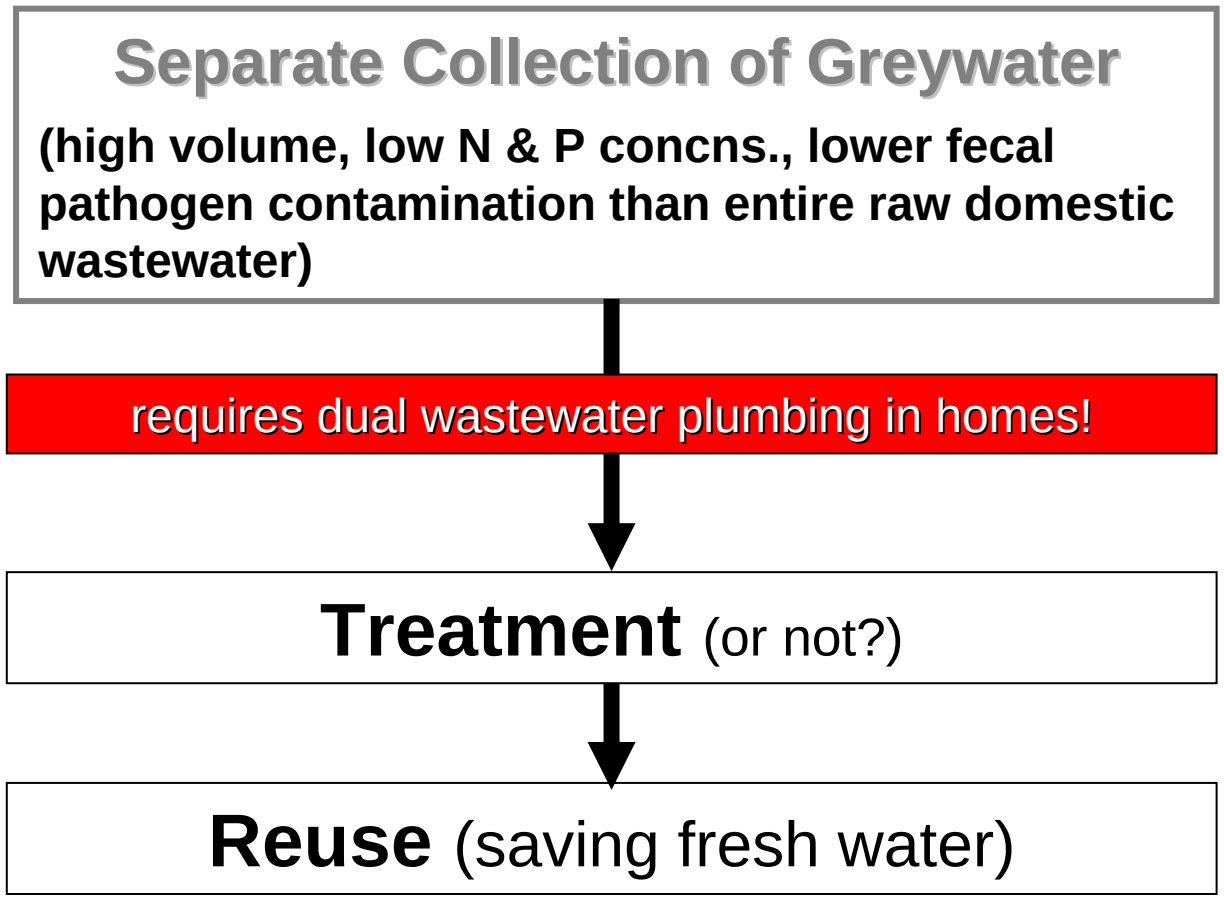


BOD_5 = 47 to 370 mg/l

COD = 189 to 700 mg/l

⇨ **high variation of organic concentrations**

Concepts


Separate Collection of Greywater
(high volume, low N & P concns., lower fecal pathogen contamination than entire raw domestic wastewater)
requires dual wastewater plumbing in homes!
Treatment (or not?)
Reuse (saving fresh water)

Concepts

On-site disposal no problem with < 500 l/(ha·d)
(Carden et al. 2007)

Separately Collected Greywater

or → Soil Aquifer Treatment

or → Without treatment (stabilisation): **rapid** reuse e.g. for direct application to the soil (if not too saline!) – **no storage!**

or → Septic Tank → Aerobic Biological Treatment (Low-tech or High-tech) → Storage

or → Anaerobic Biological Treatment (Biogas) → Aerobic Biological Treatment → Storage

Disinfection?

Storage → Further Treatment (RO, Solar Photocatalytic Oxidation…)

Reuse of Stabilised Greywater:
Gardening
Laundry?
Car-washing?
Fire Water
Toilet Flushing?
Groundwater Recharge?

Further Treatment → **High Quality Demand Reuse**

e.g. Millennium Dome, London/UK *(Birks et al. 2004)*

Potential Benefits of Greywater

Quantity:

Usually largest fraction of domestic wastewater

Quality:

Lowest N and P nutrient load among the particular domestic wastewater streams,
low microbiological load,
safe segregation of industrial wastewater.

High Reuse Potential:

⇨ If collected separately: Good source for reuse (after proper treatment) reducing fresh water demand

Study in southern Brazil: Potable water saving of 25 to 35 % by greywater use for toilet flushing, laundry and cleaning *(Ghisi & de Oliveira 2007, Ghisi & Ferreira 2007)*

Potential Benefits of Greywater

Reduced tap water demand offers a lot of secondary benefits:

- reducing water bills for individuals
- reducing competition of big cities with surrounding farmers for scarce water sources
- reducing tapped water demand reduces the release of the ozone-depleting gas chlorine (unless more chlorine is utilised for disinfection of reclaimed greywater)
- If greywater is an additional water source leading to increased supply of irrigation water, this can stimulate an increase in agricultural and forestal production.
- More trees and plants have benefits:
- They absorb carbon dioxide helping to mitigate global warming;
- trees provide shade and protection from the sun (reduction of skin cancer);
- trees increase evaporation and thus condensation of the evaporated moisture as clouds and finally lead to a greater chance of precipitation;
- leaves from the trees create soil organic matter;
- roots of trees increase permeability retaining water from storms and preventing runoff thus reducing soil erosion and increasing ground water recharge;
- plants generally enhance the asthetic value of an area.

Risks/problems

• ***Dual plumbing*** (for separate greywater collection) in large houses (mansions) may be costly.

• Because of ***high BOD concentrations***, microorganisms can grow in untreated greywater during storage

("Gastro-intestinal illness can be transmitted through improper use" *[Canterbury City Council]*)

However: "Despite all sorts of grievous misuse …, there has not been a single documented case of grey water transmitted illness in the US." *[oasis design]*

Droplets from greywater sprinklers can evaporate to leave harmful microorganisms in the air.

• Risk from ***viruses*** contained in greywater is the most prominent in a greywater reuse system without disinfection *[Ottosson & Stenstroem 2003]*

(high excretion, environmental persistence, low infectious doses of viruses).

• Acid-loving plants tend to have a hard time with greywater (because of eventually slightly alkaline pH and reasonable ***alkalinity***).

• Greywater is reasonably ***saline*** (depending on household chemicals applied): limitedly useful for crop irrigation (especially in irrigation systems with high evaporation rates).

Risks/problems

[oasis design]

http://www.oasisdesign.net/greywater/misinfo/

Grey water "main" running down a Tijuana street — a bona fide health threat. In theory, this water could produce fruit and green relief in a sanitary way. **Unfortunately, extremely high salt concentration from hand washing with small amounts of hand-carried water and generous amounts of "Fab one-Shot" from little day-glo packets renders this resource unusable**;
even though it is year-round water in a desert, not even weeds grow from it.

A enlightened soap factory with a line of biocompatible cleaners and a suitable marketing plan could dramatically transform the colonia environment, exchanging fetid, mucky streets for thriving, shade, and fruit-providing large trees.

Risks/problems

• Gross et al. (2005) found ***accumulation of salts*** in plots irrigated with raw greywater not more pronounced than in plots irrigated with fertilized freshwater.

• Detergents with high ***boron*** concentrations exert negative effects on soil properties when greywater is used for irrigation *(Gross et al. 2005)* – boron is phytotoxic!

(another reason for selecting detergents properly)

• Soils irrigated with raw greywater might become more hydrophobic due to ***surfactants*** –

(hydrophobic soils are not suitable for healthy plant growth) *(Gross et al. 2005)*

• Therefore: raw greywater is not suitable for unlimited irrigation *(Gross et al. 2005)*.

Risks/problems

- ***Groundwater/drinking water pollution*** – if soakaways or greywater drain fields are close to shallow groundwater tables and/or close to wells
- Clogging of U shaped tubes, perforations in irrigation tubes with ***suspended solids*** (unless removed by septic tank or sand filter) –

drip irrigation with non-stabilised greywater only works for a few weeks; then perforations are clogged due to microorganism growth.

- ***Trace organics*** are contained in greywater even subsequent to biological treatment.

However, recalcitrant chemicals are also found in surface waters and even in the atmosphere (some are associated with airborne dust particles).

- Treatment train fast filtration/***chlorination bears the risk of trihalomethane formation*** (carcinogenic)!
- Storage of untreated greywater leads to ***odours*** due to reasonable BOD.
- ***Aesthetic problem*** (e.g. when using treated greywater for toilet flushing): Biological treatment of greywater generates humic substances and leads to appearance of a slightly yellowish colour of the treated greywater.

Treatment Technologies

RBC economically more feasible than MBR
(Friedler & Hadari 2006)

Biological treatment: Anaerobic pre-treatment (bio-gas?)

Aerobic processes (MBR, SBR, RBC, BAF, constructed wetlands, ponds…)

[Slow sand filtration (1.2 – 1.5 m) is able to reduce adenovirus and coliphages by 99 – 99.9 %, but norovirus only by 91 % (Bauer, 2007)]

"Polishing" of biologically pre-treated greywater: Reverse osmosis

Distillation (also solar options like solar stills)

Removal of trace organics with "advanced oxidation processes", AOPs

(e.g. solar photocatalytic oxidation – kills also microorganisms)

Disinfection: Chlorination (if drinking water quality is required)

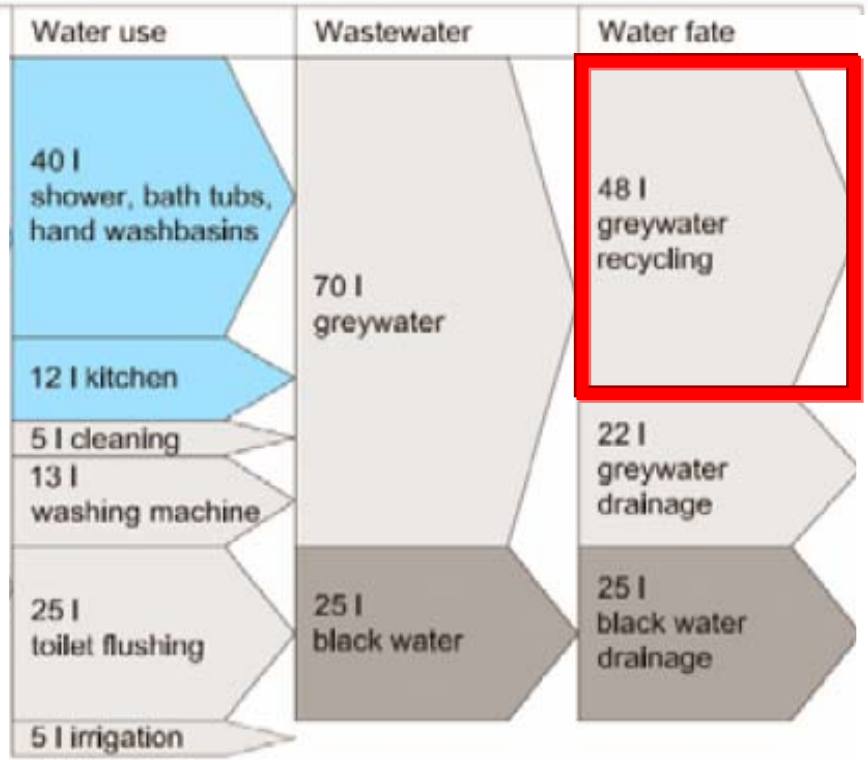
UV disinfection

AOPs

Less recommended technologies:

separation processes not able to stabilise greywater (e.g. fast filtration) with subsequent chlorination (AOX formation!)

Possible greywater reuse scheme (suggested by “DecRen Water Consult”):



Σ = 100 l

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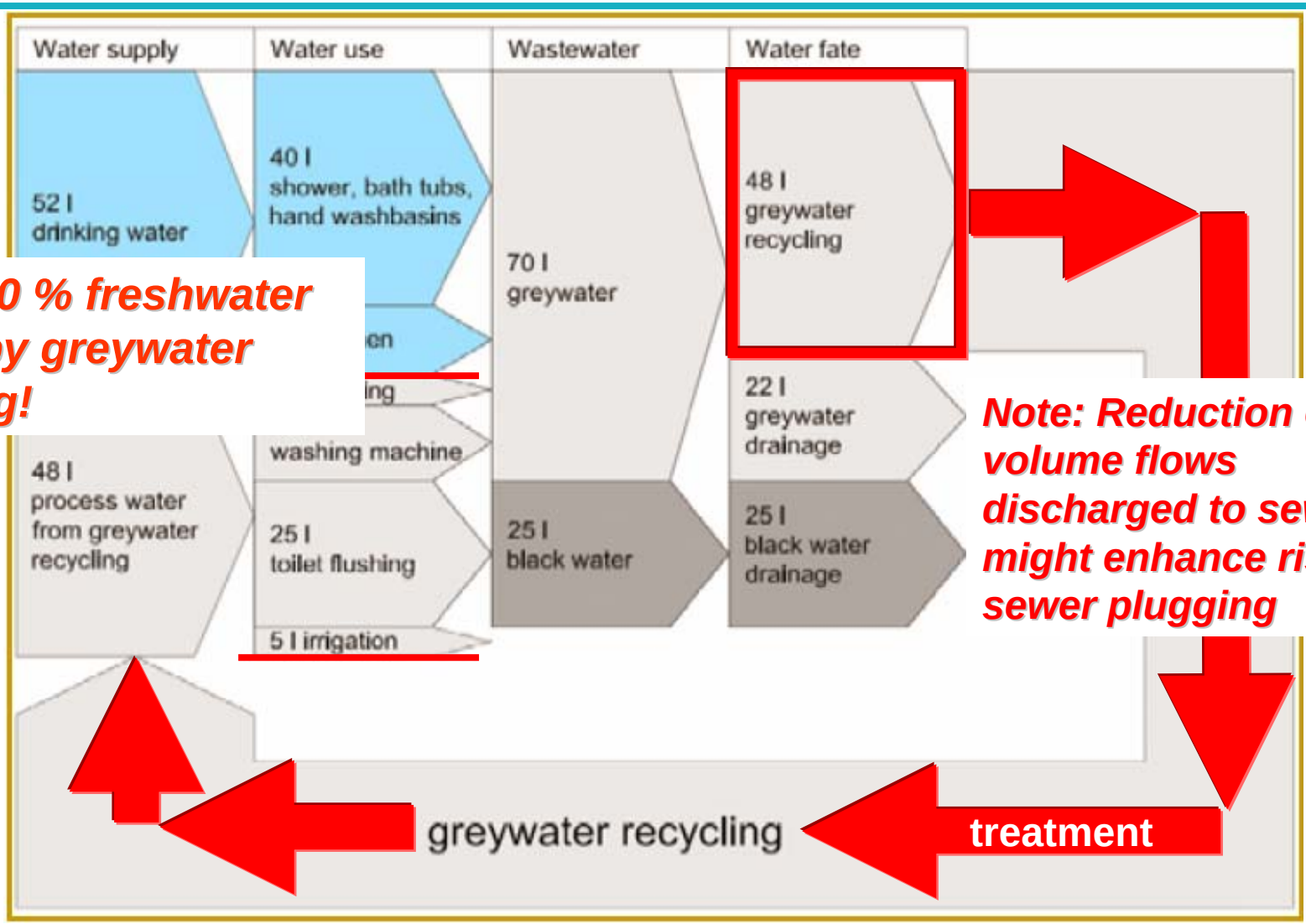

Nearly 50 % freshwater saving by greywater recycling!

Note: Reduction of volume flows discharged to sewers might enhance risk of sewer plugging


Thank you!
Constructed wetlands for greywater treatment at
the eco-settlement Luebeck/Flintenbreite, Germany