Greywater Re-Use for Flushing Toilets

Vanessa Delair, Rob Melk and Michael Elwell
Aliaxis Group

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Aliaxis: A global leader in fluid handling solutions

Turnover **~3 billion**

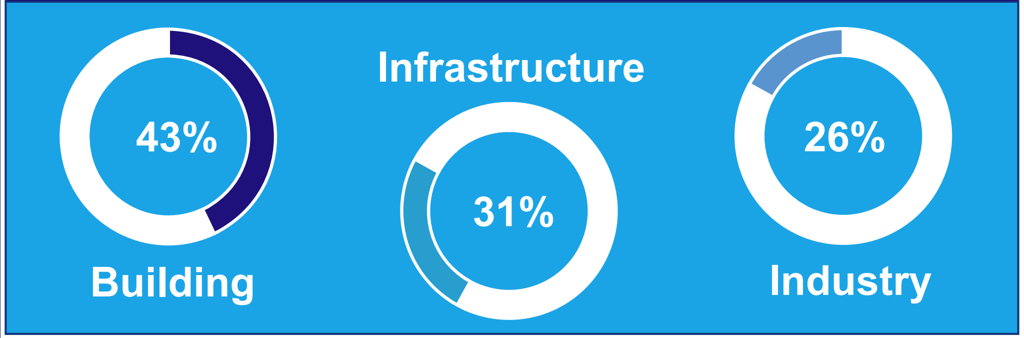
80+ manufacturing sites

120+ distribution centres

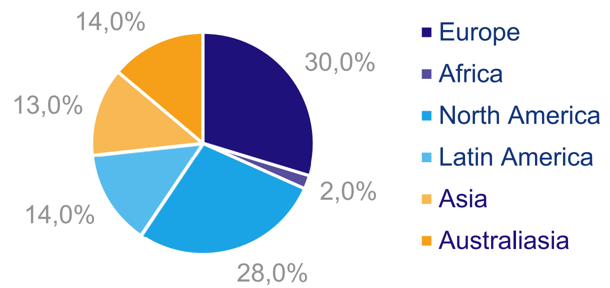
+16.000 colleagues

The company is privately-owned with headquarters based in **Belgium**, selling products worldwide.

Market Segment Split



Regional Turnover Split



We connect people with water and energy

Context and purpose

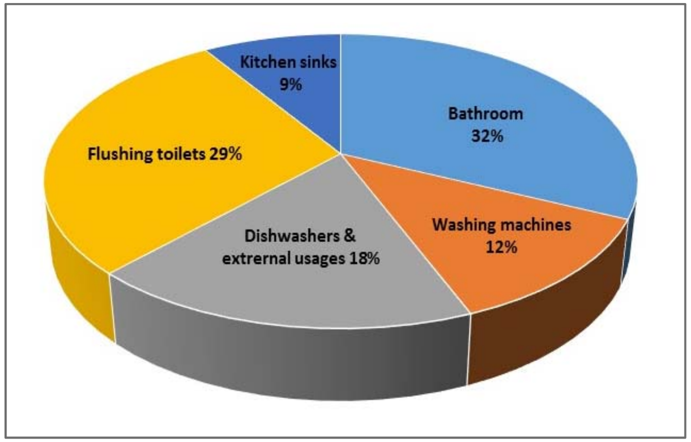
- Today, we have increasing demands for water by an expanding population

- In terms of consumed volume, the quantity of water we use for baths and showers is similar to that for toilet flushing (32% vs 29%)

- At the moment no standard exists in any country:
  - Only guidelines and guides of practices are in existence today

- The required quality of the water is dependent upon the target application

- Can we use greywater for flushing toilets without affecting human health?

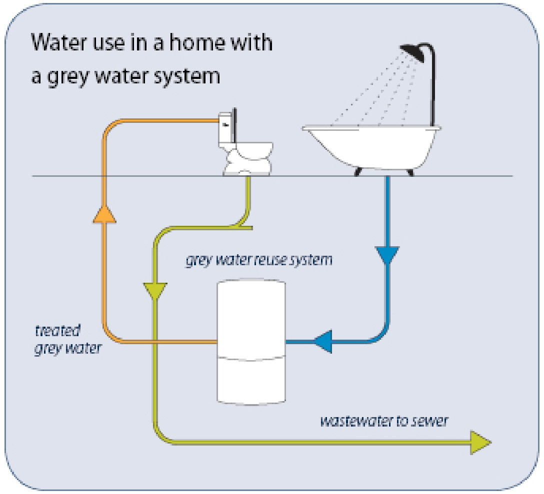


Average distribution of domestic water use for 7 countries (1)

(1) Lazarova, V., Hills, S., Birks, R.; Using recycled water for non-potable, urban uses: a review with particular reference to toilet flushing, 2003.

Greywater origins and composition

- Greywater can broadly be defined as wastewater generated in the house by bathroom sinks, baths and showers:
  - In some cases it can include laundry facilities, dishwashers and kitchen sinks
  - In most cases, only greywater from baths and showers are considered for re-use.
- For the end user, greywater can be *perceived* as “lightly” loaded in organic material and bacteria; however, reality is somewhat different:
  - For some parameters, values are in close proximity to the values for raw wastewater
  - The wide variation in composition lends support to the fact that one standard treatment process cannot fit with each case.



		Greywater		
		$\dot{x}$	min	max
Volume	$L.pers^{-1} j^{-1}$	**110,00**	**80,00**	**170,00**
pH		**7,37**	**6,06**	**8,93**
Cond	$\mu S.cm^{-1}$	**1471,00**	**116,00**	**2393,00**
Turb	NTU	**73,00**	**25,00**	**265,00**
SS	$mg.L^{-1}$	**331,00**	**45,00**	**838,00**
COD	$mg\ O2.L^{-1}$	**621,00**	**228,00**	**1898,00**
COD_D	$mg\ O2.L^{-1}$	**473,00**		**1071,00**
BOD5	$mg\ O2.L^{-1}$	**291,00**	**58,00**	**1049,00**
COD	mg C.L-1	**172,00**	**18,00**	**621,00**
TensAn	$mgSABM.L^{-1}$	**37,00**	**0,00**	**95,00**
Ctot	logUFC/100n	**7,10**	**1,80**	**8,70**
Cféc	logUFC/100n	**58,00**	**1,10**	**6,90**
EnCO	logUFC/100n	**3,30**	**0,80**	**5,60**

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Two case studies: aerobic and anaerobic processes

Case #1 : Aerobic process with short storage and basic disinfection	**Case #2:** Anaerobic process with re-circulation and strong chlorination
Detailed process: Skimming which involved short storage with air being supplied and a basic disinfection	***Detailed process:*** Primary filtration (100 microns), settlement, chlorination, storage with re-circulation and re-chlorination every 8 hours.

Test plan:

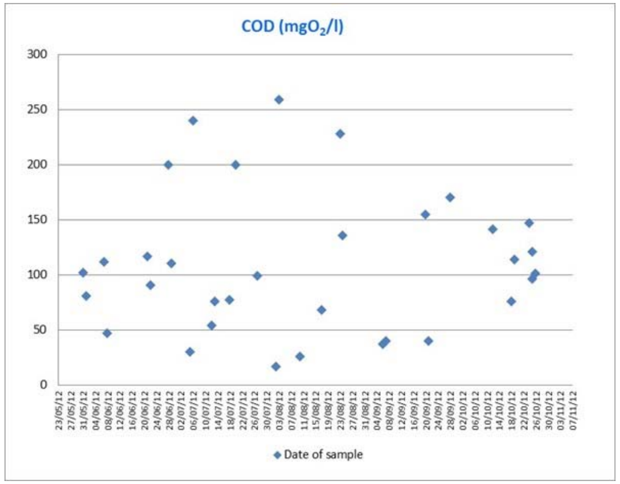
- Each device set up in a factory for testing under real conditions.
- 2 showers per day and flushing undertaken manually to try to reproduce what takes place in a house.
- Samples taken at the inlet meaning on raw greywater and in the toilet-pan of the system.
- Samples subjected to chemical and micro-biological analyses to assess the treatment performance and potential health issues of such a re-use.

Measured parameters	Frequency of measurement
Chemical parameters	
Suspended Solids (SS) (mg/l)	At every sampling
pH	At every sampling
Turbidity (NTU)	At every sampling
Dissolved Oxygen	Continuous measurement
COD and/or BOD_5 (mgO_2/l)	At every sampling
Greywater flow rate (volume of shower)	At every sampling
Fresh water flow rate	Sometimes
Nitrogenous (NTK, mgN/l)	At every sampling
Phosphorous (P, mg/l)	Sometimes
Microbiological parameters	
E. coli (CFU/100ml)	At every sampling
Faecal coliforms (CFU/100ml)	At every sampling
Enterococci (CFU/100ml)	At every sampling

Case-study #1:
Aerobic process + short storage + basic disinfection

Key results: chemical parameters

- A high dispersity in the results for each parameter (COD, BOD_5 and SS).
- No real improvement on the COD and BOD_5 results with the use of disinfectant
  - Treatment efficiency on COD is around 65%
  - Treatment efficiency on BOD_5 is around 76%
  - Treatment efficiency for SS is around 58%.
- Emergence of a biological treatment in the system:
  - simultaneous presence of dissolved oxygen supplied by the air blower
  - presence of active microorganisms and nutrients
  - It was not enough to reach low contents of organic material in the toilet pan.
- Biofilms appearing on the walls of the storage tank and some parts of the biofilm were sometimes washed.

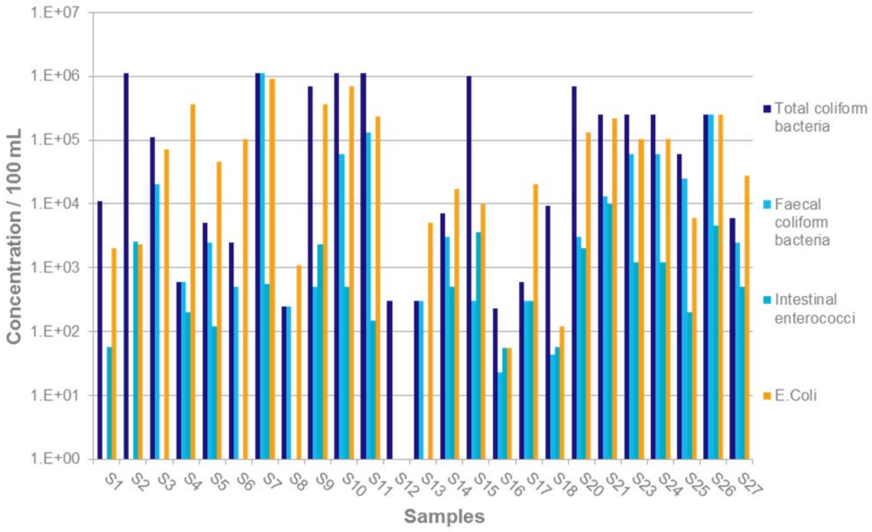


		Average content without disinfectant			Average content with disinfectant
Parameter	Unit	Average	Min	Max	Average
COD	(mgO_2/l)	109	17	258.8	112
BOD_5	(mgO_2/l)	38.2	2	96	21
Suspended Solids (SS)	(mg/l)	17.5	4	491	17
NTK	(mgN/l)	6.8	1.5	27.8	6.5
Turbidity	(NTU)	15	1	41	18
P	(mgP/l)	1.1	0.45	2.3	

Case-study #1:
Aerobic process + short storage + basic disinfection

Key results: micro-biological parameters

- A high dispersity in the results and high concentrations of bacteria in the samples.
- In each sample, a high quantity of pathogen microorganisms were observed
  - The average concentration for total coliforms was 105.5 CFU/100 ml
  - The average concentration for E.coli was 105 CFU/100 ml.
- Toilet pan was often dirty with particles inside and biofilms appeared on the walls of the storage tank of the system.
- The disinfection in place was not strong enough.



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Case-study #2:
Anaerobic process + re-circulation + strong chlorination

Key results: chemical parameters

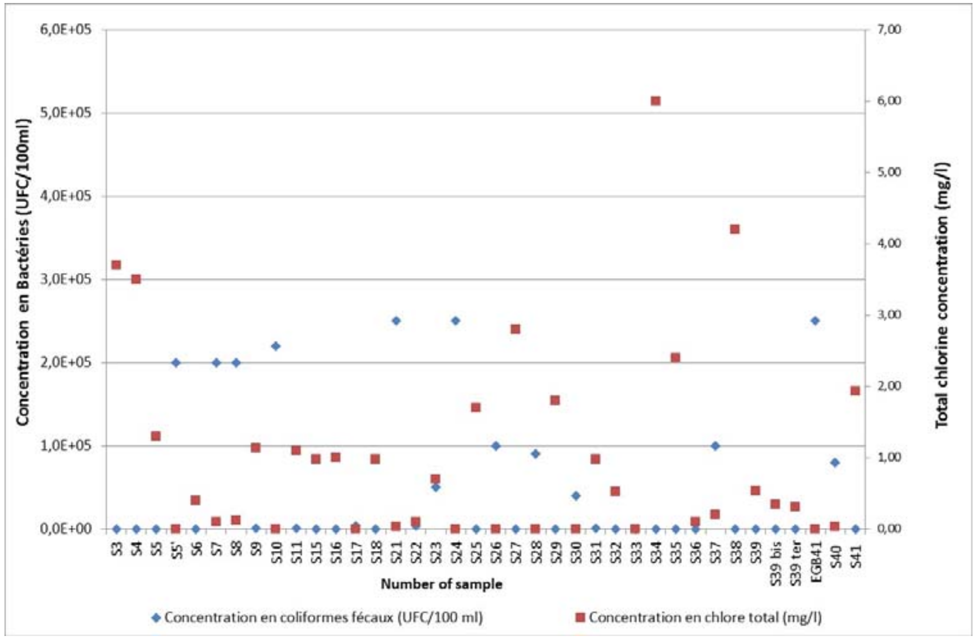
- Quite a high dispersity in the results.
- Removal of organic material within this system due to:
  - the filter
  - settlement in the tank
  - injection of chlorine.
- Time of storage had no influence on the chemical quality of the treated water.
- The results obtained for the chemical parameters in Case #2 suggest an improvement vs Case #1.

Parameter	Average	Min	Max
$[COD]_{outlet}$ (mgO_2/l)	136.7	62	447
$[BOD_5]_{outlet}$ (mgO_2/l)	29.5	2	52
$[SS]_{outlet}$ (mg/l)	11,9	3,5	30
$[Turb]_{outlet}$ (NTU)	23,2	2	49
$[NTK]_{outlet}$ (mgN/l)	7,9	3	25

Case-study #2:
Anaerobic process + re-circulation + strong chlorination

Key results: micro-biological parameters

- Close relationship existing between residual total chlorine and faecal bacteria concentration.
- When total chlorine concentration > 0.5 ppm no faecal coliforms were detected in the samples.
- Important to have enough total chlorine to avoid the revivification of bacteria.
- Homogenization of the chlorinated greywater is a key factor to have good performance
  - When greywater is not well mixed it separates as different layers in the tank
  - Different contents of organic material, chlorine and bacteria disturb the chemical treatment process.



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Case-study #2:
Anaerobic process + re-circulation + strong chlorination

Results on secondary parameters:

- In addition to the chemical and micro-biological parameters reported, secondary parameters were also recorded to evaluate the global behaviour of the system:
    - electrical consumption
    - cleanness of the toilet pan based on colour change
    - odour emission
    - failure frequency.

- The toilet pan was separated from the global system of re-use, meaning that they worked independently.

- Although the contamination process was well managed (correct level of chlorine) some biofilm development was observed in the toilet cistern.

Visual appearance of the interior of the toilet cistern after 6 months of use

Appearance of traces of corrosion

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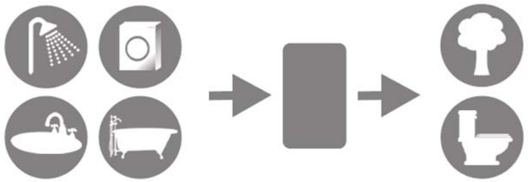
Conclusions: challenges of greywater re-use



Key insights from the two case-studies:

- In comparing the two processes the storage stage was observed to be the weak point.
- Although time for storage was different, a biological treatment resulted in the generation of primary sludges and activated sludge.
- Small biofilms appeared on the walls of the storage tanks increasing the set-up of a biological treatment, leading to the generation of unpleasant odours and foams.
- The re-use of greywater for flushing toilets without generating health issues for the end-user appears to be less straightforward than expected.

Connect with us on www.aliaxis.com

Head Office
Av. Arnaud Fraiteur 15-23
1050 Brussels
Belgium

Australasia
26 College Street - Darlinghurst NSW 2010
PO Box 747 - Darlinghurst NSW 1300
Australia

North America
1425 North Service Road East, Unit 3
Oakville – Ontario
L6H 1A7
Canada

Latin America
Oficentro Sigma
Edificio B, 2º Piso
San Pedro, San Jose
Costa Rica

Europe, Middle East, Africa (EMEA)
Av. Arnaud Fraiteur 15-23
1050 Brussels
Belgium

Asia
15A Tuas Ave 18, 03-01
Singapore 638905

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