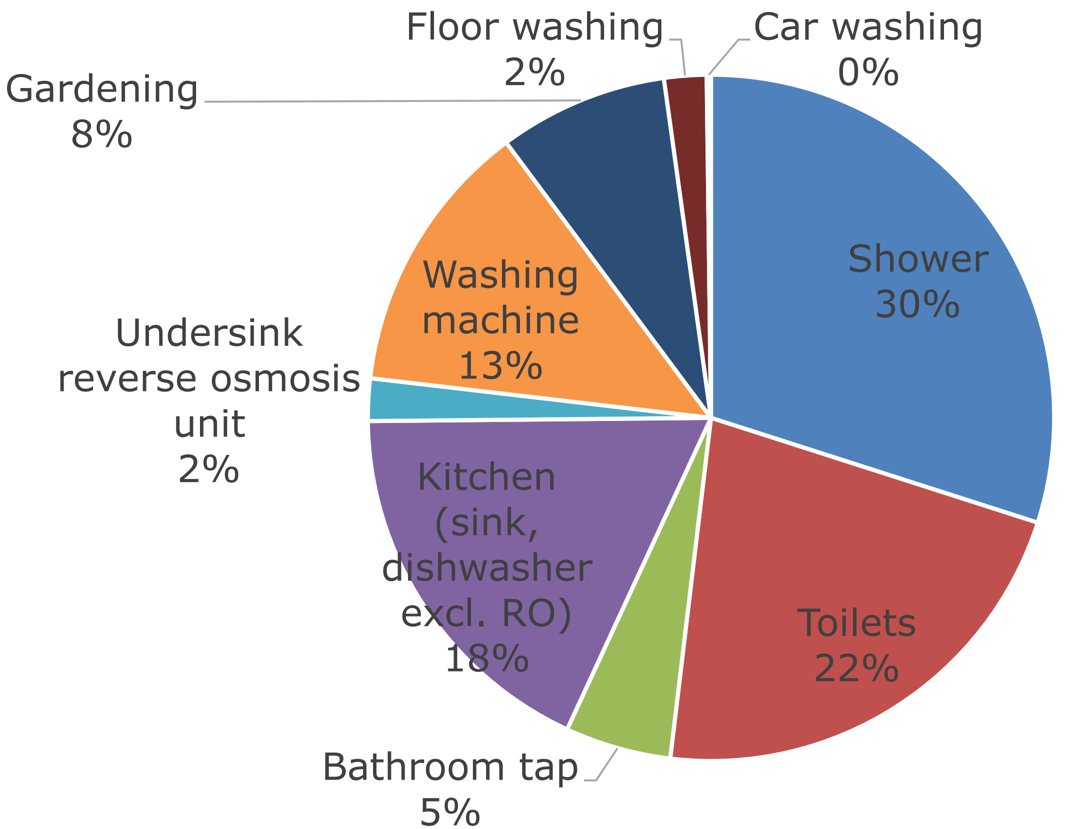
Greywater recycling technologies

Capacity Building Workshop on 'Non-Conventional Water Resources Management: Local Solutions'
14th November, 2019 - MCAST

Alter-Aqua III
Non-Conventional Water Resources – Programme in the Mediterranean

Maltese Household (Average) Water Consumption



Notes:
EWA (2014)
Water audits of 32 households in Malta and Gozo
Average household size of 3.5 persons
Metered average water consumption of 75 litres / capita / day

Maltese Hotel (Average) Water Consumption

Hotel	Wash-hand basins	Showers	Toilets	% of total consumption
5 star	4.90%	27.72%	13.26%	45.88%
4 star	7.55%	44.76%	16.38%	68.69%
3 star	9.43%	45.06%	22.01%	76.50%
Totals	**7.23%**	**42.12%**	**16.75%**	**66.10%**

Source: *MBB (2013) The hotel industry – a shift to greener and lower cost operations. EU LIFE+ Investing in Water Project. Malta Business Bureau.*

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Definition of greywater

"Wastewater from bathing and washing facilities that does not contain concentrated human waste (i.e. flush water from toilets) or food waste (i.e. kitchen sink, food waste grinders). Examples include bath and shower water, hand wash water, and laundry washwater. Greywater typically contains high concentration of salts and minerals from detergents and soaps."

Source: Metcalf & Eddy (2007)

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Greywater reuse

- The reuse of bathing and washing water for non-potable applications (landscape irrigation, toilet flushing and washwater)

Greywater Reuse Applications

- Decentralised solutions at different scales
  - Single household: micro-systems
  - Tenement/multi-occupancy housing
  - Hotels/Tourist Accommodation/Residential homes
- New-build / Retrofit

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Dual-Plumbing Systems

- **Dual-piping systems**: A system of water supply consisting of dual separate mains (pipelines from separate sources) and designed to concurrently provide two separate water supplies to the consumer. One main conveys drinking (potable) water, the other conveys appropriately treated non-drinking water
- **Cross-connection**: any connection or arrangement physical or otherwise, between any potable water supply systems either directly or indirectly connected to a water main, and any fixture, storage tank, receptacle, equipment or device through which it may be possible for any non-potable, used, unclean, polluted or contaminated water, or any other substance to enter any part of such potable water system under any condition.

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Greywater composition

Parameter	Mean	Range	SD	Parameter	Mean	Range	SD
pH	7.24	6.4–10	0.37	SO_4^{-2} (mg-SO_4/l)	157	0.5–72	146
TSS (mg/l)	52	2–1070	28	TAN (mg-N/l)	3.46	1–75	3.27
VSS (mg/l)	45	6–413	22	NO_3^- (mg-N/l)	1.21	0.1–17	1.48
Turbidity (NTU)	28	20–279	19	NO_2^- (mg-N/l)	4.9	0.04–0.4	7.2
COD (mg-O_2/l)	174	7–2570	30	TN (mg/l)	10.5	0.1–128	7.5
TOC (mg-C/l)	27	73–93	7.7	Faecal coliforms (cfu/100 ml)	3.0×10^5	2×10^2–6×10^6	3.8×10^5
Cationic surfactants (mg/l)	0.64	NA	0.30	Heterotrophic plate count (cfu/ml)	8.8×10^6	8×10^6–3×10^7	7.9×10^6
Anionic surfactants (mg_{MBAS}/l)	2.87	1.4–56	2.20	*P.aeruginosa* (cfu/100 ml)	3.0×10^4	3×10^3–3×10^4	3.9×10^4
PO_4^{-3} (mg-PO_4/l)	1.9	0.1–49	1.0	*S. aureus* (cfu/100 ml)	1.2×10^4	2×10^3–1×10^4	1.8×0^4

Source: Summary of WQ range reported in literature as given by Alfiya *et al.* (2012)

To watch out for in greywater source:

- Chemicals may be toxic to treatment organisms or irrigated plants
- Removal of salts not typically included in small GyW treatment applications – source control
- E.g. disinfectants, fabric softeners, chemotherapy medications, high amounts of oils and grease, brine (high recovery RO or regeneration of water softeners).

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Public Perceptions to Greywater Reuse

- A good percentage of people recycle domestic water included using air conditioner, dehumidifier and washing machine waste water for watering plants or for flushing toilets.
- A small minority of older local expressed a distrust in terms of hygiene
- Those already informally using grey water (irrespective of age) expressed a positive attitude to extending this use by modifying plumbing and fixtures accordingly; they demonstrated a positive attitude to using this recycled water for any domestic use except drinking, showering, laundry and cooking;
- Awareness of what the recycling will entail, and the quality of water produced, is poor among local participants – this clearly limited their willingness to consider using such water for washing
- Participants who expressed a willingness to carry out modifications in their homes to introduce domestic water recycling strongly stated that they would expect financial incentives to do so – in this context they referred to incentive schemes linked with solar panels or solar water heaters in the past. They clearly stated that without these incentives there was little chance that households would make the necessary changes of their own accord.
- Foreign participants were particularly irritated by the limitations imposed by the fact that they lived in rented accommodation and as such could not exert full control on their choices. One younger respondent stated that "it would be my appeal to the government to ensure that properties that are for rent are equipped with the necessary infrastructure to enhance water efficiency."

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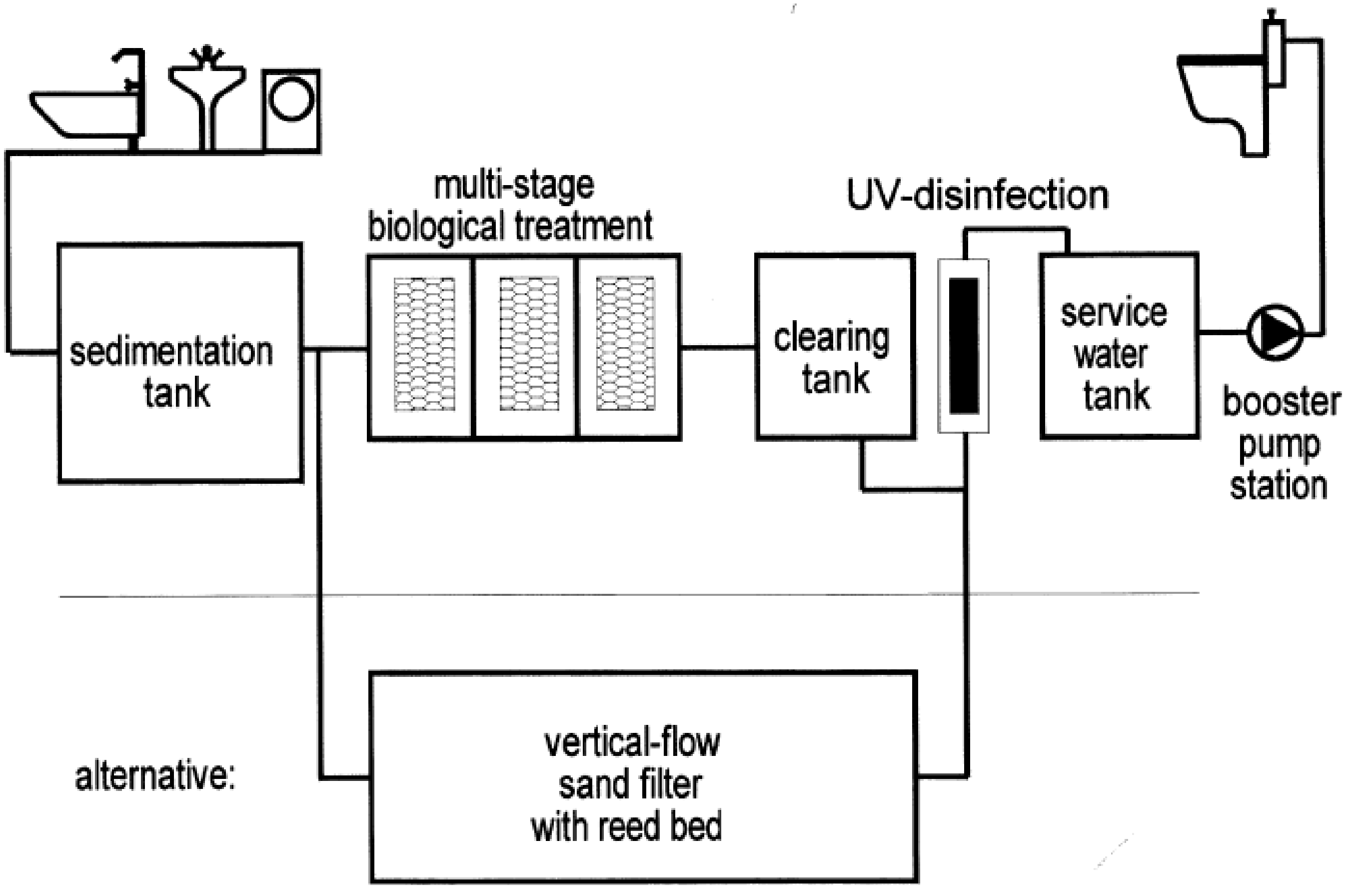
Greywater Treatment

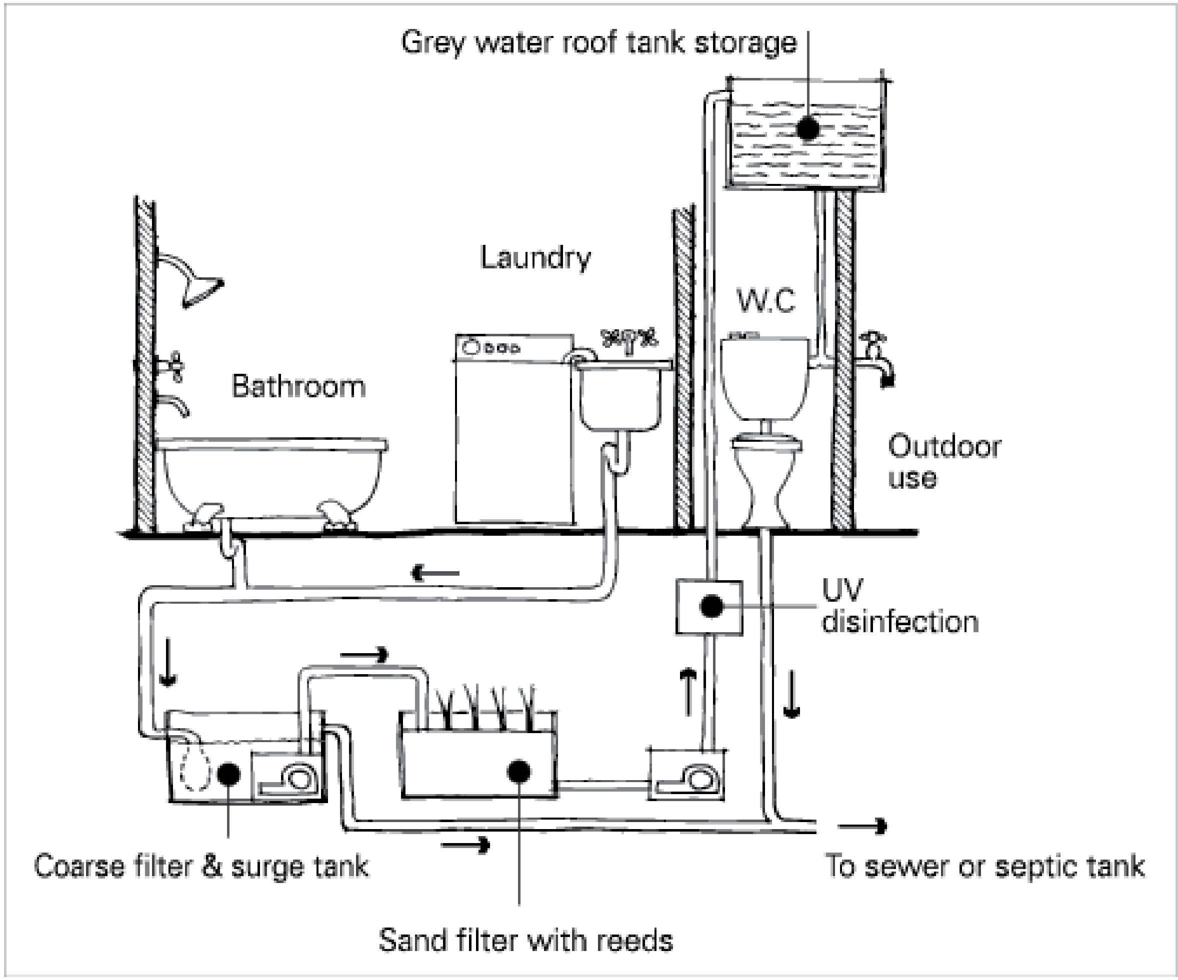
- Challenges/Requirements:
  - Provide the required level of treatment (meet effluent standards)
  - High variability in flowrate and concentration
    - Peaking factor (Household) = 6 (Range 4 – 10)
    - Peaking factor (Hotel) = 7.5 (Range 6 – 10)
  - Site specific limitations
  - Economic constraints (from water tariff and no WW tariff)
  - (Ideally) little to no maintenance
  - Easy to operate
  - Storage time of effluent water

Greywater Treatment - Components



Source: *Nolde* (1999)

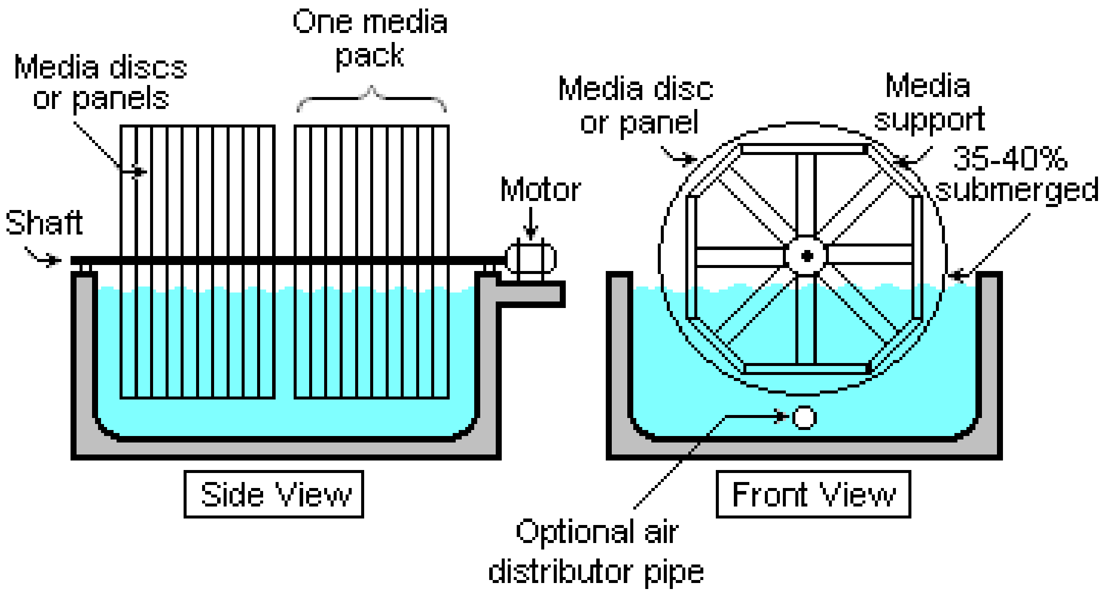
Greywater Treatment



Source: YourHome, Australian Guidelines for Environmentally Sustainable Homes
http://www.yourhome.gov.au/water/wastewater-reuse

Greywater Treatment - Biological

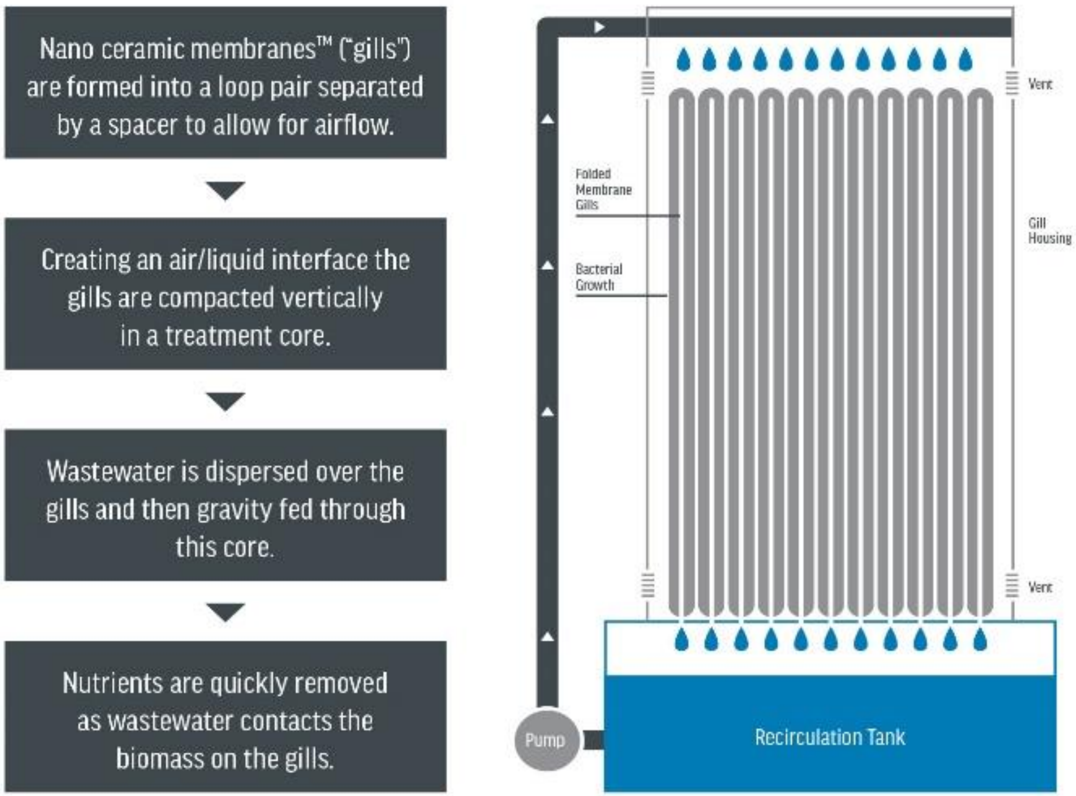
- Rotating Biological Filter



Source: *Wikipedia*

Greywater treatment - Biological

Non-submerged synthetic media biofilter



Source: *Biogill.com*

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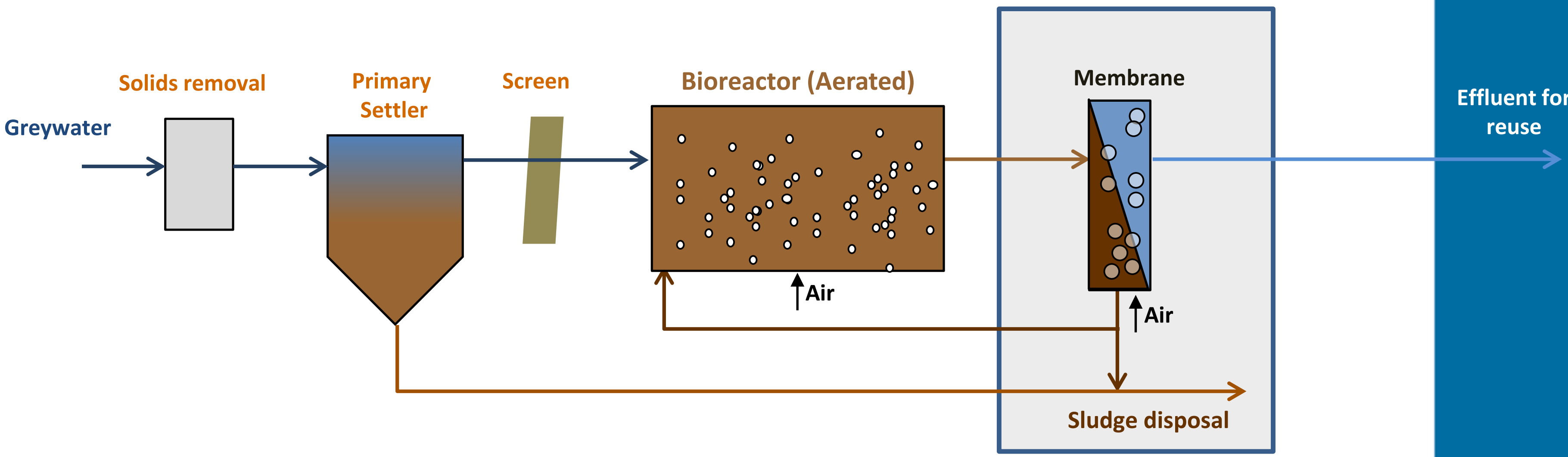
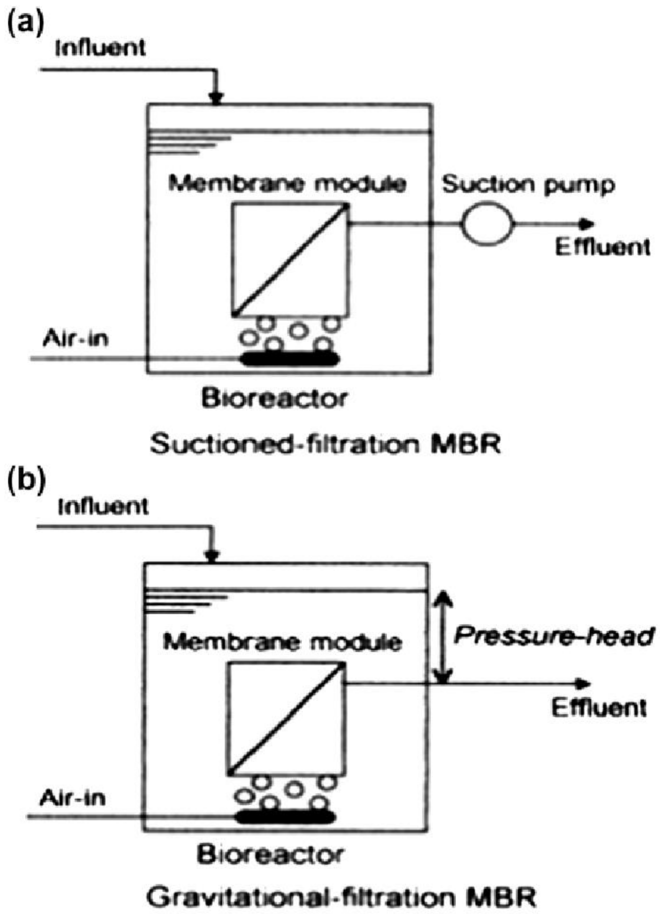
Greywater treatment - Biological

Membrane Bioreactor (MBR)



Greywater treatment - Biological

Gravity Driven Membrane Bioreactor (MBR)



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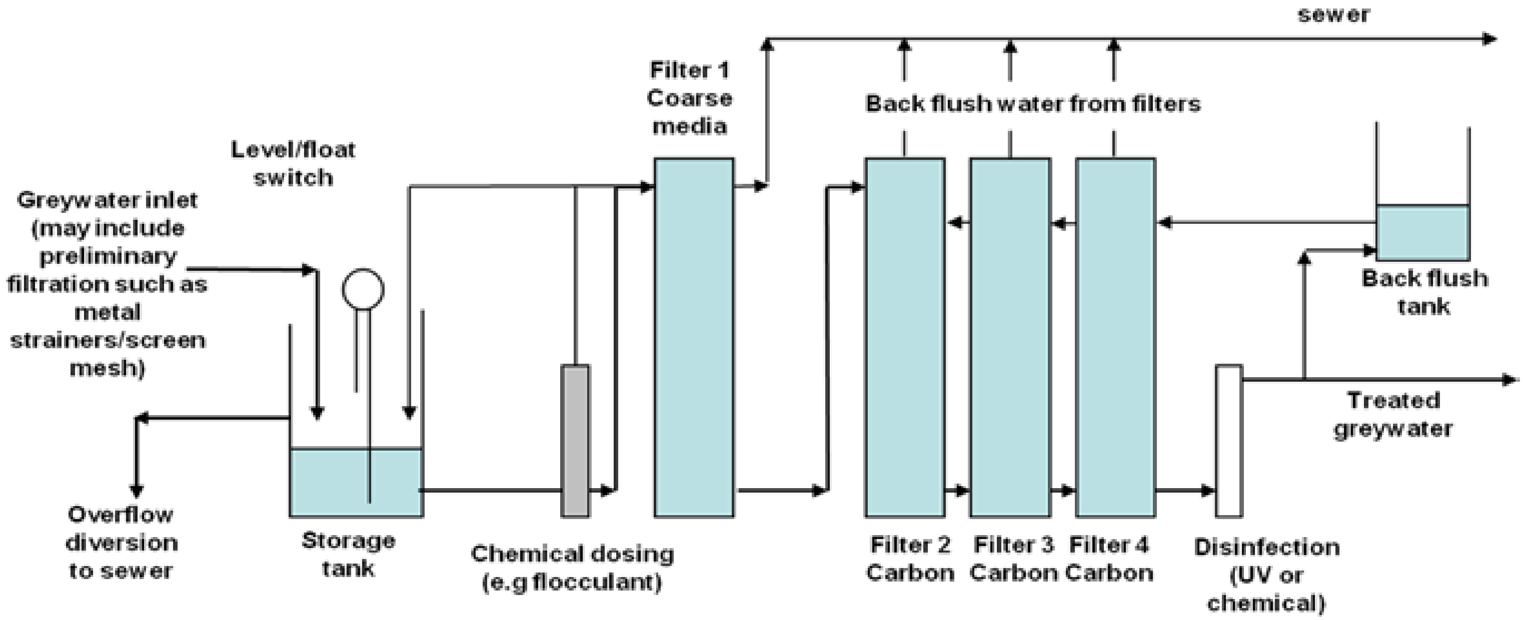
Greywater treatment - Chemical

Chemical-based greywater treatment technology



Source: *Toifl et al. (2019)*

Greywater Reuse Systems in Malta

- Domestic systems
  - 'Home-made' systems

- Hotels for toilet flushing
  - MBR (x1)
  - High-rate sand filtration (+ coagulant) and chlorination (x2)
  - "Recycled greywater is a very cheap source of water, estimated at €0.40 per m3. Costs for equipment start at around €60,000 with a repayment period of around 3 year." – MBB Investing in Water
- Alteraqua Greywater Systems
  - MCAST, IAS
  - Helen Keller resource centre

Global Water Partnership Mediterranean

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Guidelines for Greywater Treatment

Country/ Organization	Water origin	Parameters and threshold values[a] for water quality criteria depending on the end-use						References
		Toilet flushing	Cold water supply for clothes washing	Car washing	Surface irrigation	Sub-surface irrigation	Garden watering	
WHO (Guideline)	Greywater[b]	$BOD_5 \leq 10$		$BOD_5 \leq 10$				WHO (2006)
		$TSS \leq 10$		$TSS \leq 10$				
		FC ≤ *10*		*FC* ≤ *10*				
US-EPA (Guideline)	Domestic wastewater	pH: 6–9		pH: 6–9				USEPA (2004)
		$BOD_5 \leq 10$		$BOD_5 \leq 10$				
		Turbidity ≤ 2		Turbidity ≤ 2				
		FC: ND		*FC: ND*				
		Res. Cl ≥ 1		Res. Cl ≥ 1				
Australia – ACT (Guideline)	Greywater[b]	$BOD_5 \leq 20$	$BOD_5 \leq 20$	$BOD_5 \leq 20$		$BOD_5 \leq 20$		ACT Heath (2007)
		SS ≤ 30	SS ≤ 30	SS ≤ 30		SS ≤ 30		
		FC ≤ *10*	*FC* ≤ *10*	*FC* ≤ *10*				
Australia – NSW (Guideline)	Greywater	$BOD_5 \leq 10$[c]	$BOD_5 \leq 10$[c]		$BOD_5 \leq 20$[c]	$BOD_5 \leq 20$[c]		NSW Health (2005)
		SS ≤ 10[c]	SS ≤ 10[c]		SS ≤ 30[c]	SS ≤ 30[c]		
		FC ≤ *10*[c]	*FC* ≤ *10*[c]		*FC* ≤ *30*[c]			
		0.5 < Res. Cl < 2.0	0.5 < Res. Cl < 2.0		0.2 < Res. Cl < 2.0			
Australia – VIC (Guideline)	Greywater[b]	$BOD_5 \leq 10$	$BOD_5 \leq 10$		$BOD_5 \leq 20$	$BOD_5 \leq 20$	$BOD_5 \leq 20$	EPA Victoria (2013)
		SS ≤ 10	SS ≤ 10	Prohibited	SS ≤ 30	SS ≤ 30	SS ≤ 30	
		E. coli ≤ *10*	*E. coli* ≤ *10*		*E. coli* ≤ *10*	*E. coli* ≤ *10*	*E. coli* ≤ *10*	

Source: *Toifl et al. (2019)*

Guidelines for Greywater Treatment

		Parameters and threshold values[a] for water quality criteria depending on the end-use						
Country/ Organization	Water origin	Toilet flushing	Cold water supply for clothes washing	Car washing	Surface irrigation	Sub-surface irrigation	Garden watering	References
United Kingdom (Guideline)	Greywater[b]	pH: 5–9.5 Turbidity < 10 Res. Cl < 2 Res. Br < 5 *E. coli* < 25 *Int. enterococci* < 10	pH: 5–9.5 Turbidity < 10 Res. Cl < 2 Res. Br < 5 *E. coli: ND* *Int. enterococci: ND*	pH: 5–9.5 Turbidity < 10 Res. Cl < 2 Res. Br: 0.0 *E. coli: ND* *Int. enterococci: ND*	pH: 5–9.5 Turbidity < 10 Res. Cl < 2 Res. Br: 0.0 *E. coli: ND* *Int. enterococci: ND*		pH: 5–9.5 Turbidity: N/A Res. Cl < 0.5 Res. Br: 0.0 *E. coli* < 25 *Int. enterococci* < 10	BSI (2011)
Germany (Guideline)	Greywater[b]	$BOD_7 < 5$ O_2 sat. > 50% *TC* < 10^4 *FC* < 10^3 *P.aeruginosa* < 10^2	$BOD_7 < 5$ O_2 sat. > 50% *TC* < 10^4 *FC* < 10^3 *P.aeruginosa* < 10^2		Class 1 (unrestricted area) *F. streptococci: ND* *E. Coli: ND* *Salmonella: ND/1 L* *Intestinal nematodes Taenia: ND/1 L*		Class 1 (unrestricted area) *F. streptococci: ND* *E. Coli: ND* *Salmonella: ND/1 L* *Intestinal nematodes, Taenia: ND/1 L*	fbr (2005)
Spain (Regulation)	Municipal wastewater	TSS ≤ 10 Turbidity ≤ 2 *E. Coli: 0* *Intestinal nematodes ≤ 1 egg/10 L*					TSS ≤ 10 Turbidity ≤ 2 *E. Coli: 0* *Intestinal nematodes ≤ 1 egg/10 L*	Ministerio de la Presidencia (2007)

Source: *Toifl et al. (2019)*

Technology Assessment

1. Risk assessment and risk management
2. Life cycle thinking
   - Life Cycle Assessment (LCA)
   - Life Cycle Costing (LCC)
   - Social Life Cycle Assessment (S-LCA)

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Risk Assessment Tools

Quantitative microbial risk assessment (QMRA)

Source: *WHO* (2016)

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Risk Assessment Tools
Quantitative microbial risk assessment (QMRA)

Step 2
Possible exposure scenarios for greywater applications

Frequency (events/year)	Quantity	Exposure scenario
1	100 ml	Accidental ingestion of greywater
90	1 ml	Routine indirect ingestion from touching plants and lawns
90	0.1 ml	Ingestion of greywater sprays from irrigation
According to the number of working days in the garden	10–100 mg	Ingestion of soil contaminated with greywater
7 for lettuce; 50 for other produce	0.36–10.8 mL/100 g; 5 mL per serve of lettuce; 1 mL for other produce	Eating a home-grown plant that was exposed to greywater

Exposure scenarios are based on: NRMMC (2006); Haas *et al.* (1999) and Shuval *et al.* (1997).

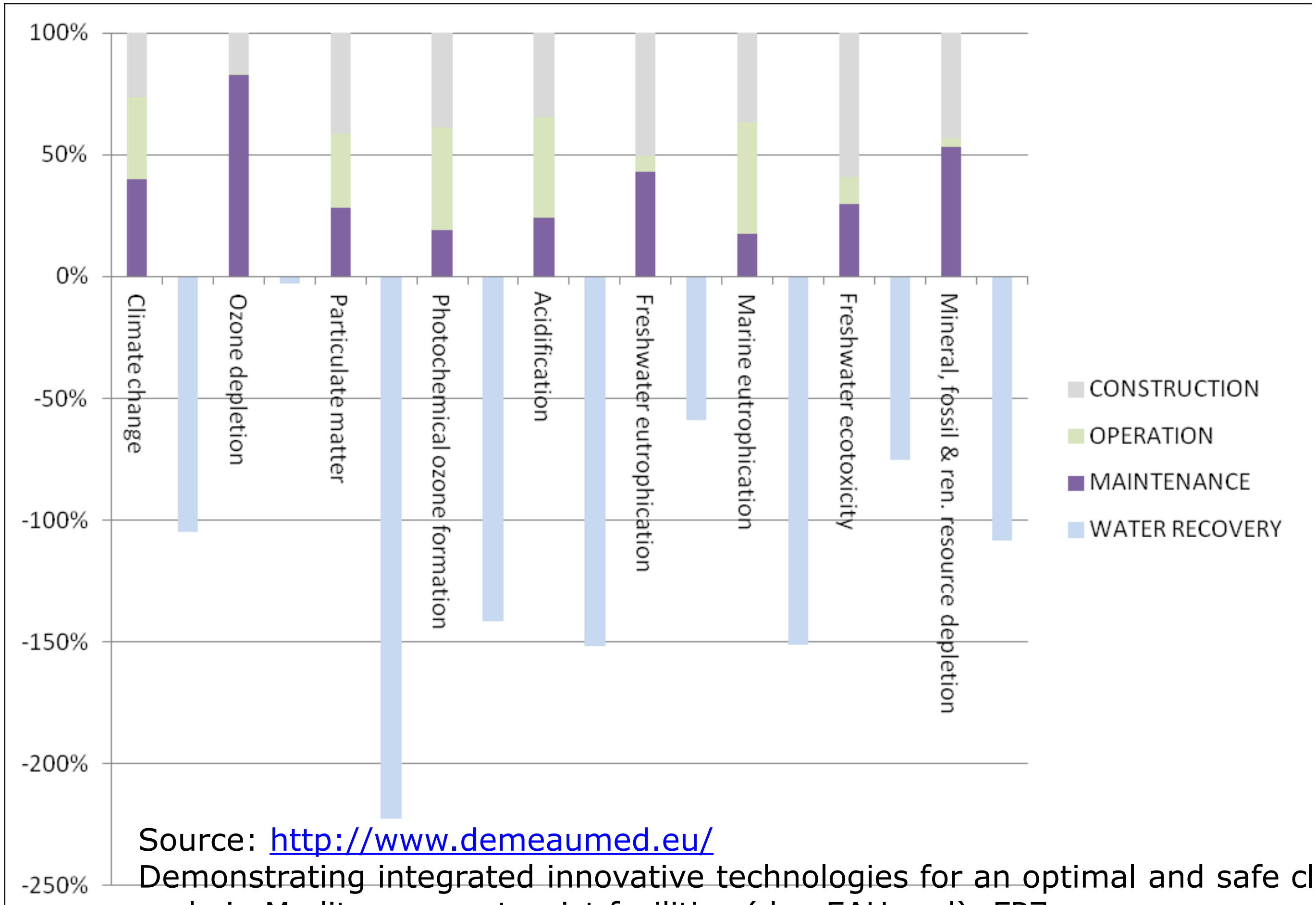
Step 4
Estimating the magnitude of risk in comparison to existing health targets, or to risks deemed ‘acceptable

Source	Rotavirus (organisms/ml)	Max dose (ml)
WHO (2006)	0.01–0.1	0.24–0.024
Ottoson and Stenstrom (2003)	0.17	0.014
NRMMC (2006)	0.8	0.003

Source: *Friedler* & Gross (2019)

Life Cycle Analysis

Environmental impact contributions of Electrochemical Ozonation technology and environmental savings of recovery and reuse greywater by using Electrochemical Ozonation process.



Source: http://www.demeaumed.eu/
Demonstrating integrated innovative technologies for an optimal and safe closed water cycle in Mediterranean tourist facilities (demEAUmed), FP7

Conclusions

- Feasibility of decentralised solutions for different scales
- Variability of GW quality and flow
- Retrofit or new build
- Operation and maintenance
- Standardized testing procedures
- Technology assessment tools

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References

- *Friedler, E. and Gross, A. (2019)* 'Greywater Reuse: Risk identification, quantification and management', in Memon, F.A. and Ward, S. (eds.) Alternative Water Supply Systems. IWA Publishing, pp. 193-216.
- Metcalf & Eddy (2007) Water Reuse : issues, technologies, and applications. McGraw-Hill Books.
- Nolde, E. (2000). *Greywater reuse systems for toilet flushing in multi-storey buildings – over ten years experience in Berlin.* Urban Water, 1(4), 275–284.
- *Toifl, M., Bulteau, G., Diaper, C. and O'Halloran, R. (2019)* 'Greywater recycling: Guidelines for safe adoption', in Memon, F.A. and Ward, S. (eds.) Alternative Water Supply Systems. IWA Publishing, pp. 217-240.

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Thank you for your Attention

Any questions?

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