IS GRAY-WATER REUSE READY FOR PRIME TIME?

A STUDY OF GRAY-WATER TECHNOLOGIES

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OVERVIEW

As a water conservation leader, Kohler is predisposed to support emerging technologies such as residential gray-water reuse. Kohler is also committed to sustainability without sacrificing the bold product design that ensures end users' experience with KOHLER plumbing products is uncompromised.

What is "gray water"?
The study defines gray water as untreated water that comes from a shower (or bathtub).

The study refers to gray water that has been processed by a reuse system as "treated gray water." This descriptive terminology is widely accepted in the industry.

The term "non-potable" water is also frequently used to describe treated gray water.

Kohler engineers purchased and installed a technological cross-section of residential gray-water treatment systems in a high-use, real world setting: the men's locker room at a Kohler manufacturing facility.

Each of the four systems treated shower water for use in flushing a group of two or three representative gravity-flush "contractor grade" KOHLER toilets. Each of the four groupings closely simulated an active household.

Over a one-year period, the team operated and maintained each system, measured water quality, surveyed users' experience, monitored toilet function and calculated costs.

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SYSTEM ONE
FILTRATION & CHLORINATION
$2,600 (hardware, without installation)

The most simple and straightforward of the systems is similar to the process used in a swimming pool.

PROCESS	Chlorination
FILTER	Yes
UV TREATMENT	No

Consumables
Homeowner adds/changes

CHEMICALS	Yes chlorine added monthly
FILTER	Yes
UV BULB	Not applicable

TANK(S)	Single

Single tank systems
Gray water influent and treated gray water mixed

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SYSTEM TWO

ADVANCED OXIDATION (H_2O_2 + UV)

$4,500 (hardware only, without installation)

Hydrogen peroxide is injected into the water, then water is subjected to ultraviolet radiation — a UV light.

PROCESS	Hydrogen peroxide injection
FILTER	Yes
UV TREATMENT	Yes

Consumables
Homeowner adds/changes

CHEMICALS	Yes
FILTER	Yes
UV BULB	Yes

TANK(S)	Single

Single tank systems
Gray water influent and treated gray water mixed

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SYSTEM THREE

MEMBRANE BIO-REACTOR (MBR)

$7,500 (hardware only, without installation)

Oxygen is bubbled into water to stimulate bacteria growth; the bacteria then consumes pollutants. Water is then filtered through a class of filters known as “ultrafiltration.” The water is actually drawn through a membrane that is fine enough to filter out bacteria, cysts and most viruses. Water is then exposed to UV light radiation.

In the water treatment world, this process is relatively new but is well understood and has been widely adopted.

PROCESS	Bio-Reactor
FILTER	Yes
UV TREATMENT	Yes

Consumables
Homeowner adds/changes

CHEMICALS	No
FILTER	Yes
UV BULB	Yes

Filter life
measured in years

TANK(S)	Multiple

Multiple tank systems
Gray water influent and treated gray water separated

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SYSTEM FOUR

BIOLOGICAL WITH MEDIA FILTER

$8,950 (hardware only, without installation)

Like MBR, oxygen is bubbled into water to stimulate bacteria growth; the bacteria then consumes pollutants. In this process, the water is pushed through a media filter consisting of sand and granulated carbon. Water is then exposed to UV light radiation.

PROCESS	Biological
FILTER	Yes
UV TREATMENT	Yes

Consumables
Homeowner adds/changes

CHEMICALS	No
FILTER	Yes
UV BULB	Yes

TANK(S)	Multiple

Filter life
estimated at one to two years

Multiple tank systems
Gray water influent and treated gray water separated

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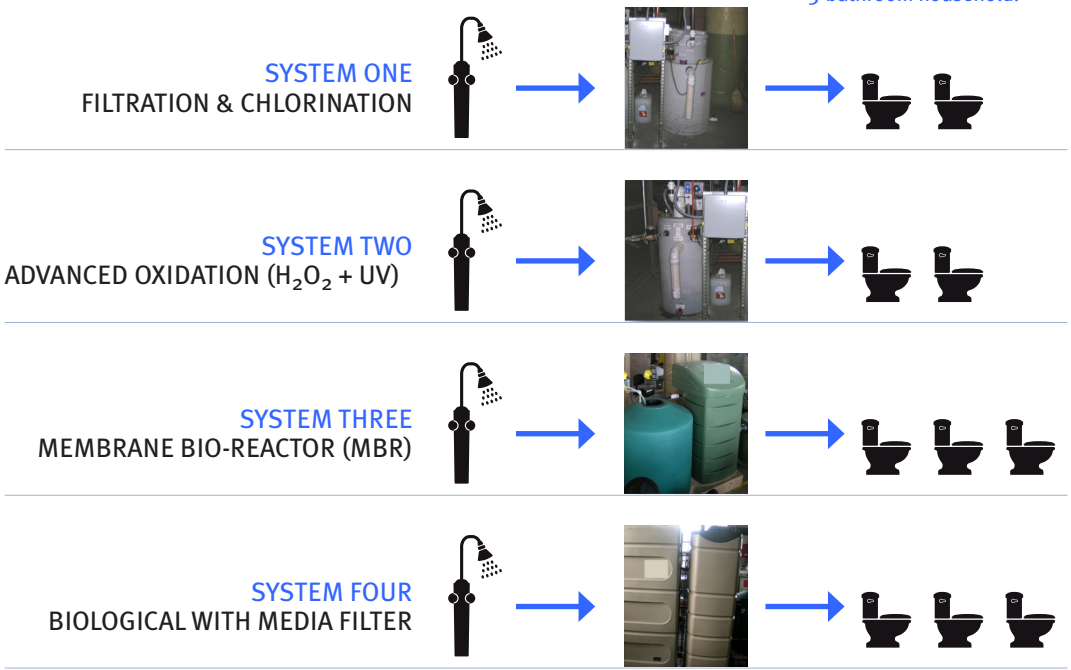
PLUMBING SYSTEM LAYOUT

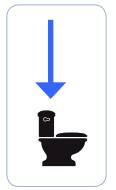
A Kohler plumber retrofitted the existing system in the men's locker room. Workers were not told that a gray-water reuse system had been installed.

All supply line plumbing between the water treatment systems and the toilets was new. Over 43,000 gallons of water was processed and delivered to 10 toilets in the first year.

Each of the four groupings simulated an active 2- or 3-bathroom household.



CONTROL
SHEBOYGAN CITY WATER



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WATER QUALITY RESULTS

Over the course of the one-year study, the team tested both influent gray water (from the showers) and the treated gray water outflow from each of the treatment systems.

The results below for clarity, biology and chemistry are average values over one year.

	CLARITY		BIOLOGY		CHEMISTRY		
	TSS Total Suspended Solids	TURBIDITY	$CBOD_5$ 5-Day Oxygen	COLIFORM E. Coli	pH	FREE CHLORINE	
NSF 350 STANDARD For Onsite Residential and Commercial Water Reuse Treatment Systems	‹10 mg/L	‹5 NTU	‹10 mg/L	‹14 col/100ml	6.5–8.5	0.5–2.5 mg/L	
SHOWER WATER INFLUENT	38	62.3	51.6	1203	7.4	NT	
SYSTEM ONE FILTRATION & CHLORINATION	10.6	5.6	16.4	8.2	7.4	0.5	SYSTEM DID NOT MEET NSF 350
SYSTEM TWO ADVANCED OXIDATION (H_2O_2 + UV)	10.2	8.3	13.3	‹1.0	7.5	NT	SYSTEM DID NOT MEET NSF 350
SYSTEM THREE MEMBRANE BIO-REACTOR (MBR)	‹1.0	0.2	‹4.3	‹1.0	7.8	‹1.0	SYSTEM PASSED MOST NSF 350 Does not inject chlorine.
SYSTEM FOUR BIOLOGICAL WITH MEDIA FILTER	‹1.2	0.5	‹2.4	‹1.0	7.6	‹1.0	SYSTEM PASSED MOST NSF 350 Does not inject chlorine.

GREEN: passed NSF 350 RED: failed NSF 350 NT: not tested

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IMPACT OF GRAY WATER ON TOILET TANKS

The quality of the treated gray water was evident on the valves and the walls of the toilet tanks.

	WATER QUALITY/ USER COMPLAINTS
CONTROL CITY WATER	Good visual water quality. No user complaints.
SYSTEM ONE FILTRATION & CHLORINATION	Tank walls black when chlorine level was low. Complaints about odor.
SYSTEM TWO ADVANCED OXIDATION (H_2O_2 + UV)	Slimy appearing water in toilet bowls.
SYSTEM THREE MEMBRANE BIO-REACTOR (MBR)	Good visual water quality. No user complaints.
SYSTEM FOUR BIOLOGICAL WITH MEDIA FILTER	Good visual water quality. No user complaints.

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IMPACT OF GRAY WATER ON FLAPPERS

The toilet flappers fed gray water by three systems — plus the control toilet — experienced a normal anticipated amount of shrinkage. Flappers are designed to continue to function properly despite shrinkage that falls within the expected range.

However, the flappers in toilets fed by System Two (Advanced Oxidation) exhibited extreme shrinkage — about 6% — as well as deformation and a loss in elasticity.

CONTROL

SYSTEM TWO
ADVANCED OXIDATION (H_2O_2 + UV)

NORMAL
The flapper in the control toilet after the one-year study.

ABNORMAL
Flapper shrinkage, deformation and stiffening.

Flapper beginning to fall into flush valve. Sticking compromised function.

Visual inspection strongly suggests significant leakage and water waste.

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CONCERNS AND CAUTIONARY NOTES

As much as Kohler encourages the exploration of gray-water systems, the findings after a study of just one year may give some buyers pause.

	INSTALLATION	OPERATION/ MAINTENANCE	ISSUES	REPAIRS
SYSTEM ONE FILTRATION & CHLORINATION	Plug leaks attributed to shipping damage. This system did not travel well.	No feedback on chemical consumption. Chlorine tablets added by hand.	Great variability in water quality in relation to air temperature. Chlorine oxidized system controller. Not functional after one year.	
SYSTEM TWO ADVANCED OXIDATION (H_2O_2 + UV)	Plug leaks attributed to shipping damage. This system did not travel well.	No feedback on chemical consumption. Extremely high usage of H2O2. Required purchase of 55-gallon drum of hydrogen peroxide.	Flappers stiffening and shrinking at highest rate of all systems.	Flapper replacement imminent. Burst fill valve.
SYSTEM THREE MEMBRANE BIO-REACTOR (MBR)		System operated well after setup. Weeks to grow desirable bacteria.	Air pump runs constantly but quietly.	Gel-like substance plugging toilet fill valves.
SYSTEM FOUR BIOLOGICAL WITH MEDIA FILTER	Plug leaks attributed to shipping damage. This system did not travel well.	System operated fairly well after fussy setup. Weeks to grow desirable bacteria. Change of media messy and smelly.	Frequent red light and buzzer warnings. Cryptic messages on small LED screen. System shutdowns.	Gel-like substance plugging toilet fill valves.
ALL SYSTEMS	All systems were a challenging retrofit in the study setting. No difficulties anticipated with a standard installation in a new building.	Toilets do not function during electrical outage. Outages can require system restart intervention.	Even in a heavy-use locker room environment, the anticipated toilet repair rate would be much lower — perhaps as low as zero in any given year.	8 out of 10 toilets required repairs during the one-year study.

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SUMMARY OF OPERATION COSTS

The average cost of residential water/sewer in the U.S.: $0.010/gal*

The only treatment system with operating costs less than the average cost of water is System Three: Membrane Bio-Reactor, when operated at full capacity.

No other system offers potential for payback.

	EQUIPMENT COST Excluding Installation	TOTAL WATER PROCESSED Gallons	CHEMICALS CONSUMED	MAINTENANCE Excluding Toilet Repairs	CONTINUOUS POWER DRAW $/Year @$0.11/kwh	COST PER GALLON Treated Gray Water	COST PER GALLON At Capacity
SYSTEM ONE FILTRATION & CHLORINATION	$2,600	14,828	$30	$120 filters	$0	$0.011	$0.011
SYSTEM TWO ADVANCED OXIDATION (H_2O_2 + UV)	$4,500	13,254	$305 hydrogen peroxide	$50 UV bulb	$49	$0.031	$0.025
SYSTEM THREE MEMBRANE BIO-REACTOR (MBR)	$7,500	11,422	$0	$50** UV bulb	$121	$0.016	$0.004
SYSTEM FOUR BIOLOGICAL WITH MEDIA FILTER	$8,950	9,669	$0	$580 UV bulb + maintenance contract	$98	$0.071	$0.013
					Does not include power to pump water.	Calculated at the volume of water used. Includes cost of pumping.	Assumed capacity is 150 gal/day (stated for MBR and Bio systems) for 365 days (54,750 gal).

* Source: Global Water Intelligence, Vol. 11, Issue 9 (Sept. 2010). Based on residential usage of 15 m^3/month

** Does not include cost of eventual membrane replacement

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EXPANDED KOHLER TOILET WARRANTY

Kohler will maintain the applicable product warranty on KOHLER toilets, urinals and associated flush valves if the below water quality conditions are met when treated gray water is used.

Acceptable water quality for Kohler to maintain the warranty is as follows:

TURBIDITY	‹5 NTU
Total Suspended Solids TSS	‹10 mg/L
CONDUCTIVITY	‹1000 uS/cm
Coliform E. COLI	‹14 MPN/100 ml Geometric Mean
DISINFECTION	‹4.0 mg/L free Cl
5-Day Oxygen BOD_5	‹10 mg/L
pH	6.0 – 9.0
PETROCHEMICALS	0 mg/L

Kohler acceptable water quality requirements are modeled on the NSF 350 Standard for "Onsite Residential and Commercial Water Reuse Treatment Systems."

SYSTEM ONE
FILTRATION & CHLORINATION
DID NOT MEET THESE REQUIREMENTS

SYSTEM TWO
ADVANCED OXIDATION (H_2O_2 + UV)
DID NOT MEET THESE REQUIREMENTS

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EXECUTIVE SUMMARY

After installing and maintaining four commercially available residential gray-water treatment systems in a real world environment for one year, Kohler engineers found user acceptance to be generally good, with toilet usage unchanged.

However, water quality was mixed, ranging from good to poor. Each of the four treatment systems presented a wide range of operational and repair issues.

Only one of the four systems had the potential to treat water at a cost below the average cost for water, and none of the systems generated a payback.

Kohler has expanded its toilet warranty policy to include gray-water reuse that meets specific levels of water quality.

THE FUTURE OF WATER REUSE

While none of the systems tested is without issues, residential gray-water technology is evolving rapidly.

Kohler anticipates that the reuse of shower water to flush toilets will become viable and cost-effective in the foreseeable future.

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