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Investigation of Residential Water Reuse Technologies

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Agenda

- Grey water technology study setup
- Water quality results
- Impact on toilets
- User experiences and costs
- Summary of findings

Overview of the Study

Objective: Learn about the operation of residential grey water systems and their impact on toilets

- Four different residential grey water treatment systems were tested over the period of 1 year.
- Each system treated shower water for use in flushing toilets (2 or 3 toilets per system).
- Gravity-flush toilets with industry standard parts were used.
- All systems operated in a manufacturing building at Kohler Co. in Wisconsin.
- Over 43,000 gallons of water were processed and delivered to 10 toilets.

Technologies Studied

Four systems were selected that represent a cross-section of technologies currently available for residential grey water treatment.

① $2,600

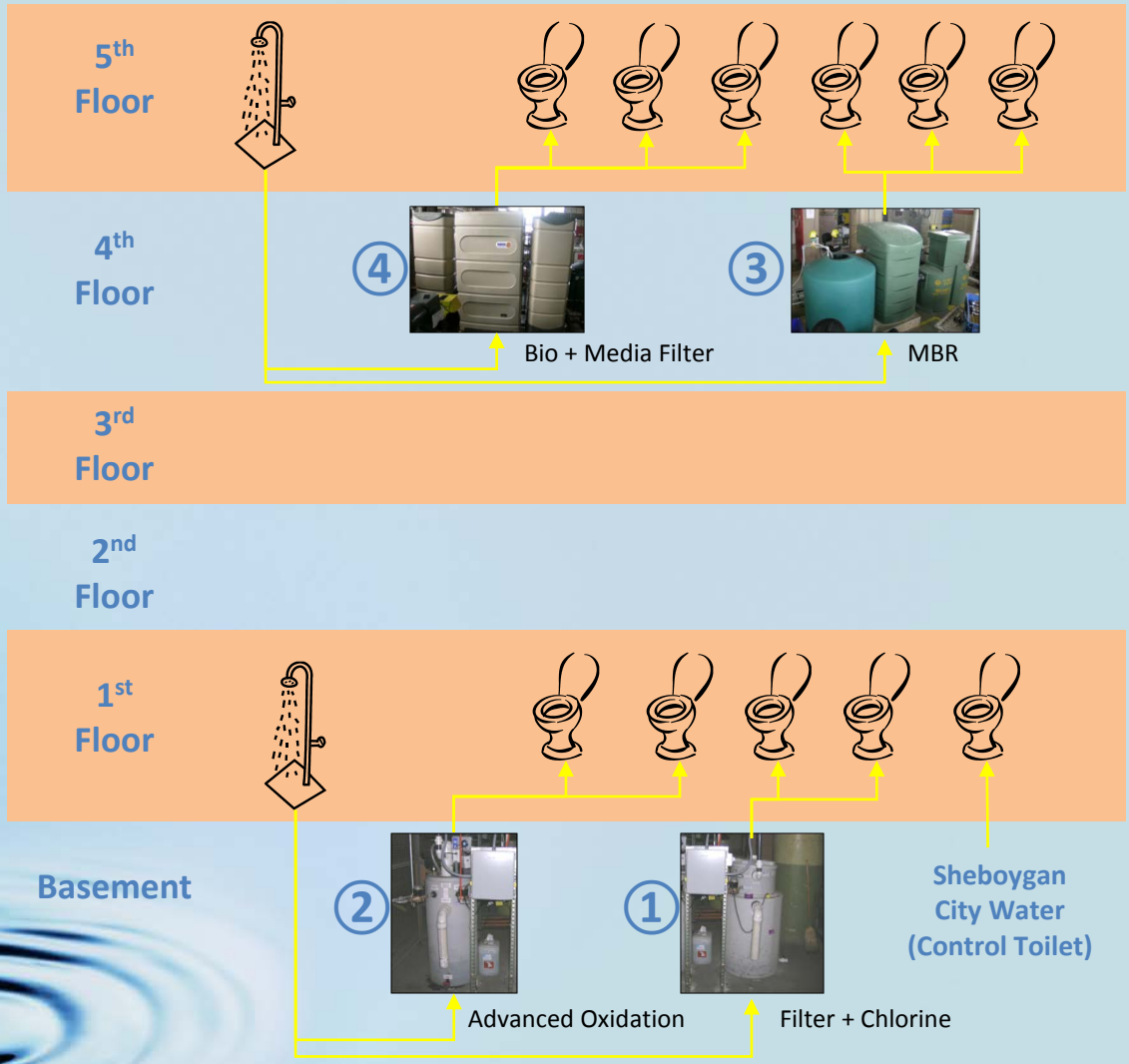
② $4,500

③ $7,500

④ $8,950

1. Filtration and chlorination
2. Advanced oxidation (H_2O_2 + UV)
3. Membrane Bio-Reactor (MBR)
4. Biological with media filter

Plumbing System Layout



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Water Quality Results – In and Out

	Shower Water Influent	Filter + Chlorine ①	Advanced Oxidation ②	MBR ③	Bio + Media Filter ④	NSF 350	Units
$CBOD_5$	51.6	16.4	13.3	<4.3	<2.4	<10	mg/L
TSS	38	10.6	10.2	<1.0	<1.2	<10	mg/L
Turbidity	62.3	5.6	8.3	0.2	0.5	<5	NTU
Coliform (E. Coli)	1203	8.2	<1	<1	<1	<14*	Col/100 ml
pH	7.4	7.4	7.5	7.8	7.6	6.5-8.5	-
Free Cl	NT	0.5	NT	<0.1	<0.1	0.5-2.5	mg/L

Average values over 1 year of testing

Pass	Fail

** Residential standard*
NT = Not Tested

NSF 350 is a standard for "Onsite Residential and Commercial Water Reuse Treatment Systems"

Impact of Grey Water on Toilet Tanks

	Control	Filter + Chlorine ①	Advanced Oxidation ②	MBR ③	Bio + Media Filter ④
18 Days					
60 Days					
90 Days					
1 Year					

Water quality and the impact on tanks and valves varies widely.

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Impact of Grey Water on Flappers

- Flappers on all toilets in this study exhibit various deteriorations after 1 year.
  - Stiffening of the elastomer.
  - Geometric shrinkage and deformation – ready to fall through hole.
- Wasting – not saving – water when leaking.

Toilet flappers after 1 year

Control Toilet

Advanced Oxidation (System ②)

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Kohler Toilet Warranty

- Kohler Co. will maintain the applicable product warranty on Kohler toilets, urinals, and associated flush valves if the below water quality conditions are met when non-potable water is used.
- Acceptable water quality for Kohler Co. to maintain warranty is as follows:

Turbidity	< 5 NTU
TSS	< 10 mg/L
Conductivity	< 1000 uS/cm
E. Coli	< 14 MPN/100 ml (geometric mean)
Disinfection	< 4.0 mg/L free Cl
BOD5	< 10 mg/L
pH	6.0 – 9.0
Petrochemicals	0 mg/L

Grey water systems 1 (Filter + Chlorine) and 2 (Advanced Oxidation) did not meet these requirements.

User Experiences

- Toilets
  - Odor complaints when chlorine was low.
  - Complaints of “slimy” appearing water in toilet bowls.
  - Toilets using treated grey water required high maintenance.
    - 8 of 10 toilets needed to be repaired.
    - 17 separate repair calls (in addition to routine maintenance and cleaning).
      - Gel-like substance plugging the toilet fill valves.
      - Flappers shrinking and stiffening.
      - Burst fill valve
  - User acceptance was generally good.

User Experiences

- Grey Water Systems
  - Retrofits into existing piping were difficult.
  - No feedback whether the systems were operating properly.
  - Chlorination system didn't work. Chlorine oxidized equipment. Manual intervention was required.
  - Hydrogen peroxide consumption was high. A 55-gallon drum was purchased.
  - Electrical issues were shutting down systems (and toilets).
  - "Just make the alarm stop ringing!"
  - LEAKS and PLUGS and BURSTS!!! Oh my!
  - High end systems ran well after commissioning.

Are these systems ready for prime time?

Summary of Operation Costs

	Equip. Cost	Total Water Processed (gal)	Chemicals Consumed	Total Maint. (6)	Continuous Power Draw ($/yr) (7)	Cost per Gallon (1)	Cost per Gallon at Capacity
① Filter + Cl	$2,600	14,828	$30	$120 (5)	$0	$0.011	$0.011
② Advanced Oxidation	$4,500	13,254	$305	$50 (2)	$49	$0.031	$0.025 (4)
③ MBR	$7,500	11,422	$0	$50 (2, 3)	$121	$0.016	$0.004 (4)
④ Bio + Media Filter	$8,950	9,669	$0	$580 (2)	$98	$0.071	$0.013 (4)

Notes:

(1) Cost per gallon calculated at the volume of water used. Includes cost of pumping.
(2) Cost of UV lamp replacement.
(3) Does not include the cost of eventual membrane replacement.
(4) Assumed capacity is 150 gal/day (stated for MBR and Bio systems) for 365 days (54,750 gal).
(5) Cost of filters.
(6) Does not include the cost of system or toilet repairs. Includes maintenance contract for Bio system.
(7) Estimate of continuous power cost at $0.11/kwh. Does not include power to pump water.

- Average cost of residential water/sewer in U.S.: **$0.010/gal**.

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

- Only one scenario where operating cost is less than the average cost of water
- No potential for payback in any other scenarios

Summary

- Kohler Co. has installed and tested four state-of-the-art residential grey water treatment systems.
- Water quality output ranged from poor to good.
- Each technology tested provided varying toilet maintenance and repair issues.
- Kohler has added water quality requirements to its toilet warranty policy for non-potable applications.
- A wide range of system installation and operational issues were noted.
- Our experience is that these systems did not generate a reasonable payback.

Questions?

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