Graywater Reuse
A Case Study at Colorado State University

Regulatory Planning
and Seeking a Cost-Effective System

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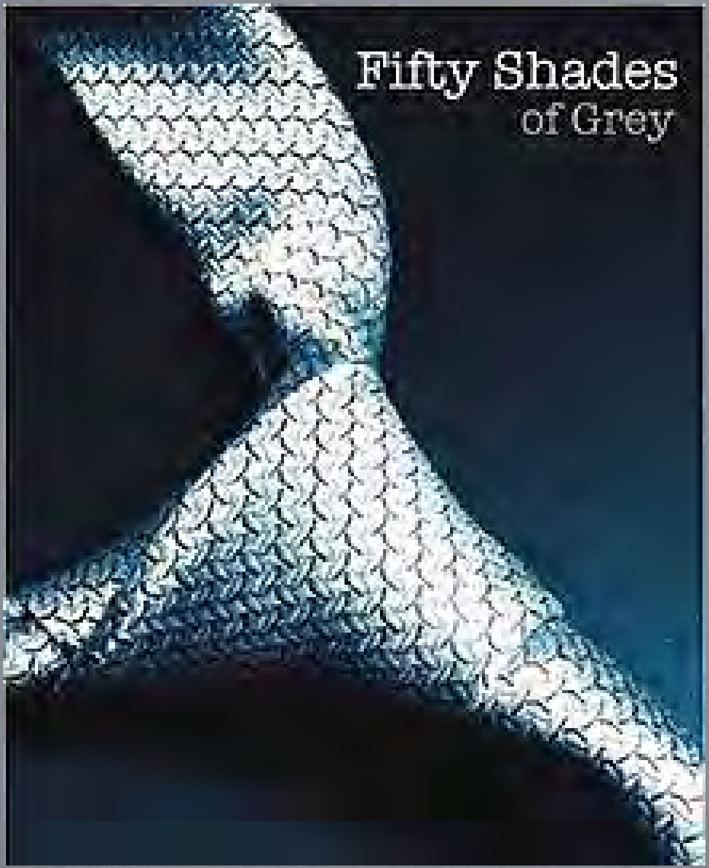


water

Aspen

- LEED Gold residence Hall at Colorado State University
- Graywater collection – 14 sinks, 13 showers
- Treatment
- Distribution for toilet flushing

Graywater Treatment Objectives

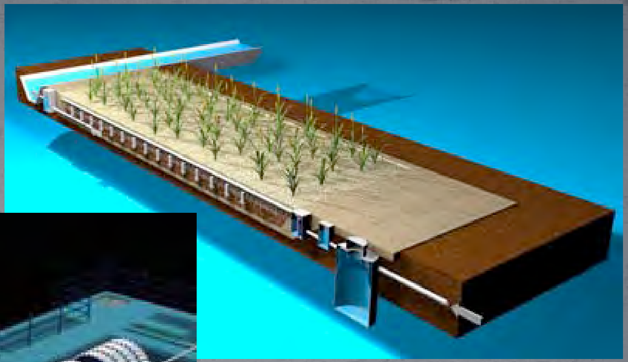
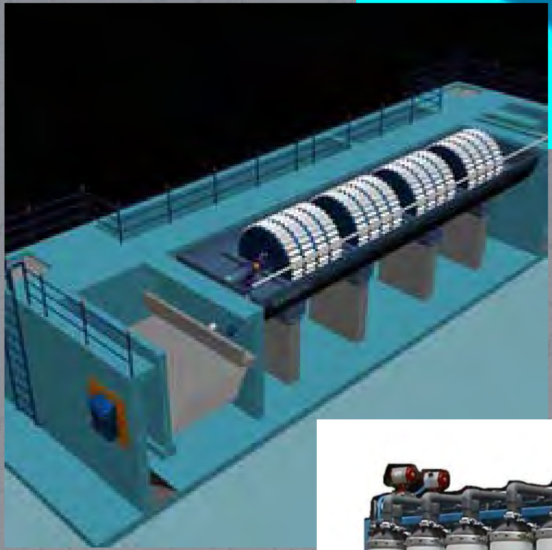
- Save water
- Protect public health
- Install a cost-effective system

CSU College of Engineering

- Dr. Larry Roesner
- Dr. Sybil Sharvelle
- Graduate students

Treatment Possibilities

- Biological
- Chemical/physical
- Disinfection



Research at Aspen Hall

- Filter types
- Disinfection methods
- Treated graywater quality
- Regrowth
- Dye interference

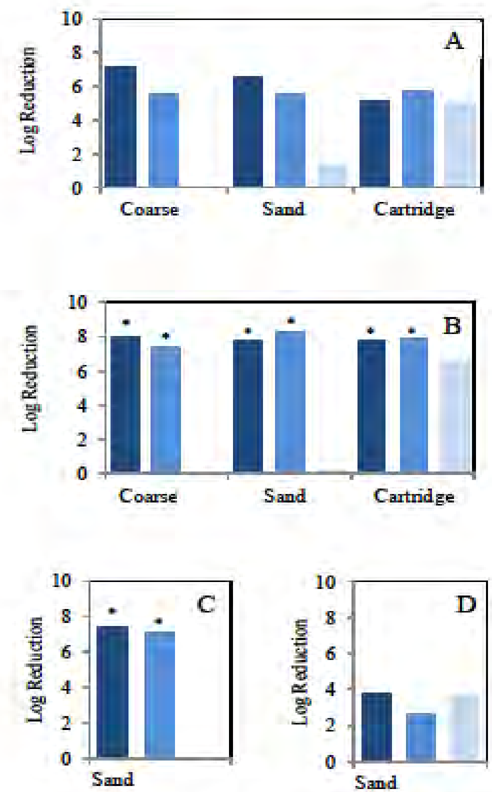


Figure 3.2 Disinfection Efficacies for Chlorine, UV and Ozone for 3 Bacteria and 1 Bacteriophage. A) *E. coli* B) *S. enterica* C) *P. aeruginosa* D) MS2 bacteriophage Chlorine results represent a contact time of 60 minutes. Log reduction of pathogens with ozone was not detected where not shown.
* indicates complete disinfection (■) chlorine, (■) UV, ( ) ozone
Table 3.1 shows average water quality parameters for these tests.

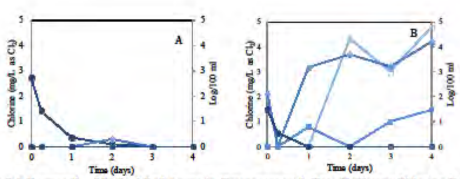
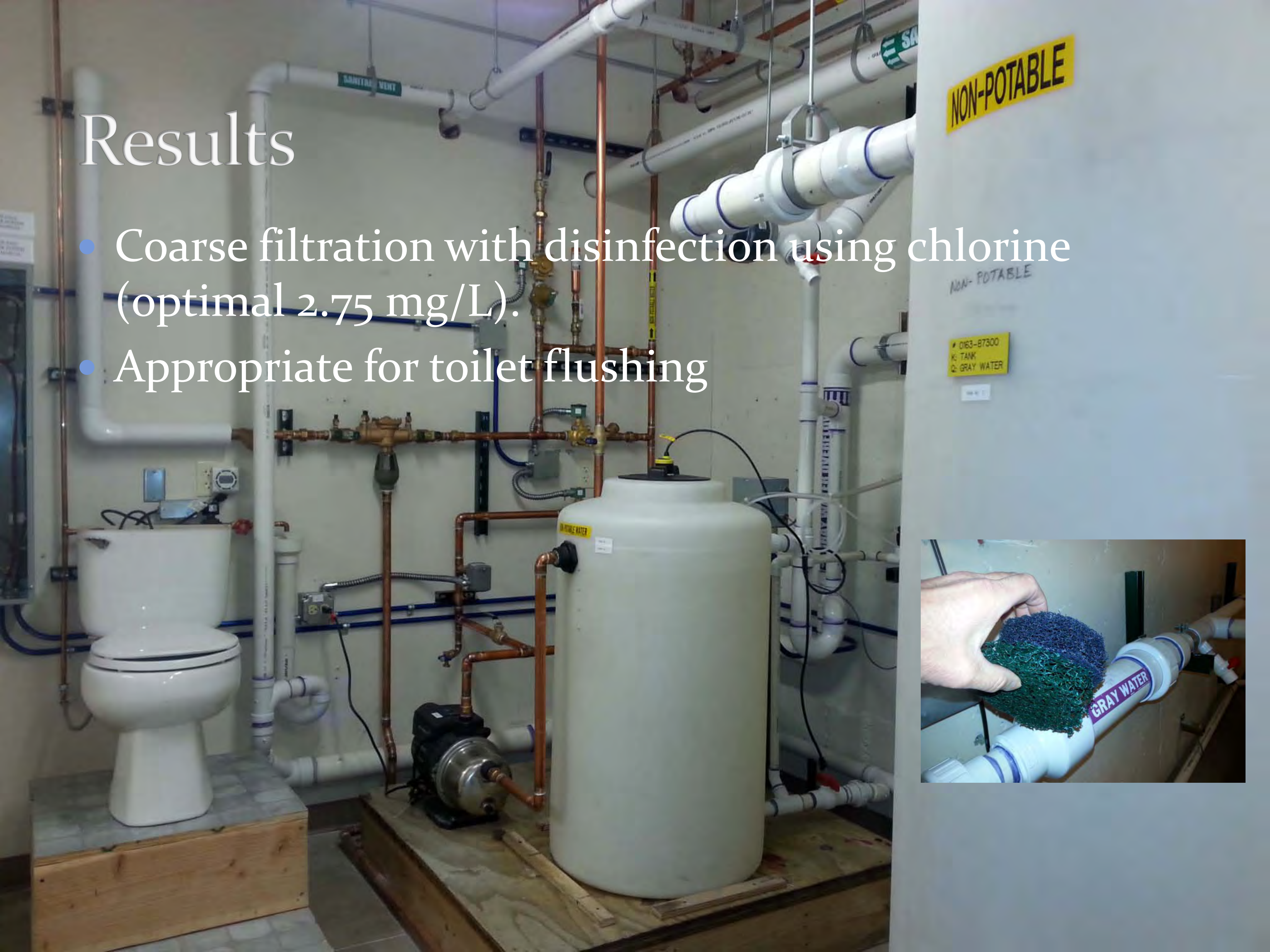


Figure 3.5 Regrowth of Spiked Pathogens in Graywater with Two Different Chlorine Residual Concentrations, 2.75 mg/L (A) and 1.5 mg/L (B) (•) chlorine residual, (■) *E. coli*, (○) *S. enterica*, (•) total coliforms, (x) *P. aeruginosa*. Influent TOC was not measured for these tests. For graywater originating from the same source (i.e. same group of students), the range of TOC was 45.0 to 85.3 mg/L-C. The average TOC was 61.6 mg/L-C with a standard deviation of 8.3 mg/L-C.

Results

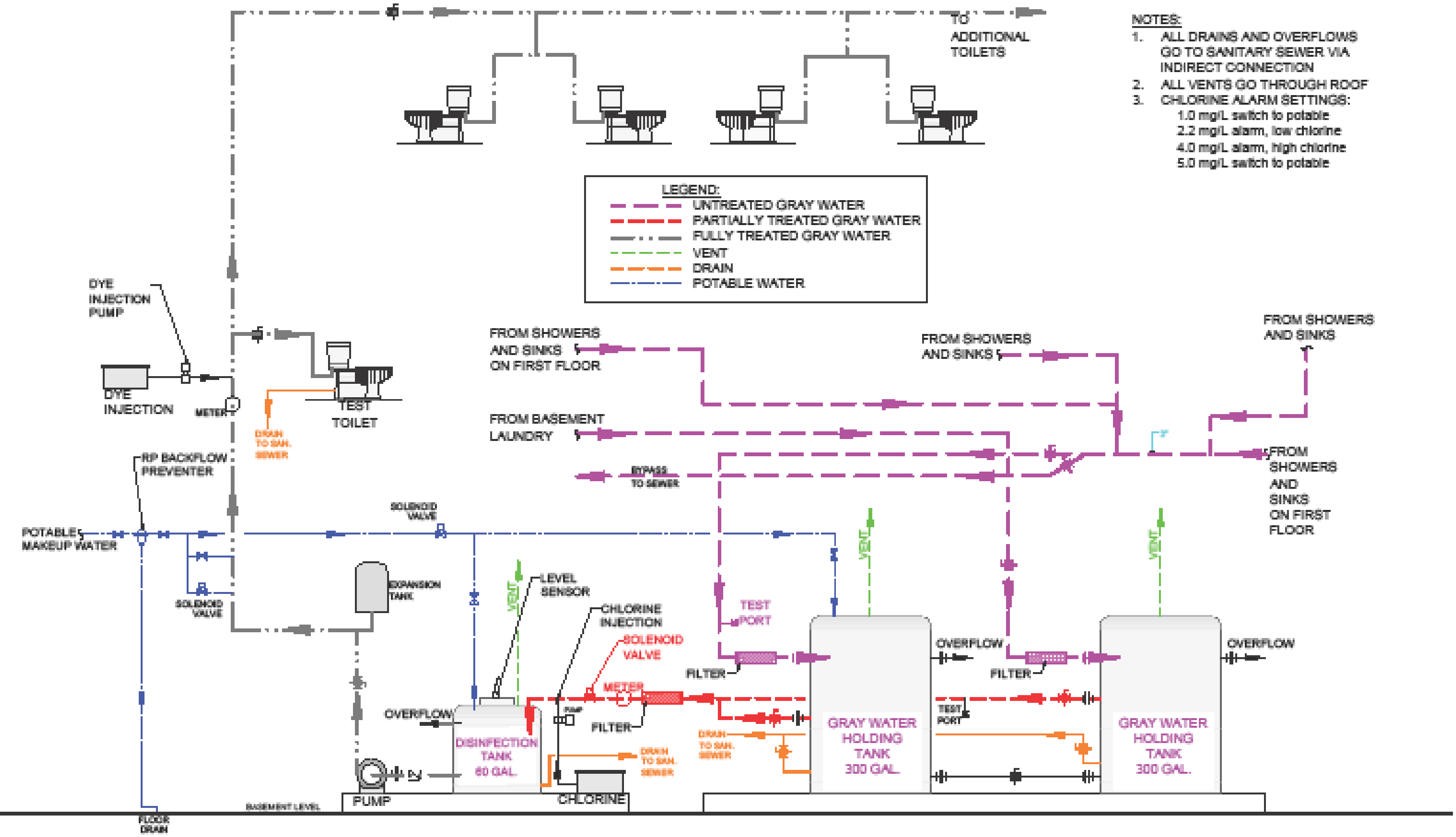
- Coarse filtration with disinfection using chlorine (optimal 2.75 mg/L).
- Appropriate for toilet flushing



Regulations and Standards

- Flushing toilets – does not need to be treated to potable water standard
- Protecting public health
- Saving water
- Safeguards
  - Disinfection
  - Backflow prevention
  - Dye
  - signs

The Aspen System




NON-POTABLE


DYE INJECTION


GRAY WATER OVERFLOW
GRAY WATER


ASPEN HALL
GRAY WATER SYSTEM
O&M MANUAL

Tank Features

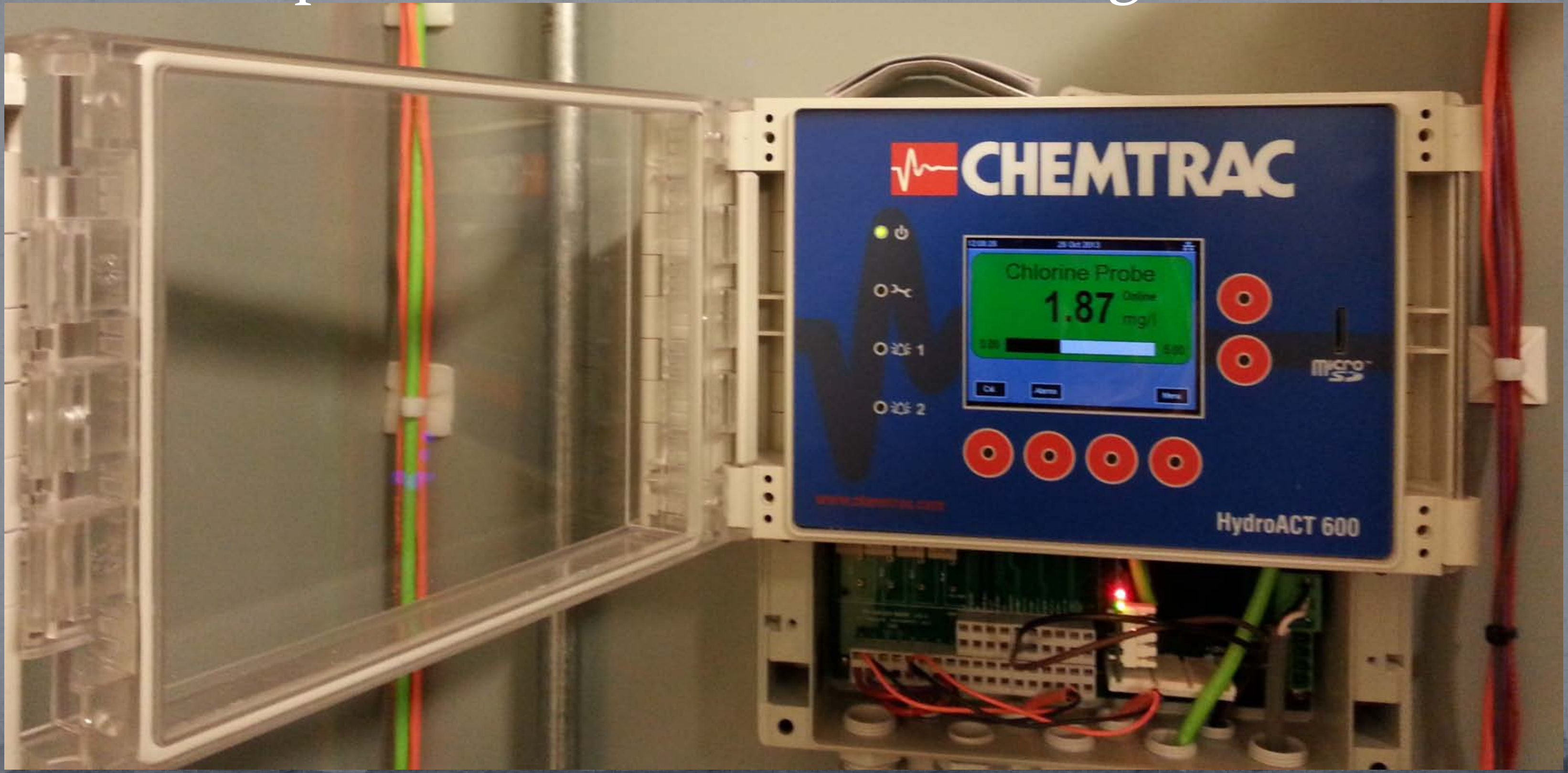
- Closed top, have vents, drains, overflows

Potable water

- RP backflow preventer
- Can feed to any tank if inadequate gray water is generated
- Solenoids to switch to potable in case of high or low chlorine in disinfection tank

Controls

- Continuous chlorine analyzer
- Building automation system alarms
- Switch to potable if out of chlorine range



Untreated Graywater

- Personal care products
- Hair
- Body fluids (sweat, urine)
- Lotion, sunscreen
- Antimicrobial hand soap
- Discarded drinks
- Cleaning chemicals
- Ramen noodle rinse water
- Fats oil and grease

Regulatory Interactions

- Water rights
- Plumbing code
- County health department
- In-house approvals

State Level

- Examining Board of Plumbers
- Office of the State Architect
- Colorado Department of Public Health and Environment
- Division of Water Resources State Engineer's Office
- Legislators – HB13-1044

Plumbing Board

- 2009 IPC requires connection of all fixtures to potable water
- Appendix C not adopted by Colorado
- Waiver required

County and City

- Larimer County Health department
- City of Fort Collins

In-House Departments

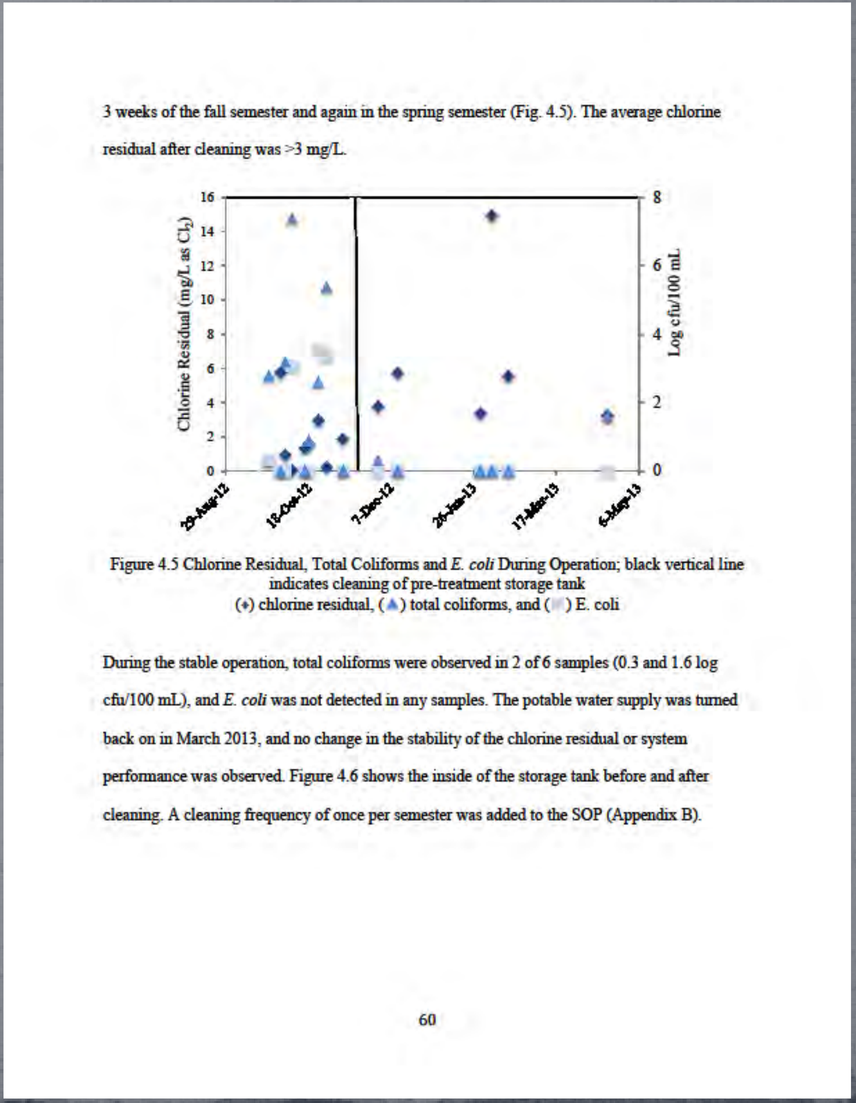
- Facilities Management
- Housing and Dining Services
- Office of Legal Counsel
- Environmental Health Services
- College of Engineering
- Research and Integrity and Compliance Review Office

What are the Standards for Toilet Flushing?

- Wide variety of standards
- Turbidity <2 NTU and up
- BOD_5 10 mg/L to 200 mg/L
- TSS 10 mg/L to no limit
- pH 6 to 9
- e-Coli 14 CFU/100 ml to 75 CFU/100 ml

Aspen Hall System Quality

- Does not meet any State or NSF standards for suspended solids or turbidity
- Meets some limits for BOD5
- Meets all published limits for pH and e-coli
- No regrowth of e-coli after two days
- Important to maintain chlorine >2.75mg/L at end of treatment system



3 weeks of the fall semester and again in the spring semester (Fig. 4.5). The average chlorine residual after cleaning was >3 mg/L.

Figure 4.5 Chlorine Residual, Total Coliforms and *E. coli* During Operation; black vertical line indicates cleaning of pre-treatment storage tank
(♦) chlorine residual, (▲) total coliforms, and ( ) E. coli

During the stable operation, total coliforms were observed in 2 of 6 samples (0.3 and 1.6 log cfu/100 mL), and *E. coli* was not detected in any samples. The potable water supply was turned back on in March 2013, and no change in the stability of the chlorine residual or system performance was observed. Figure 4.6 shows the inside of the storage tank before and after cleaning. A cleaning frequency of once per semester was added to the SOP (Appendix B).

60

Why treat for solids and turbidity?

- Suspended solids
- Turbidity

- Drinking water
- Surface waters

- Graywater toilet flushing – not potable, discharged to sanitary sewer.

Complex Treatment

- Backwash (wastes water and energy)
- Membrane cleaning (high energy consumption)
- Ultraviolet light (photoreactivation)

Costs

Capital Costs	
Plumbing, collection and distribution piping	$20,100
Treatment system	$38,400
In-line monitoring and control	$8,000
Total Capital Costs:	**$66,500**

O&M Costs	
Operation and maintenance costs (est.)	$5,000/year

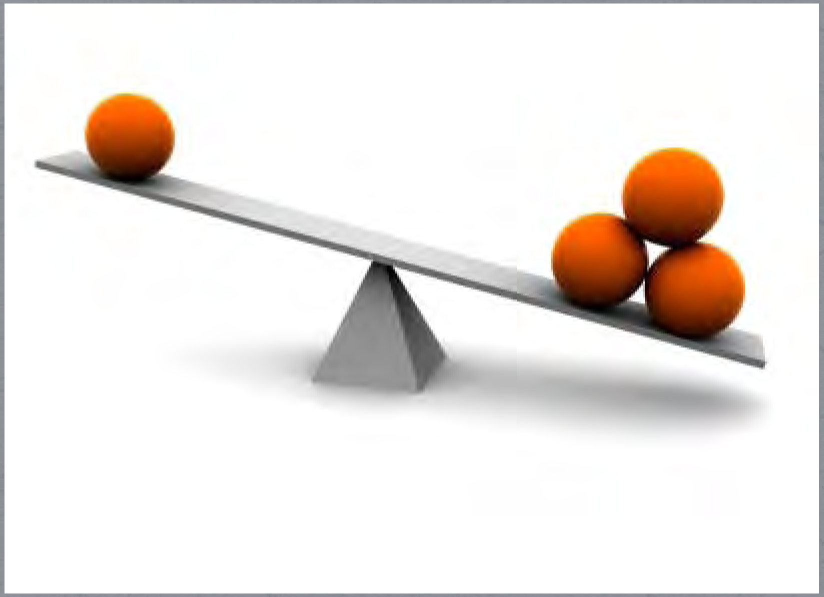
Savings

- (1.28 gal/flush)*(5 flushes/person/day)*(28 persons)*(365day/yr)= 65,408 gallons per year
- Cost of water $5.89 per thousand gallons
- Savings $385 per year

Comparison

- High capital cost due to stepwise construction, research system, changes required by plumbing board.

- Savings $385 per year



- O&M $5,000 per year

Hypothetical Scenario

- Multi-family residential building
- Graywater for toilet flushing
- Ten-year payback

Single-Family Scenario

- No tangible payback with toilet flushing alone
- Incorporate irrigation component
- Social, environmental and economic considerations = net benefit.

Conclusions from the Aspen System

- Coarse filtration and disinfection
- Uses non-potable water for toilet flushing
- Prevents regrowth of e-coli
- Includes safeguards to prevent cross-connection
- Includes education of users
- Is simple and relatively inexpensive to operate

Thank you.