INTEGRATING BIOLOGICAL FILTRATION TREATMENT SYSTEMS

New England Water Treatment Technology Assistance Center
Department of Civil Engineering
University of New Hampshire

NE-WTTAC at the University of New Hampshire

Vasiliki Partinoudi,
M. Robin Collins,
Michael Unger, and
Peter Dwyer

UNIVERSITY of NEW HAMPSHIRE

Technology Assistance Centers located throughout the U.S.

- University of New Hampshire
- University of Missouri, Columbia
- Mississippi State University
- Montana State University
- University of Illinois, Champaign
- Western Kentucky University
- Pennsylvania State, Harrisburg
- University of Alaska, Sitka

TACs Mission Statement

The small public water systems Technology Assistance Centers form a network with the common goal to protect public health, improve water system sustainability, and enhance compliance. They do this by applying university resources to address the needs of rural and small public water systems or public water systems that serve Indian Tribes in the following areas:

- Technology Verification
- Pilot and Field Testing of Innovative Technologies
- Training and Technical Assistance

Biological Filtration Systems

- Riverbank Filtration (*RBF*) sites
- Pilot Slow Sand Filters (*SSF*)
- Biological Activated Carbon (*BAC*) Filtration

Treatment Focus

- Organic Precursor Removal
- Microbial Removal

Processes Taking Place During Biological Filtration

- Physical / Chemical
  - Straining
  - Adsorption (transport and attachment)
- Biodegradation Processes
  - Predation
  - Scavenging
  - Natural death
  - Inactivation
  - Metabolic breakdown

The Schmutzdecke

- German: “Schmutz” = dirt; “Decke” = covering
- Definition: “a layer of material, both deposited and synthesized, on the top of the filter bed that causes headloss disproportionate to its thickness” (AWWARF 1991)
- 2 Regions
  - Biomat (slime)
  - Biologically active media

Key Biofilter Design Parameters

- Quality of influent water
- Hydraulic loading rate/Flow rate/Seepage velocity
- Media type/size/depth
- Contact time/ Travel time

Common Design Parameters

Parameter	RBF	SSF	BAC
EBCT	<1 day	3-10 hr	>5 to <15 min
Media Type	Native subsurface material	Sand	GAC/Anthracite
Media Depth	Travel distance 10m-600m	0.75-1.25 m	1-2 m
HLR	Seepage velocity 0.03-1m/hr	0.1-0.3m/hr	5-25 m/hr

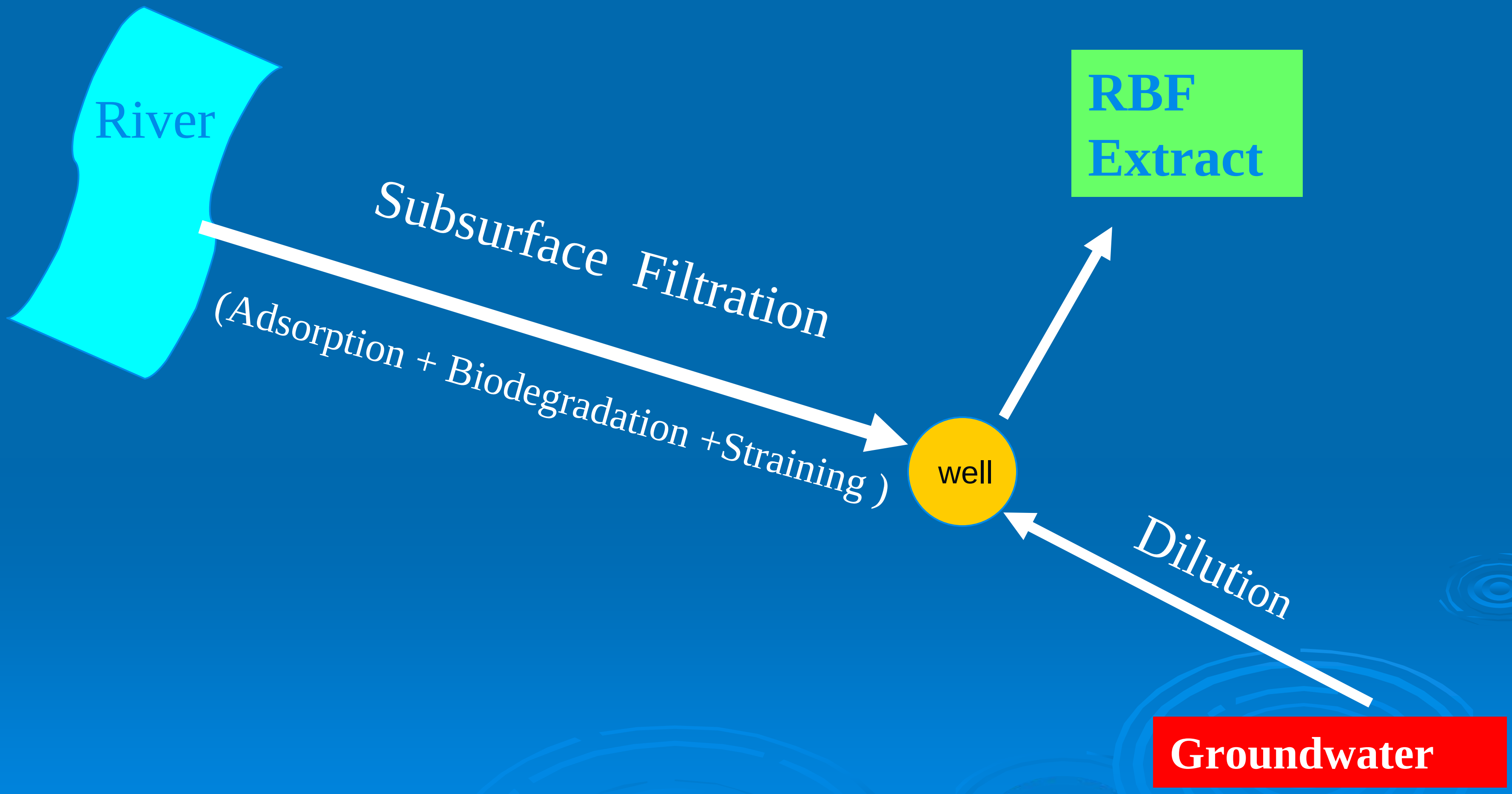
What is Riverbank Filtration?

"Bank filtered water is surface water, seeping from the bank or the bed of a river or lake to the production wells of a water treatment plant. During its ground passage the water quality parameters change due to microbial and physical processes and by the mixing with groundwater" (Fokken, 1995)

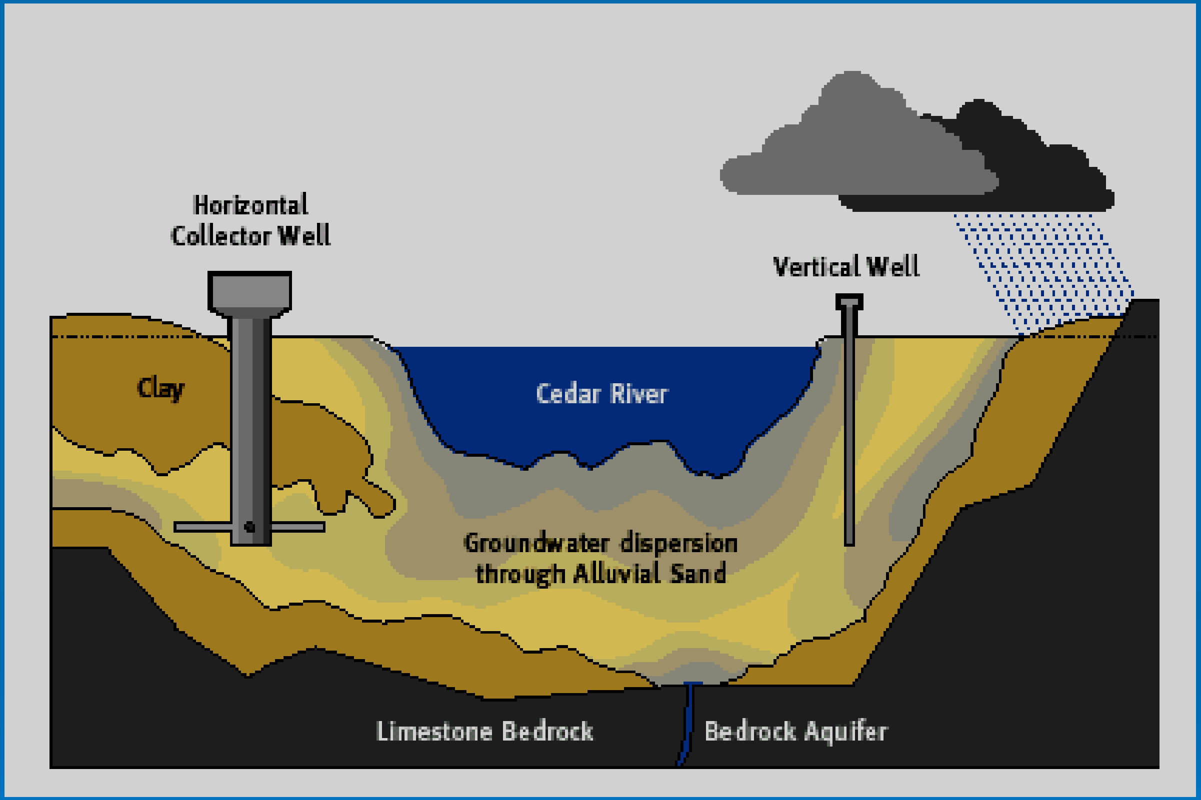
Advantages of RBF

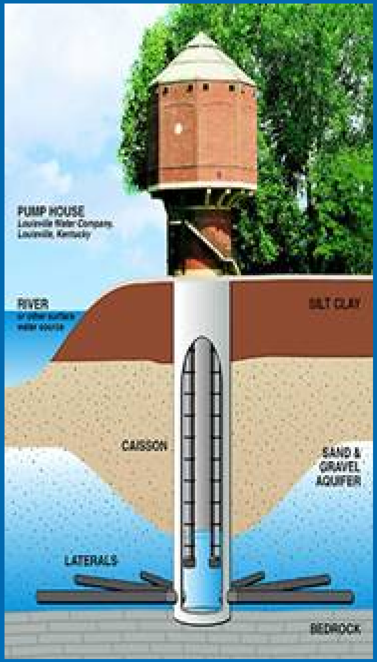
- Multibarrier approach to water treatment
- May attenuate concentration & temperature peaks
- Requires fewer and less skilled operators
- Requires fewer/no chemicals

Removal Processes Taking Place at an *RBF* Site



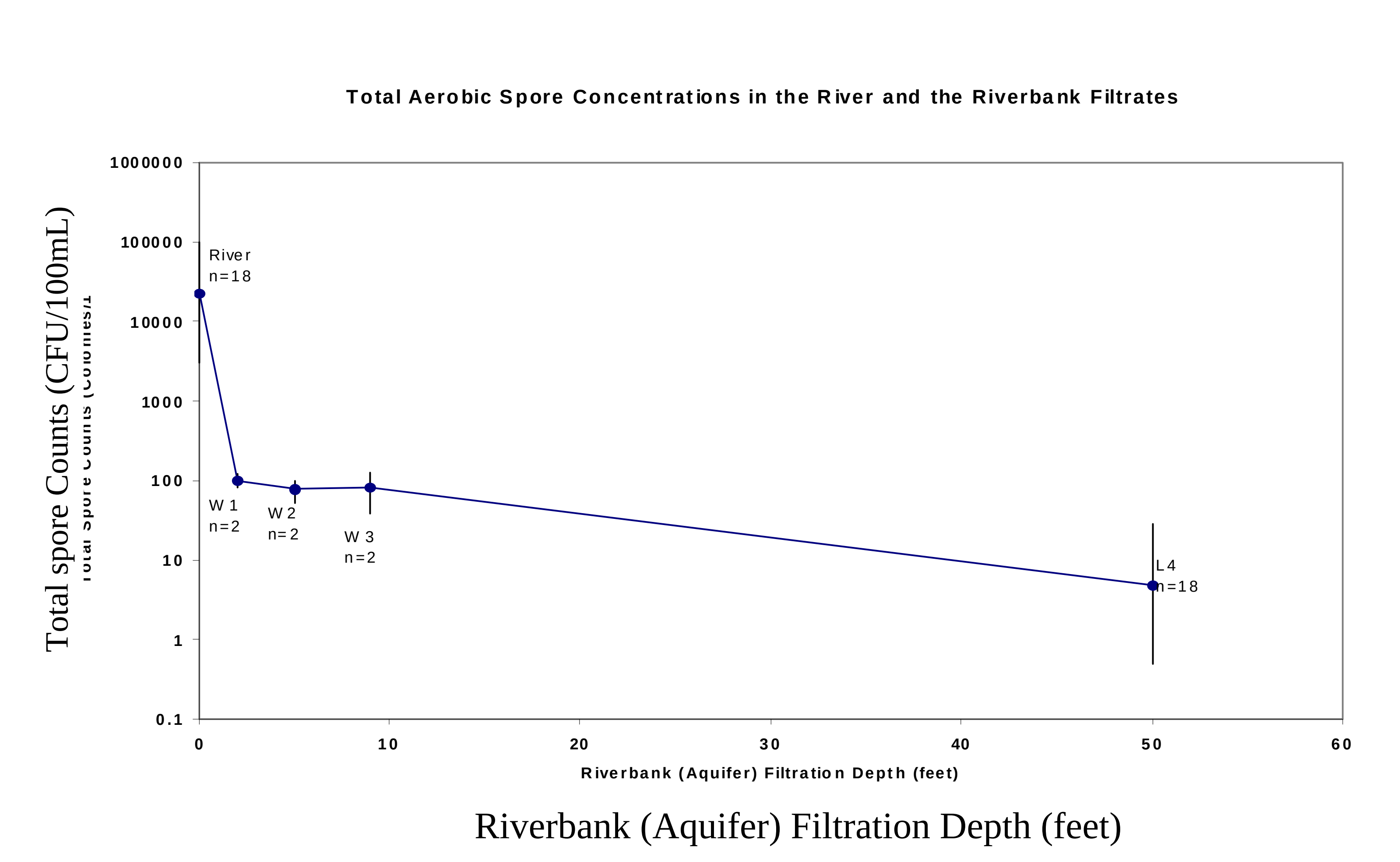
Typical Layout of a RBF Well



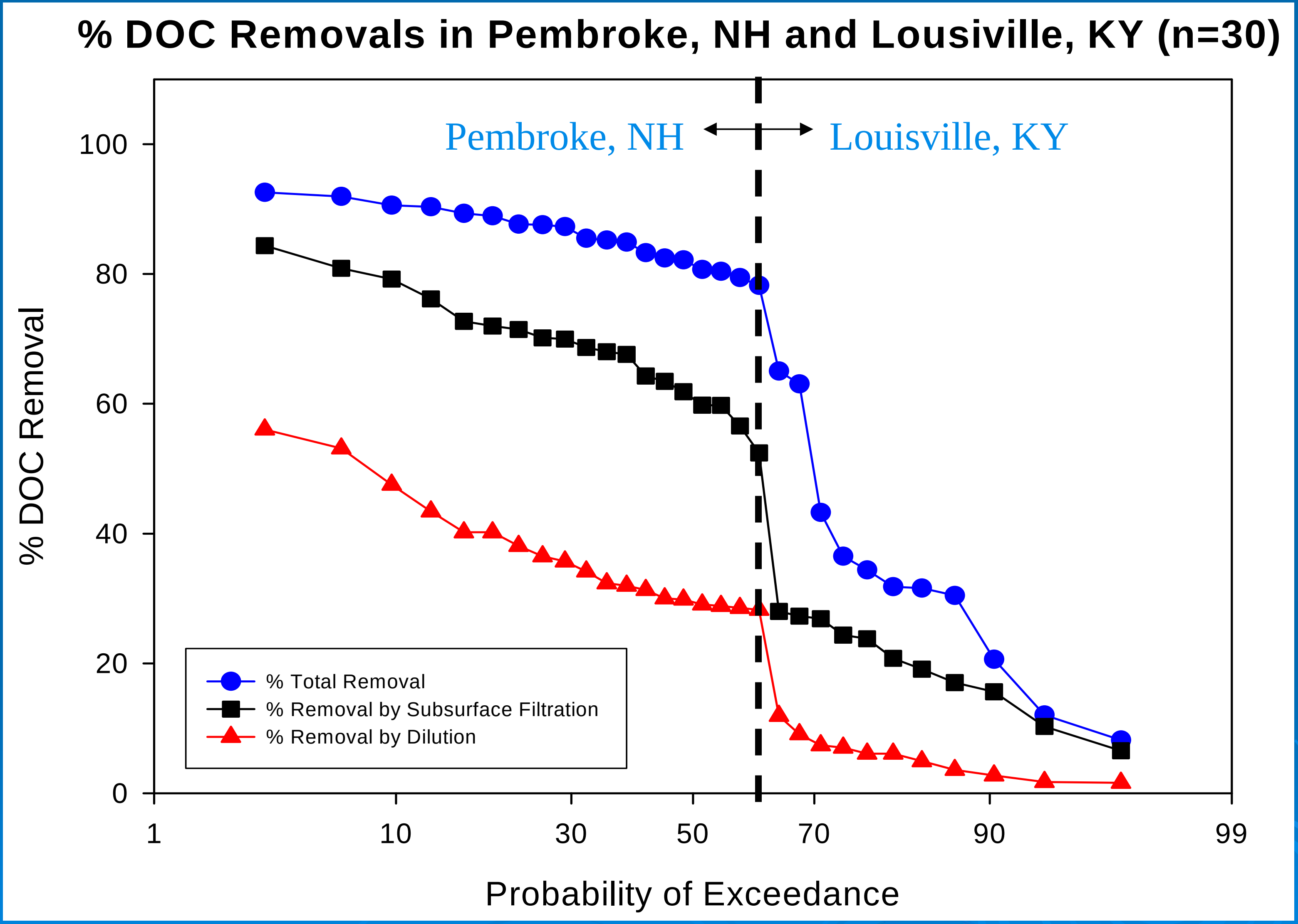


Cedar Rapids, IA

Louisville, KY



Source: Wang et al. (2002)

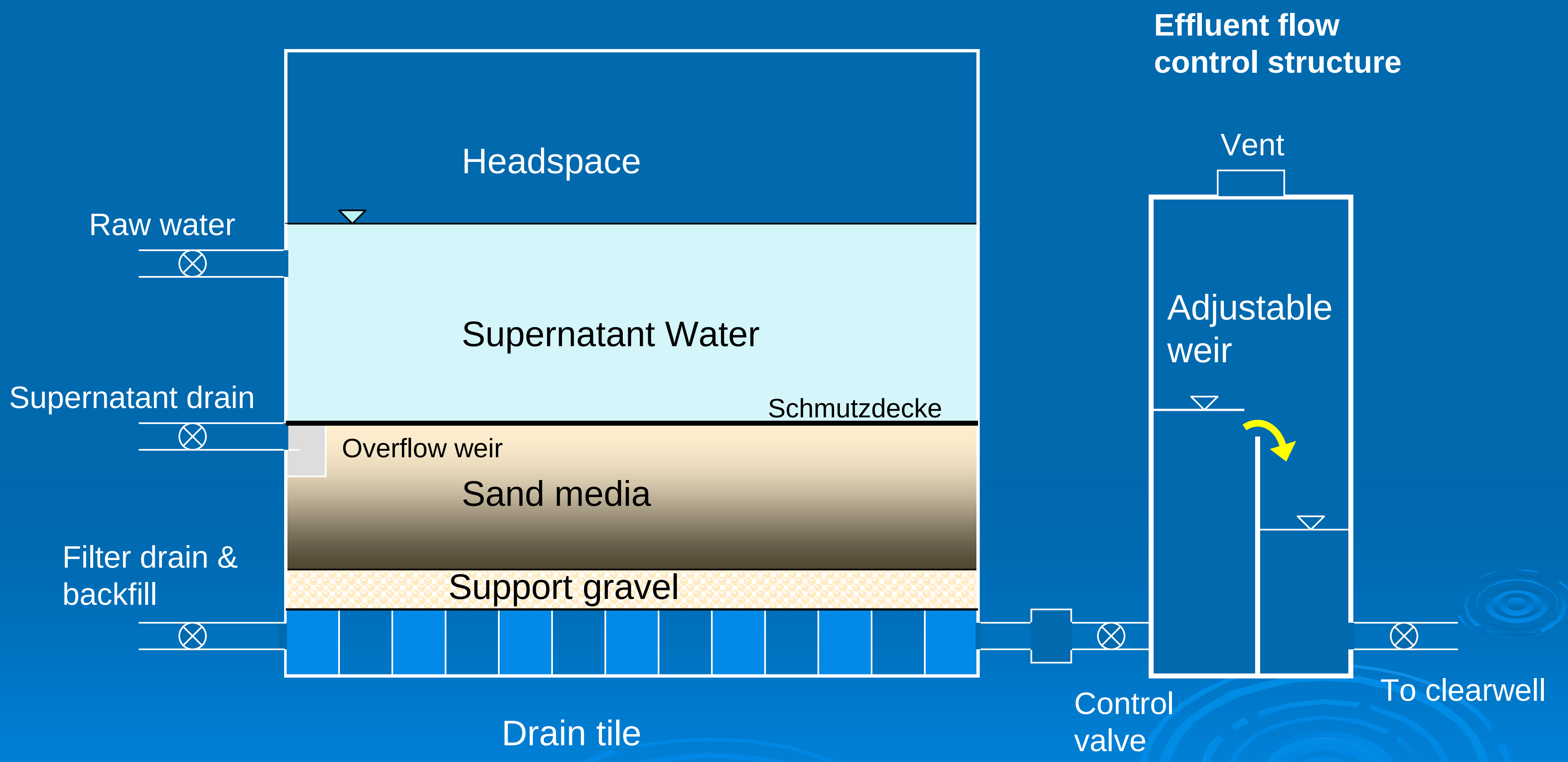


Source: Partinoudi, 2004

What is Slow Sand Filtration?

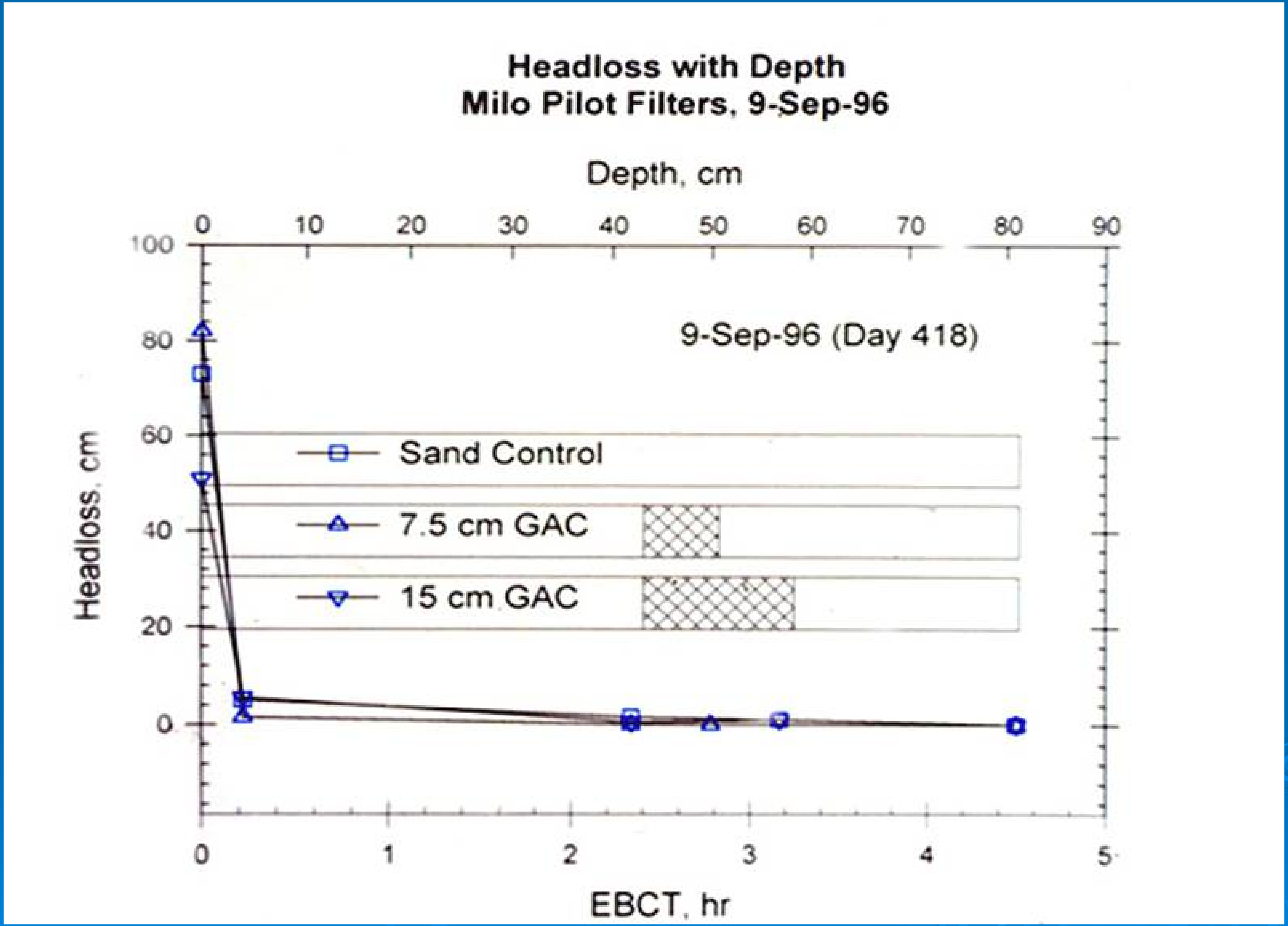
- During SSF untreated water very slowly percolates through a bed of porous sand. Below the sand bed is a layer of gravel for support and also at the bottom an underdrain system that collects the filtered water. As water passes through the filter microorganisms colonize the sand grains. Organic and inorganic matter also accumulates at the sticky mat known as schmutzdecke.

Typical Layout of a Slow Sand Filter

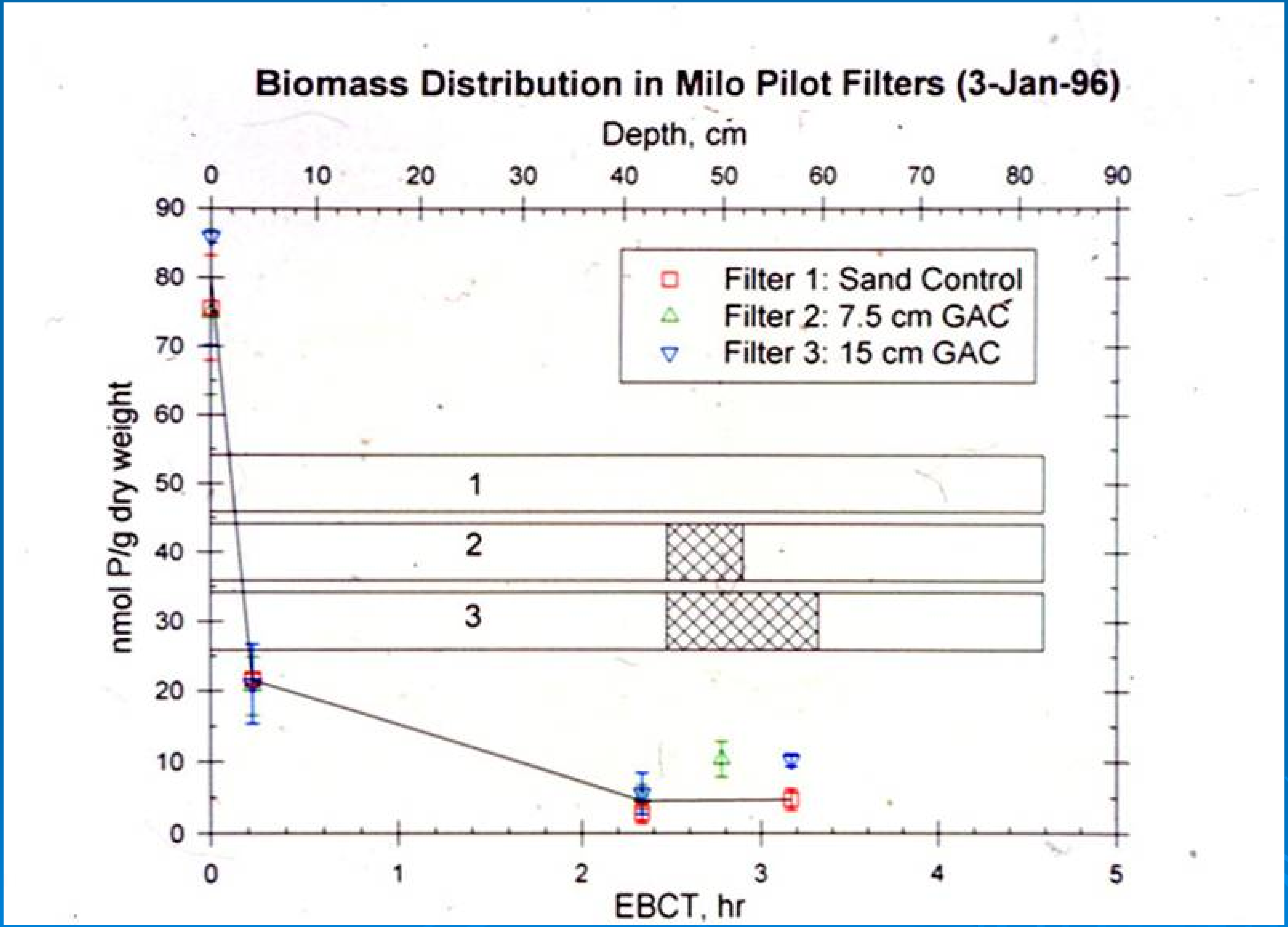


Advantages of SSF

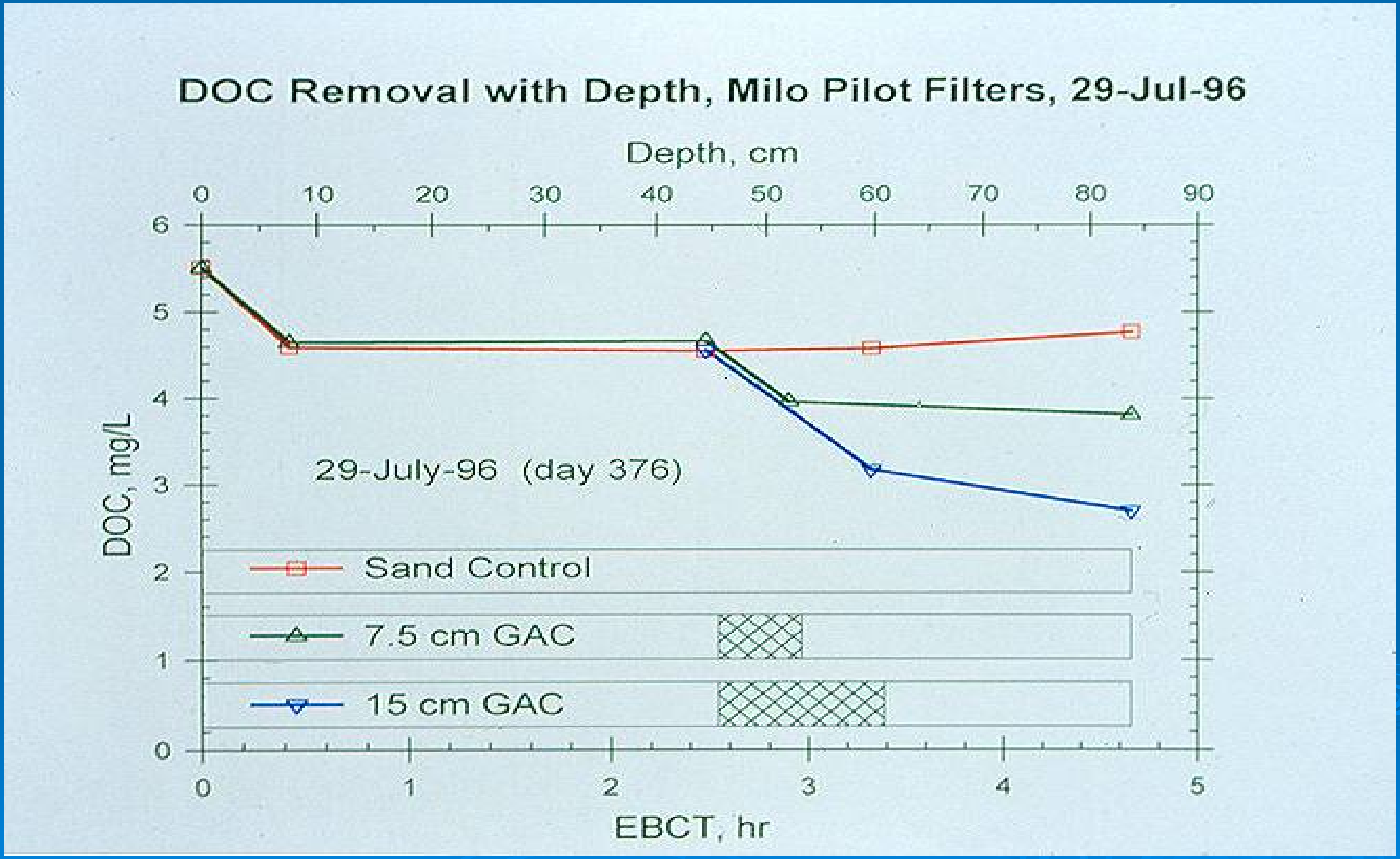
- May attenuate concentration & temperature peaks
- Inexpensive O&M
- Requires fewer and less skilled operators
- Requires fewer/no chemicals
- Produces almost no sludge



Source: Page (1997)

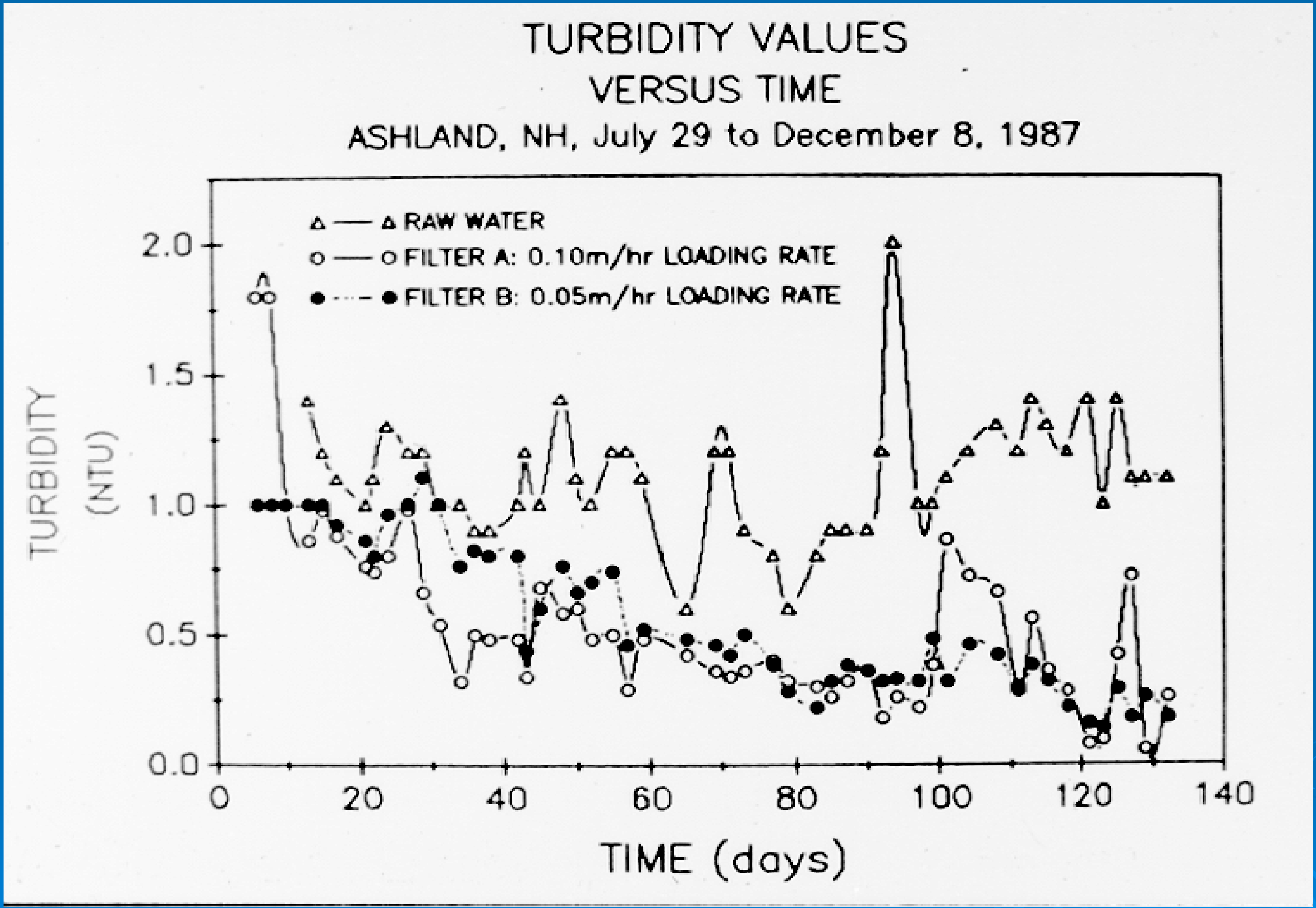


Source: Page (1997)



Source: Page (1997)


Filter #3
CONTROL
National Bureau of Standards



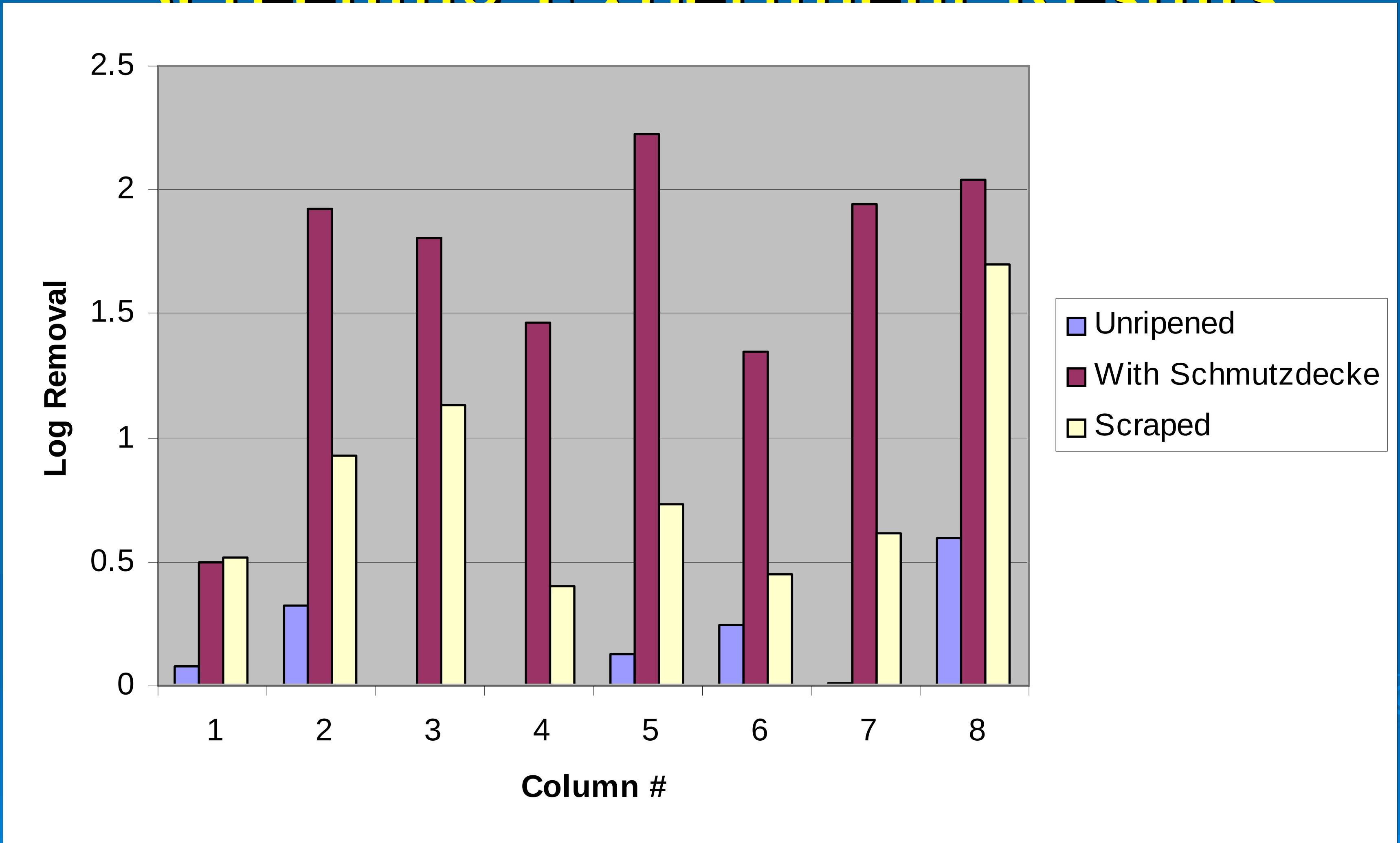
Source: Collins et al. 1989

Screening Design Column Study

4 Parameters / 2 Levels

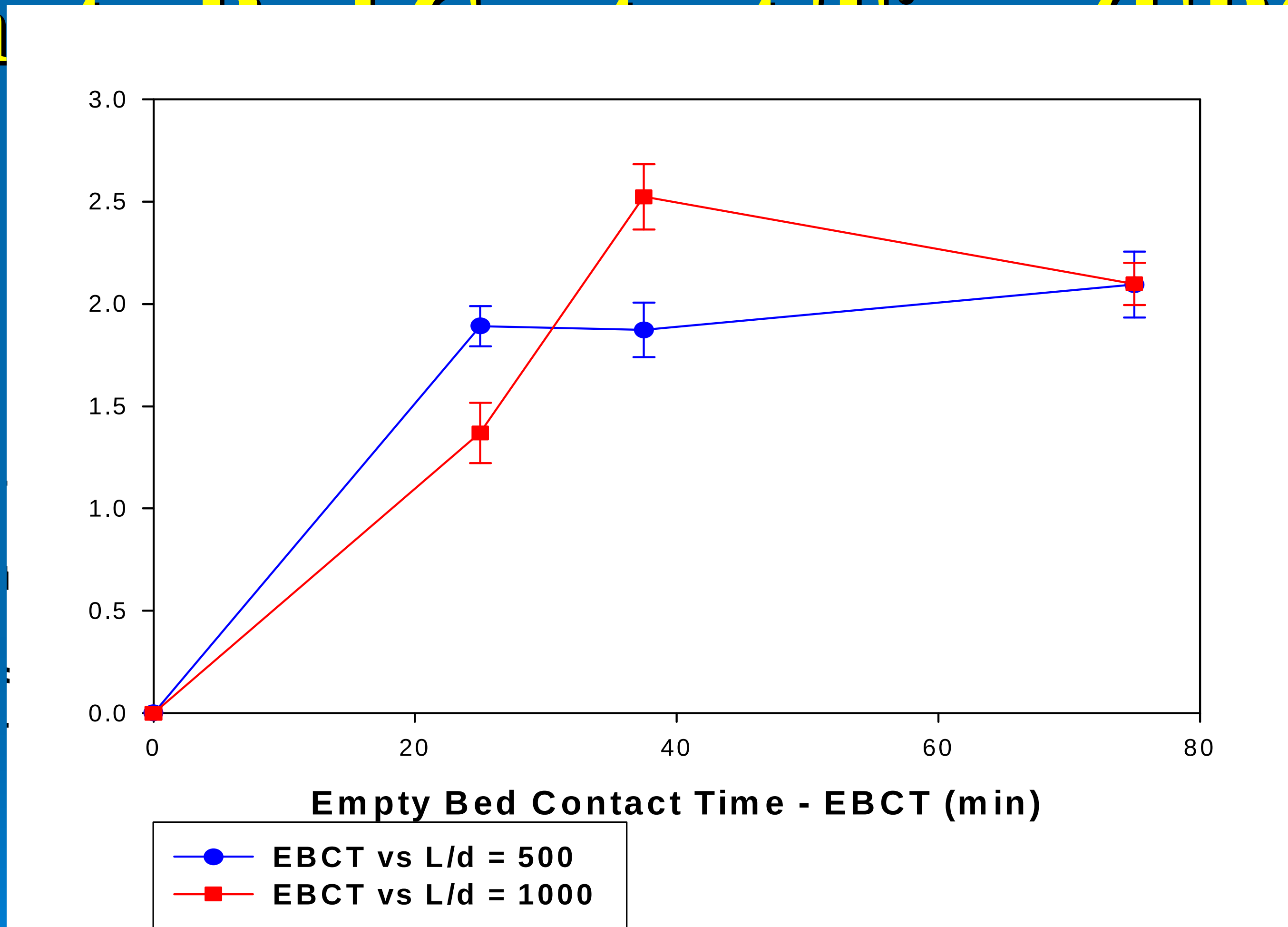
1. **Empty Bed Contact Time: 15 min, 60 min**
2. **Hydraulic Loading Rate: 0.2 m/hr, 0.6 m/hr**
3. **Filter Media Size: based on sieve analysis**
4. **Extent of Biological Ripening: “ripened”, virgin**

Screening Experiment Results



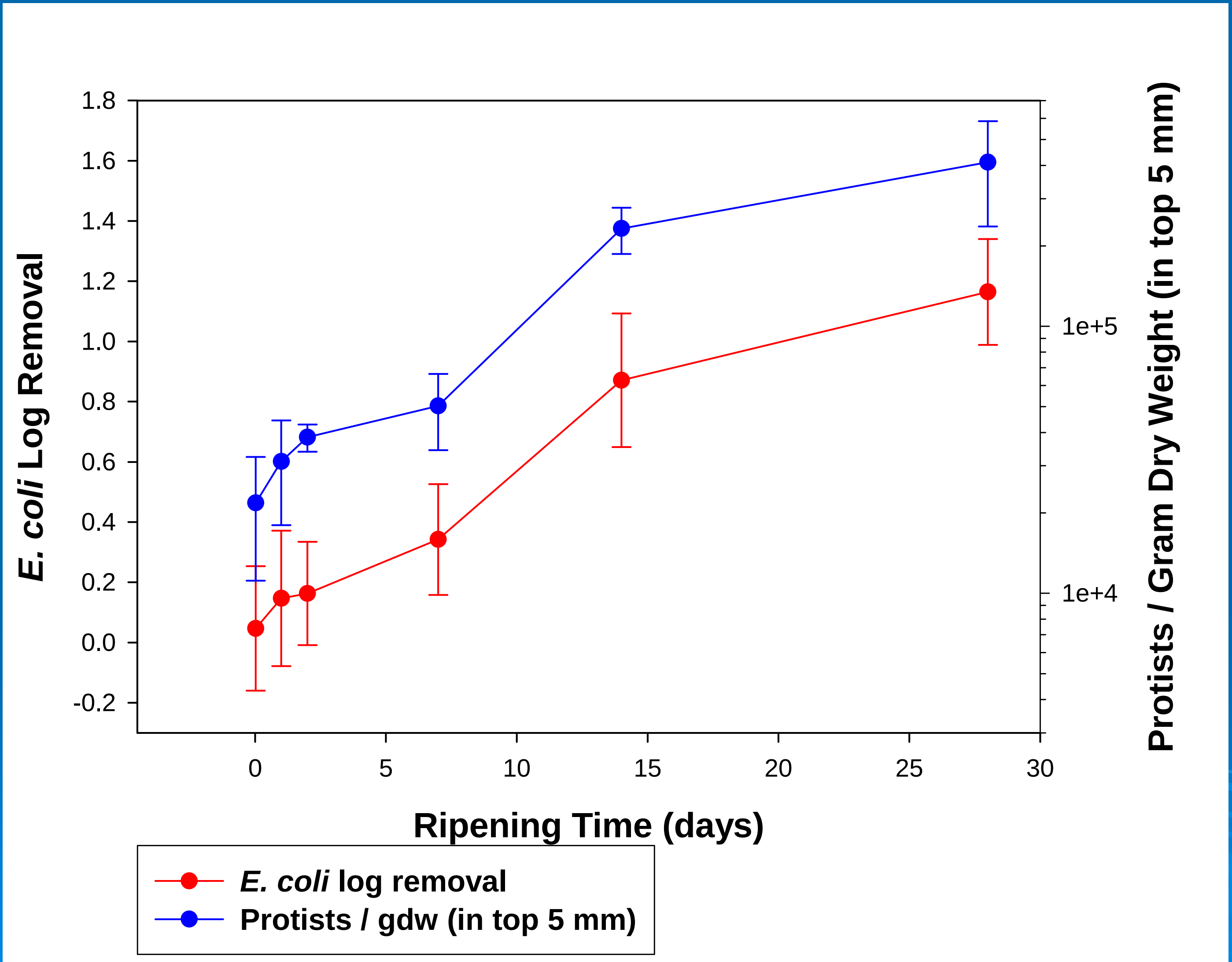
Unger, 2006

Length:Diameter (L/d) & Em CT)



Unger, 2006

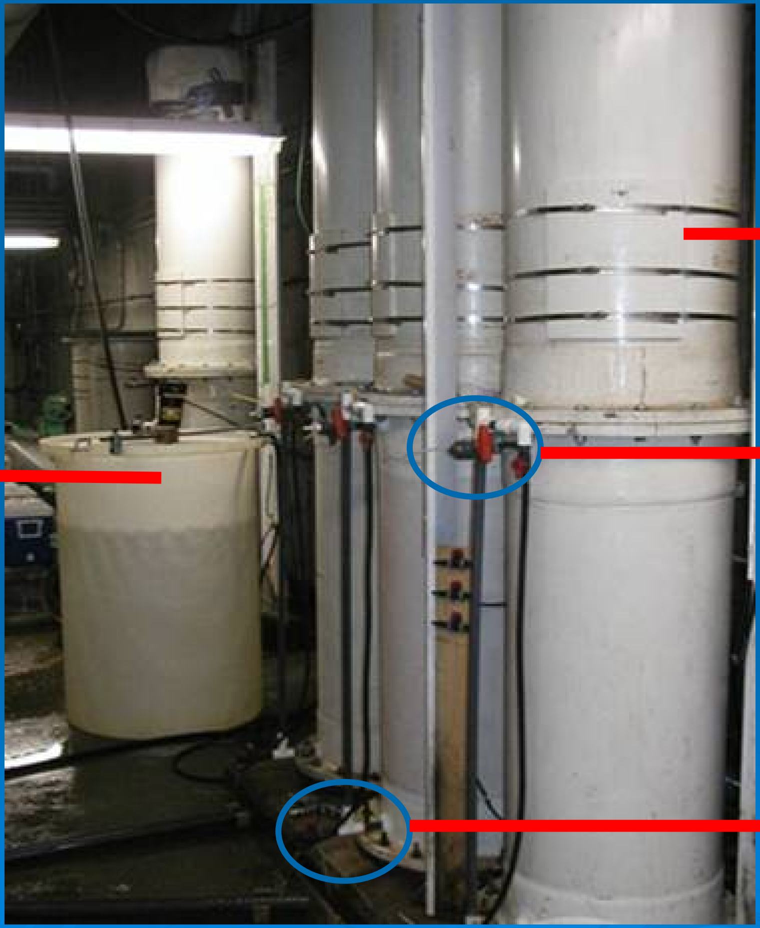
Protistan Abundance



Unger, 2006

Temperature Effects on SSF Study
Winthrop, ME

110 Gal Tank with
Microchallenge Solution



Removable Door

(Sand Coring)

Surface
Drain

(Influent)

Bottom
Drain/Backfill

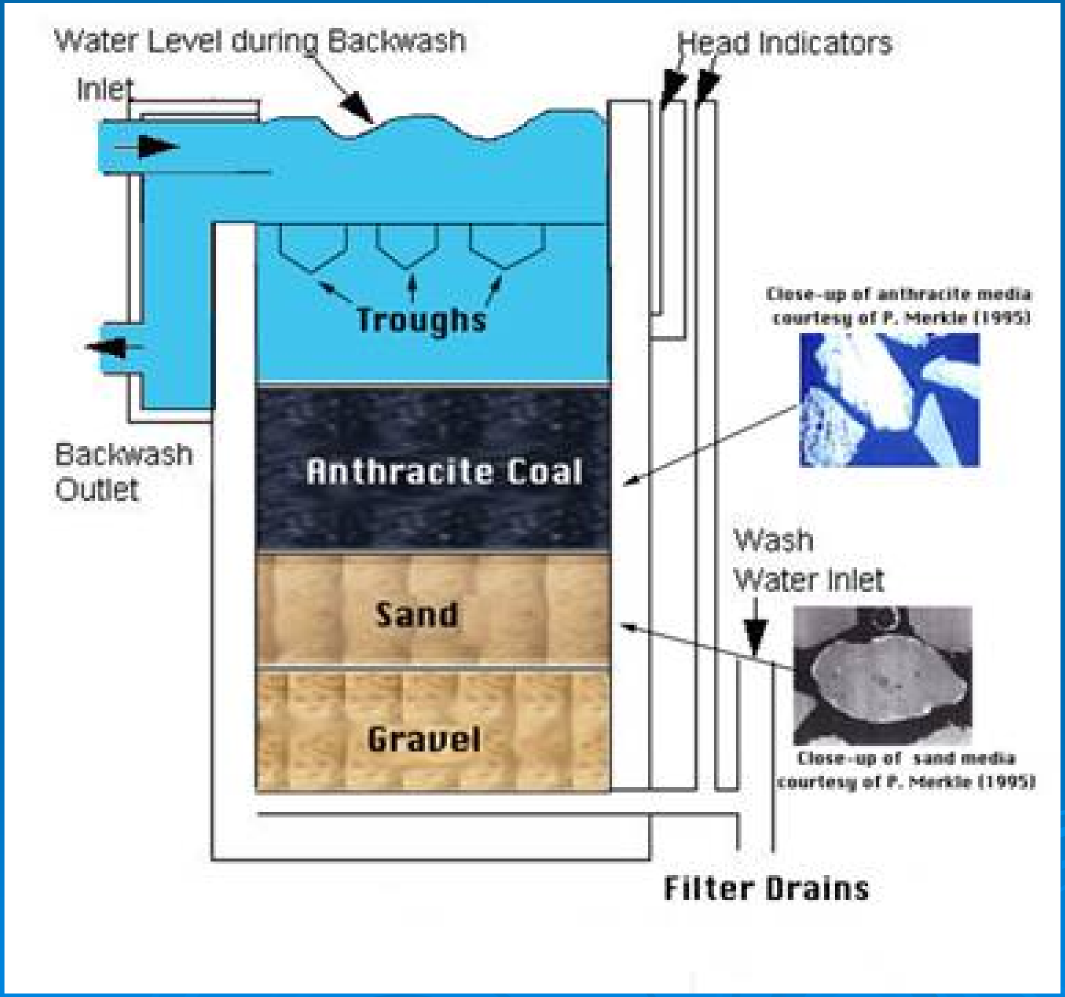
(Effluent)

Pilot SSF in Winthrop, ME

What is Biological Activated Carbon Filtration?

- Two major steps in this process:
  - Ozone as pre-oxidation
  - Biological Activated Carbon Filtration (Rapid Filtration)

Typical Layout of a BAC

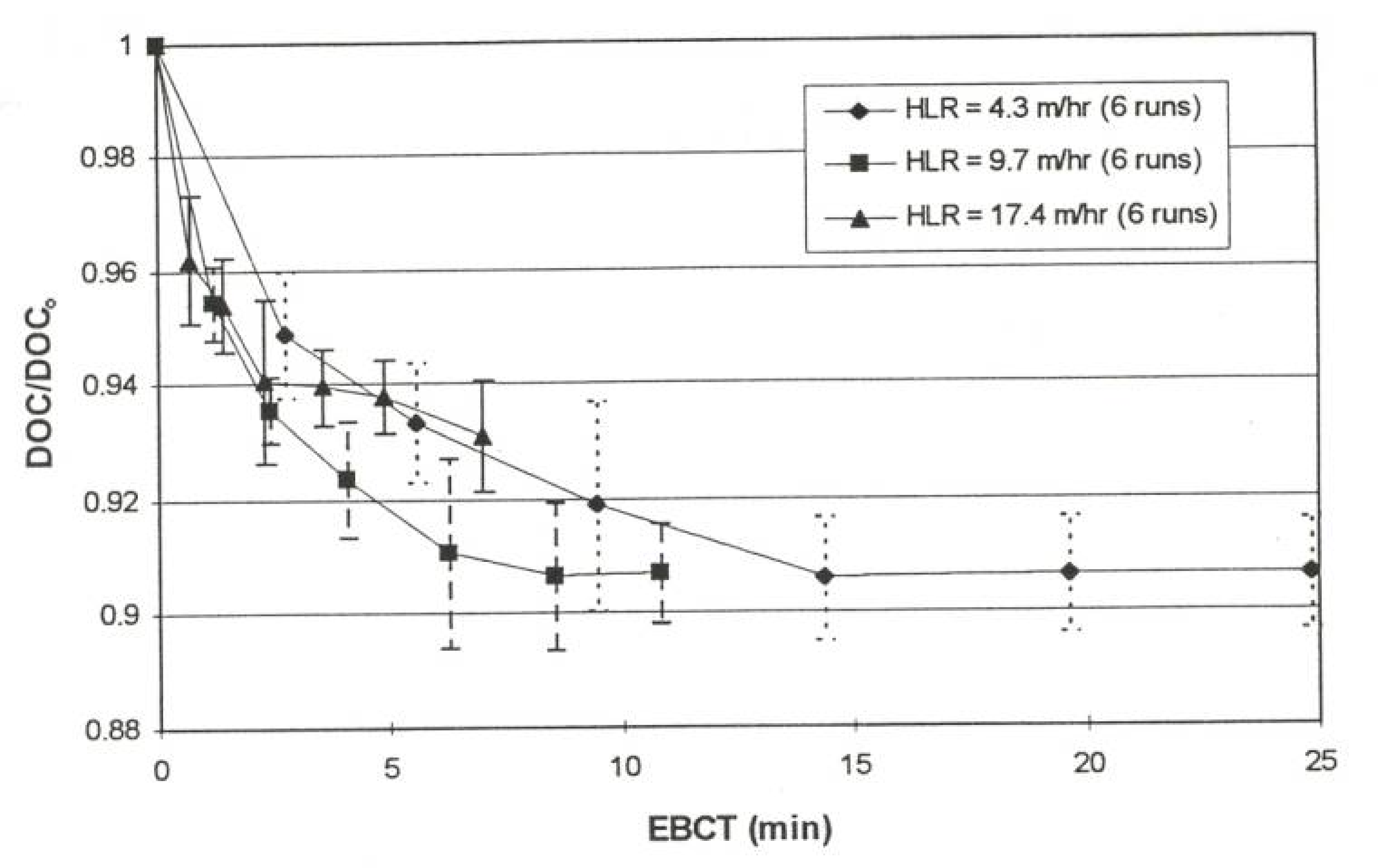


Source: Amy & Carlson (2005)

Advantages of BAC

- Has a relatively small footprint
- Can be more easily adjusted/modified
- Can be easily integrated with existing conventional treatment systems

DOC Removal vs. EBCT and HLR



DOC ∝ EBCT; DOC ∝ 1/HLR

Comparison of RBF and SSF based on Partinoudi (2004) and literature values

Parameter	Removal by **RBF** (Partinoudi, 2004)	Removal by **SSF** (Partinoudi, 2004)	Removal by **SSF** (based on literature)
DOC	41-85%	13-19%	8-25%
Total Coliforms	>1-1.6 logs*	>1.8-2.2 logs	>1-2 logs*
E.coli	>0.3-0.8 logs*	>1.8logs	>3-4 logs*
Aerobic spores	>1.9-3.5 logs*	>2.1-2.3logs*	>2 logs
Turbidity	77-99%	75-90%	60->90%

* Reduced to detection limit

Conclusions

- SSF and RBF are better at removing microorganisms than BAC
- Protists predation typically found in SSF and RBF but not in BAC
- Removal of DOC are comparable except in RBF where groundwater dilution can play a dominant role
- RBF is more robust to water quality/variations than SSF and BAC because of greater residence times/travel distances
- SSF and BAC are more amenable to modifications/improvements than RBF

Acknowledgments

- EPA for funding this project
- Senators B. Smith and J. Gregg for sponsoring the TACs
- The operators and managers of all the treatment facilities involved in these studies.
- NE-WTTAC staff and past grad students

QUESTIONS ?