



# **ASSESSMENT OF THE MICROBIAL REMOVAL CAPABILITIES OF RIVERBANK FILTRATION**



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# PROJECT OBJECTIVES

- To assess riverbank filtration as a viable treatment and pretreatment option;
- To quantify the contribution of river water and groundwater to the *RBF* extraction water;
- To compare riverbank filtration to slow sand filtration in terms of particulate, organic precursors and microbiological removal capabilities expressed in log removal credits.



# ASSESSING REMOVAL CAPABILITIES OF RBF

- Difficult to assess removal capability:
  - What is the travel time from the river to the well?
  - due to subsurface filtration?
  - due to groundwater dilution?



# OPERATIONAL FIELD SITES SELECTED

- Pembroke, NH (8/01-11/02, n=19)
- Milford, NH (11/01-11/02, n=13)
- Jackson, NH (5/02-11/02, n=3)
- Louisville, KY (9/01-5/03, n=11)
- Cedar Rapids, IA (9/02-4/03, n=5)



Cedar Rapids, IA

Louisville, KY





# PEMBROKE, NH

- Soucook River
- Vertical well
- 30.5cm diameter
- 17m deep well
- 55m from the river
- Samples collected
  - River
  - Groundwater source
  - RBF extraction well





# MILFORD, NH

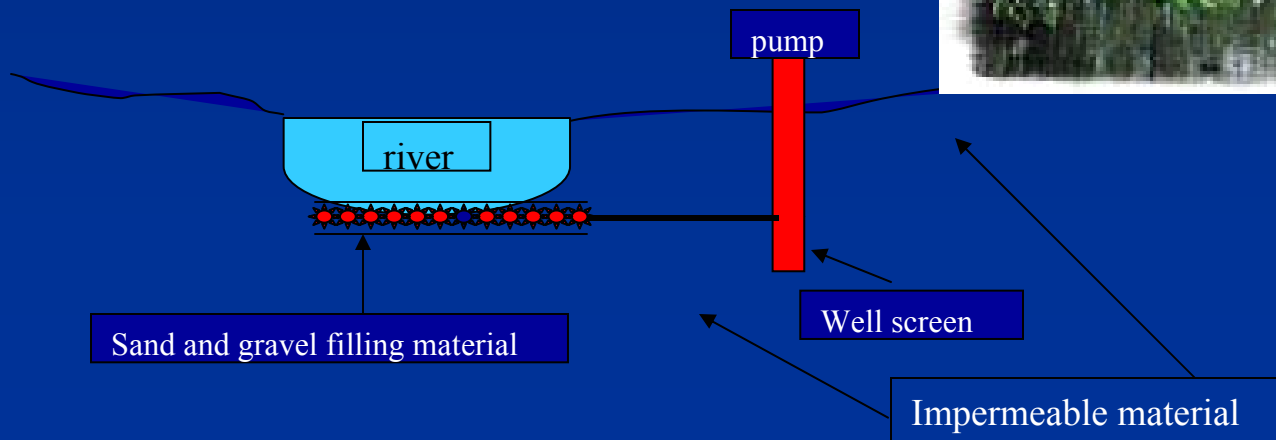
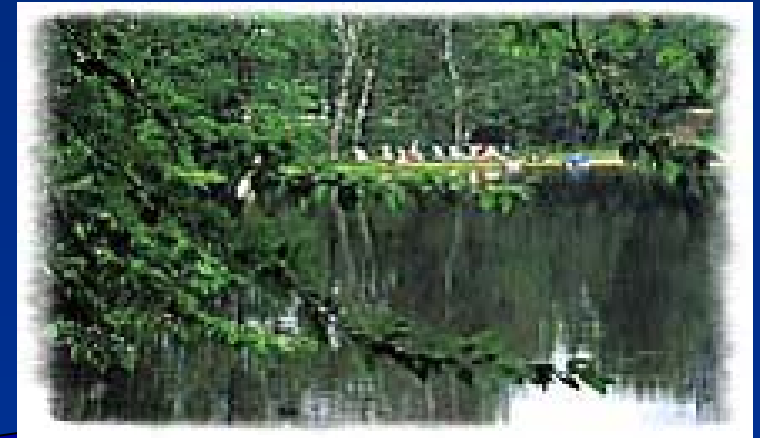
- Souhegan River
- Vertical well
- 61cm diameter
- 19.8m deep well
- 23m from the river
- Samples collected
  - River
  - Groundwater source
  - RBF extraction well





# JACKSON, NH

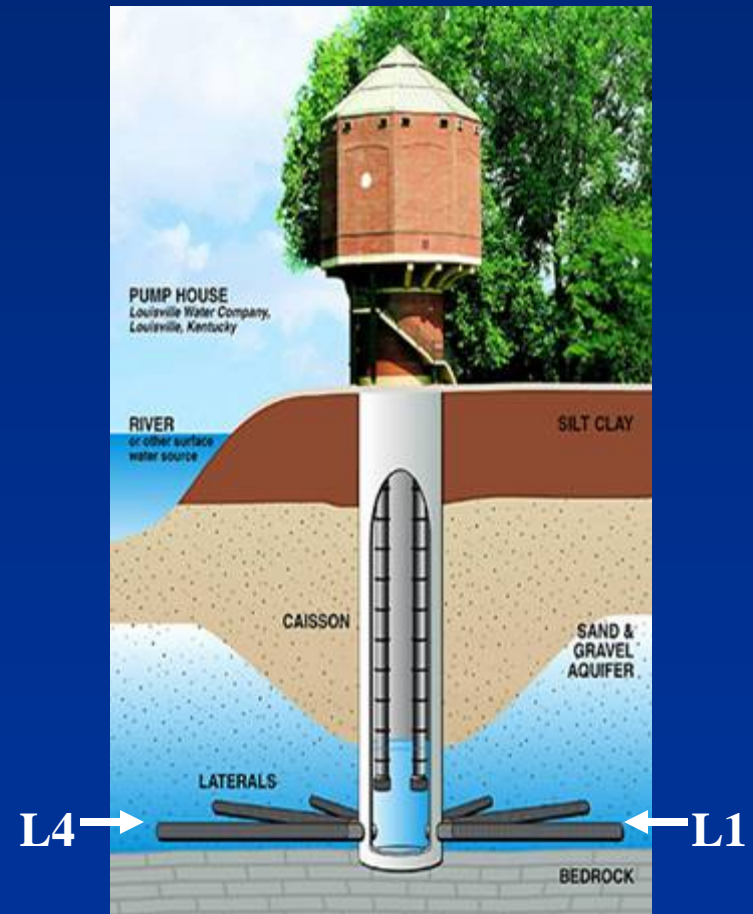
- Ellis River
- 5 infiltration galleries
- 6.1m long, 1.2m deep, 1.2m wide each
- Samples collected
  - River
  - Groundwater source
  - RBF extraction well





# LOUISVILLE, KY

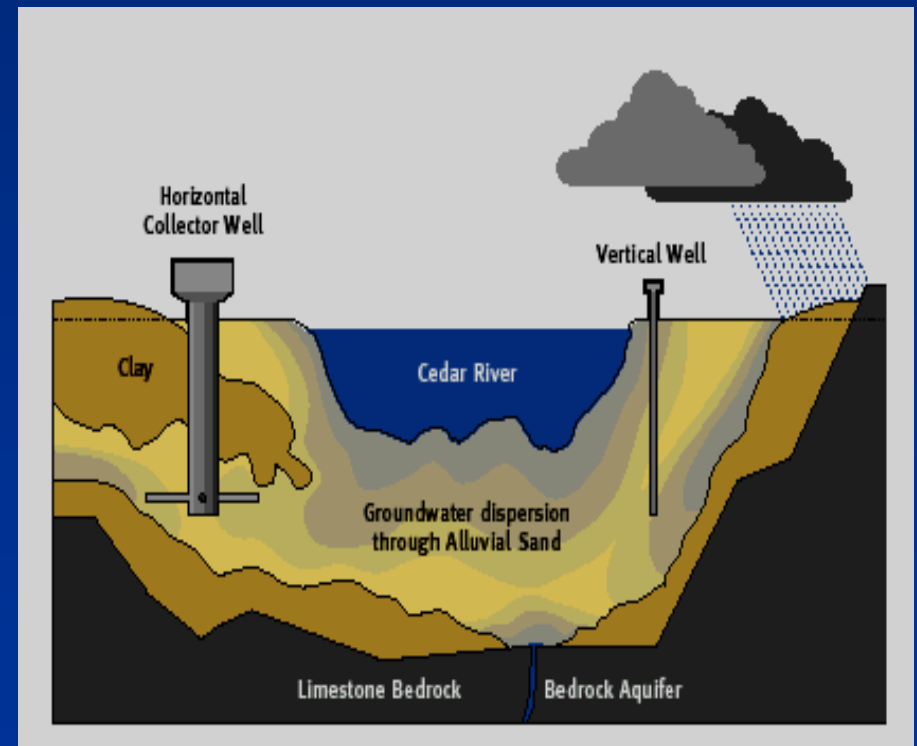
- Ohio river
- Horizontal well
- 7 laterals
- 6.1m diameter caisson
- 12.2m deep
- Samples collected:
  - River
  - L1 (used as groundwater source)
  - L4 (used as RBF extract)





# CEDAR RAPIDS, IA

- Cedar Rapids River
- Vertical well
- 19.5m from the river
- 17.4m deep
- 10.7cm diameter
- Samples collected:
  - River
  - Groundwater source
  - RBF extraction well





# CHARACTERIZATION OF SAMPLING SITES

Sampling Site	Source river water	Distance between the RBF well and the river
Pembroke (NH)	Soucook River	54.9m
Milford (NH)	Souhegan River	22.9m
Jackson (NH)	Ellis river	5 infiltration galleries each: 6.1m long, 1.2m deep, 1.2m wide
Louisville (KY)	Ohio River	Horizontal well RBF sampling lateral 12.2m below the riverbed
Cedar Rapids (IA).	Cedar River	19.5m



# What is the estimated travel time from the river to the well?

Sampling Site	Travel Time	Evaluation of Travel Time
Pembroke, NH	5 days	Darcy's Law in terms of seepage velocity
Milford, NH	1 day	Darcy's Law in terms of seepage velocity
Jackson, NH	<2hrs	Infiltration Gallery
Louisville, KY	1 day	Information provided by the LWC (AWWARF, 2002)
Cedar Rapids, IA	5 days	Information provided by the City of Cedar Rapids Water Department (Schulmayer, 1999)



# How much removal is due to filtration and how much due to dilution with groundwater?

Color	Temperature	Conductivity
Sulfate	UV <sub>254</sub> absorbance	Hardness
Chloride	Particle counts	Alkalinity
pH	Radon	Redox potential



# How much removal is due to filtration and how much due to dilution with groundwater?

	% river water in <i>RBF</i> well	% Groundwater in <i>RBF</i> well	Parameter upon which ratio is based
Pembroke, NH	40.7±3.7	59.3±3.7	Conductivity
Milford, NH	40.8±6.4	59.2±6.4	Sulfate
Jackson, NH	100	0	Infiltration Gallery
Louisville, KY	78.1±4.4	21.9±4.4	Hardness
Cedar Rapids, IA	70	30	Groundwater Flow Modeling



# SELECTED WATER QUALITY PARAMETERS REMOVALS

<b>Parameter</b>	<b>% Total Removal Range</b>	<b>Weighted % average of RBF total removals observed</b>
DOC	18-92	63
UV254 abs.	23-100	73
True Color	50-100	89
Particle Counts	70-99	94
Turbidity	72-99	87



# INFLUENCE OF GROUNDWATER DILUTION ON SELECTED PARAMETERS

<b>Parameter</b>	<b>% TOTAL Removal</b>	<b>% Removal due to DILUTION</b>	<b>% Removal due to SUBSURFACE FILTRATION</b>
<b>DOC</b>	<b>63</b>	<b>11</b>	<b>55</b>
<b>Turbidity</b>	<b>87</b>	<b>10</b>	<b>77</b>



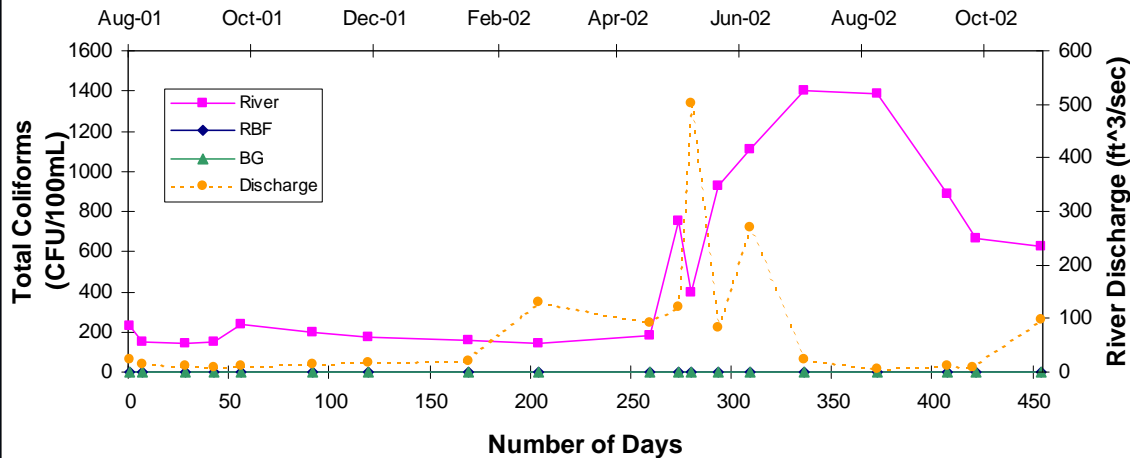
# MICROBIAL ANALYSES

- Total coliforms and *E.coli*
- Aerobic Spore Forming Bacteria
- Virus indicators (male specific & somatic bacteriophage)
- Enteric Viruses
  - Adenovirus Type 40 and 41
  - Astrovirus
  - Enterovirus (poliovirus, coxsackie virus, rotavirus and echovirus)



# TOTAL COLIFORMS (CFU/100mL)

Typical Total Coliforms (CFU/100mL) Variations (n=19) as a Function of River Discharge in Pembroke, NH (8/01-11/02) Including Groundwater Dilution Impacts

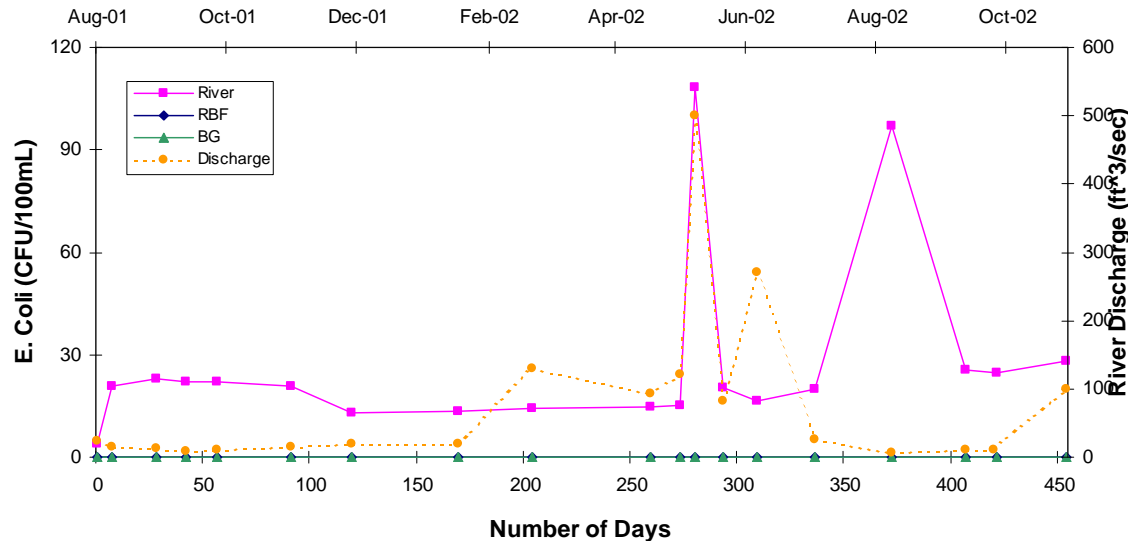


Sampling site	Total removal
Pembroke, NH	>2.1 log
Milford, NH	>2.6 log
Jackson, NH	>0.5 log
Louisville, KY	>1.0 log
Cedar Rapids, IA	>1.4 log



# *E.coli* (CFU/100mL)

Typical Variations of *E. Coli* (CFU/100mL) (n=19)  
as a Function of River Discharge in Pembroke, NH (8/01-11/02)  
Including Groundwater Dilution Impacts

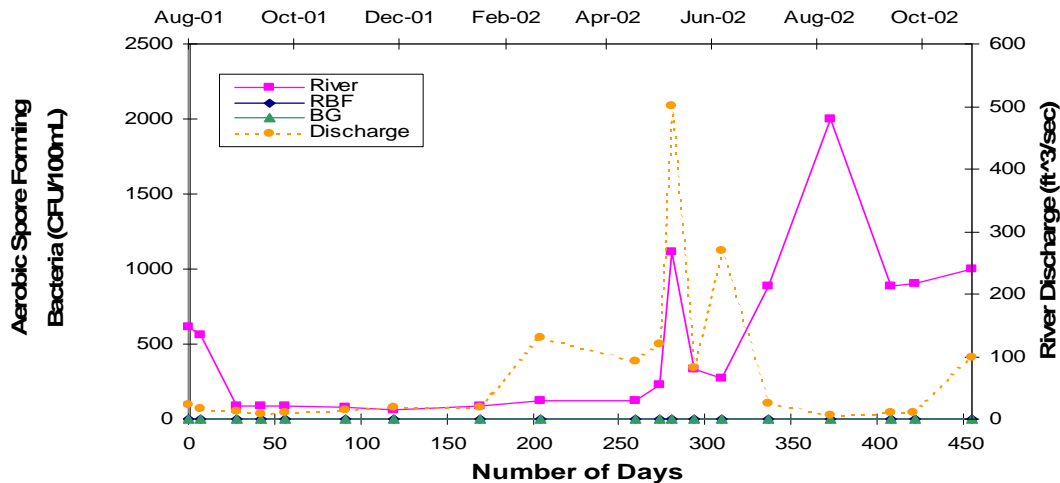


Sampling site	Total removal
Pembroke, NH	>0.6 log
Milford, NH	>0.8 log
Jackson, NH	>0.4 log
Louisville, KY	>0.3 log
Cedar Rapids, IA	>0.7 log



# AEROBIC SPORE FORMING BACTERIA (CFU/100mL)

Typical Aerobic Spore Forming Bacteria (CFU/100mL) Variations (n=19) as a Function of River Discharge in Pembroke, NH (8/01-11/02) Including Groundwater Dilution Impacts



Sampling site	Total removal
Pembroke, NH	>1.9 log
Milford, NH	>2.1 log
Louisville, KY	>3.5 log
Cedar Rapids, IA	>2.6 log



# VIRUS INDICATORS (PFU/100mL)

- Male Specific Bacteriophage (including MS2)
- Somatic Bacteriophage
- Intensive sampling (Dec 2002): Louisville (n=4)

Cedar Rapids (n=5)

		Range (PFU/100mL)		
Sampling site	Total removal of MS	river water	RBF extracted water	Groundwater
Louisville, KY	$\geq 0.2 \log$	4622 $\pm 25$	3703 $\pm 22$	3402 $\pm 18$
Cedar Rapids, IA	$\geq 0.7 \log$	3453 $\pm 20$	753 $\pm 9$	BDL

Where Range=average  $\pm$  analytical error

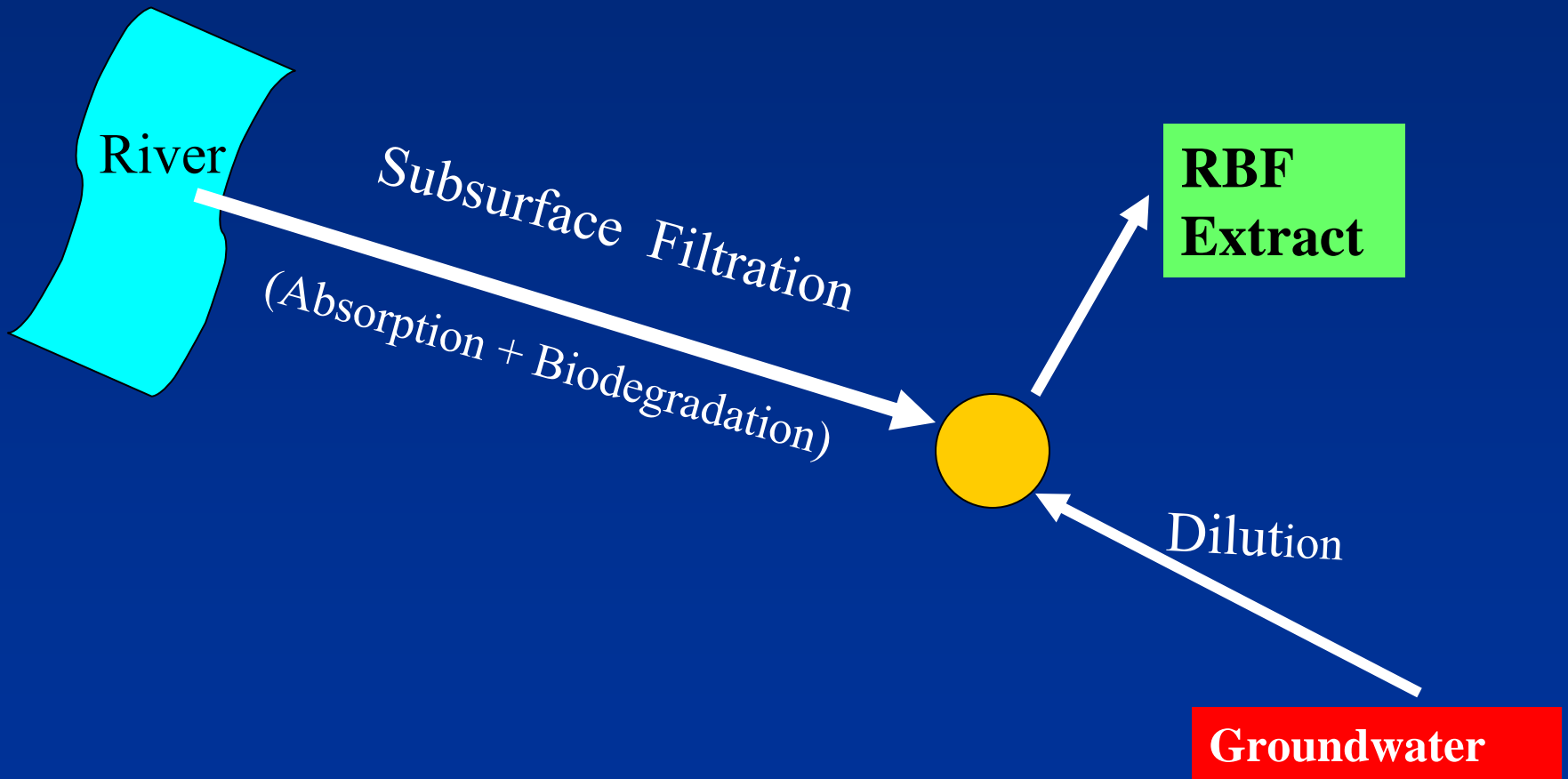


# VIRUSES

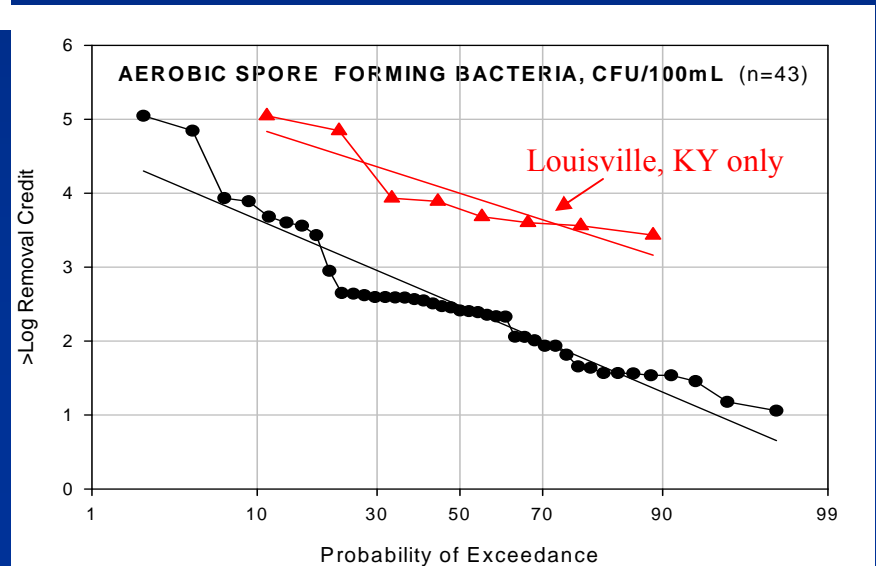
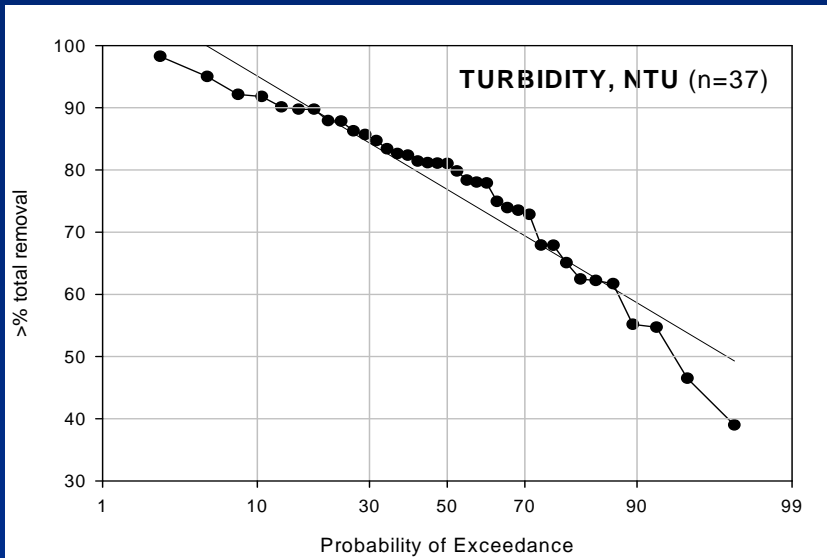
- None detected (ICC-RT-nPCR method) in the samples collected in Louisville, KY nor in Cedar Rapids, IA.

	Liters of water collected	
Sampling site	River	RBF extract
Louisville, KY (3/03)	100L	1000L
Cedar Rapids, IA (1/03)	362L	995L

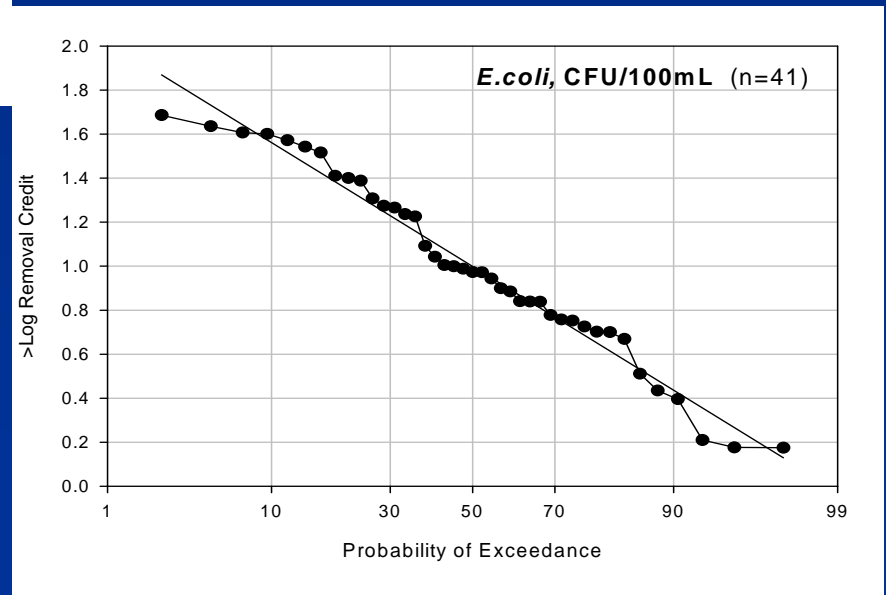
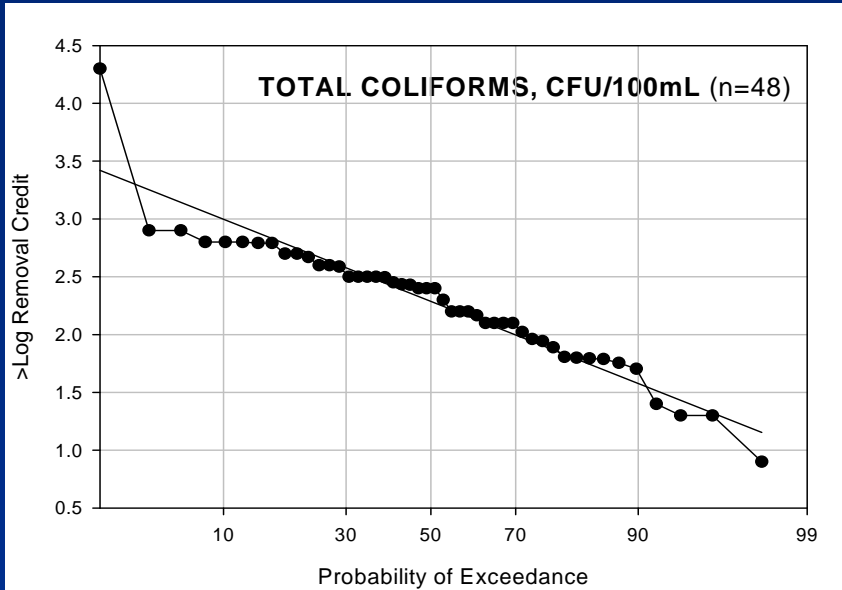
# Processes Taking Place at an RBF site



# TREATMENT PROBABILITY DUE TO SUBSURFACE FILTRATION (most conservative estimation for RBF)



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# SUBSURFACE FILTRATION MICROBIAL PROBABILITY REMOVALS

Parameter	>70% (probability of exceedance)	>90% (probability of exceedance)
Turbidity	73%	55%
Total coliforms	2.1 log	1.7 log
<i>E.coli</i>	0.8 log	0.4 log
ASFB (spores)	2 log	1.5



# SUMMARY OF MOST CONSERVATIVE AVERAGE SITE REMOVALS

Parameter	Minimum removal*
Turbidity	>74%
E.coli	>0.3 log
Total coliforms	>1.0 log
Aerobic Spores	>1.9 log

\*based on subsurface filtration only, limited by river water concentrations, and RBF site of lowest average removals.



# CONCLUSIONS

RBF shows potential to be a viable pretreatment and treatment process and warrants log removal credits for microbial pathogen removal



# AKNOWLEDGEMENTS

- EPA for funding this project through the New England Water Treatment Technology Assistance Center
- N. Ballester & J. Fontaine, UNH
- The Pembroke, NH Waterworks personnel
- The Louisville Water Company, KY
- The Milford, NH Fish Hatchery personnel
- The Jackson, NH Waterworks personnel
- The Cedar Rapids Water Department, IA
- M. Smith, UNH



QUESTIONS?