Meeting
Filtration and Disinfection By-Product Rules
with
Modified Slow Sand Filtration

Clean and Safe Drinking Water Workshop
Newfoundland and Labrador
2011

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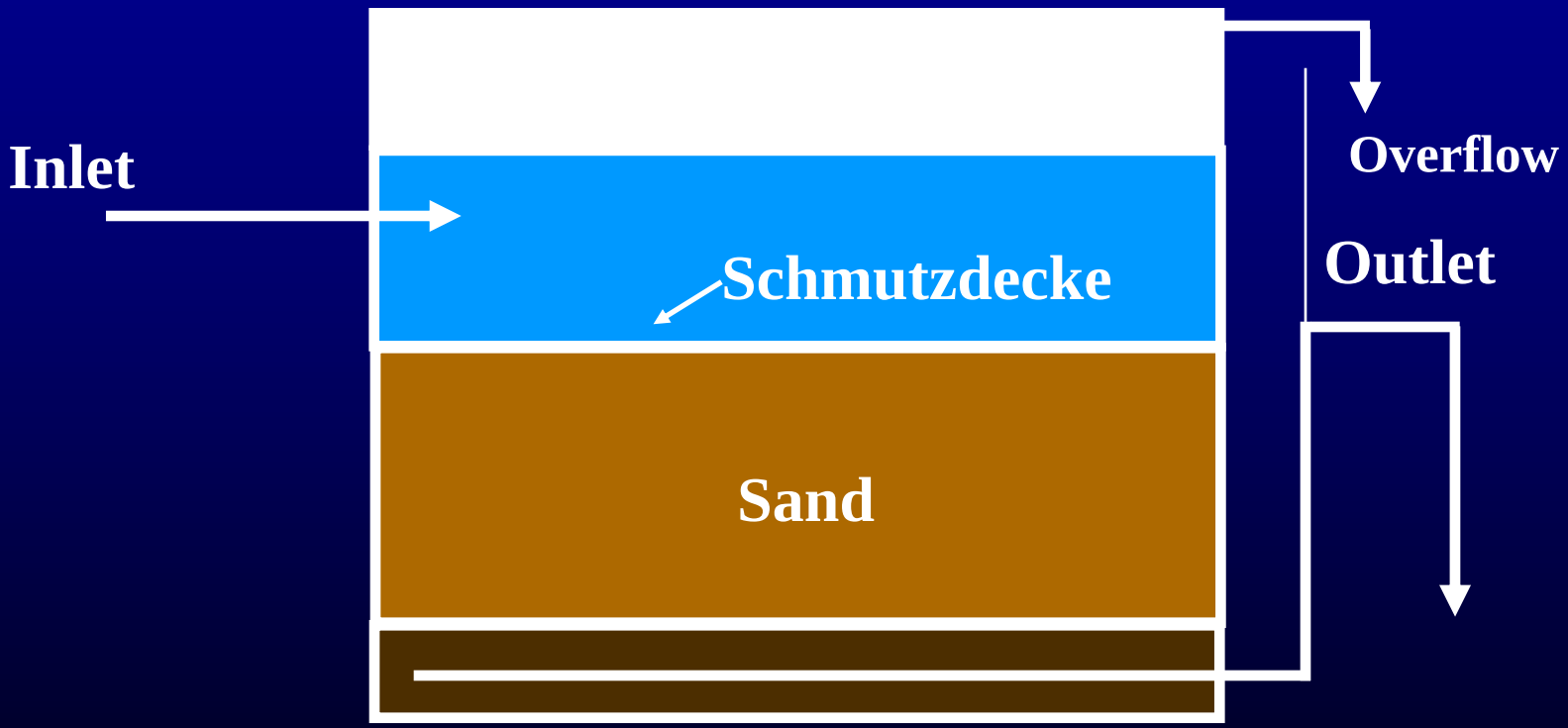
Slow Sand Filtration

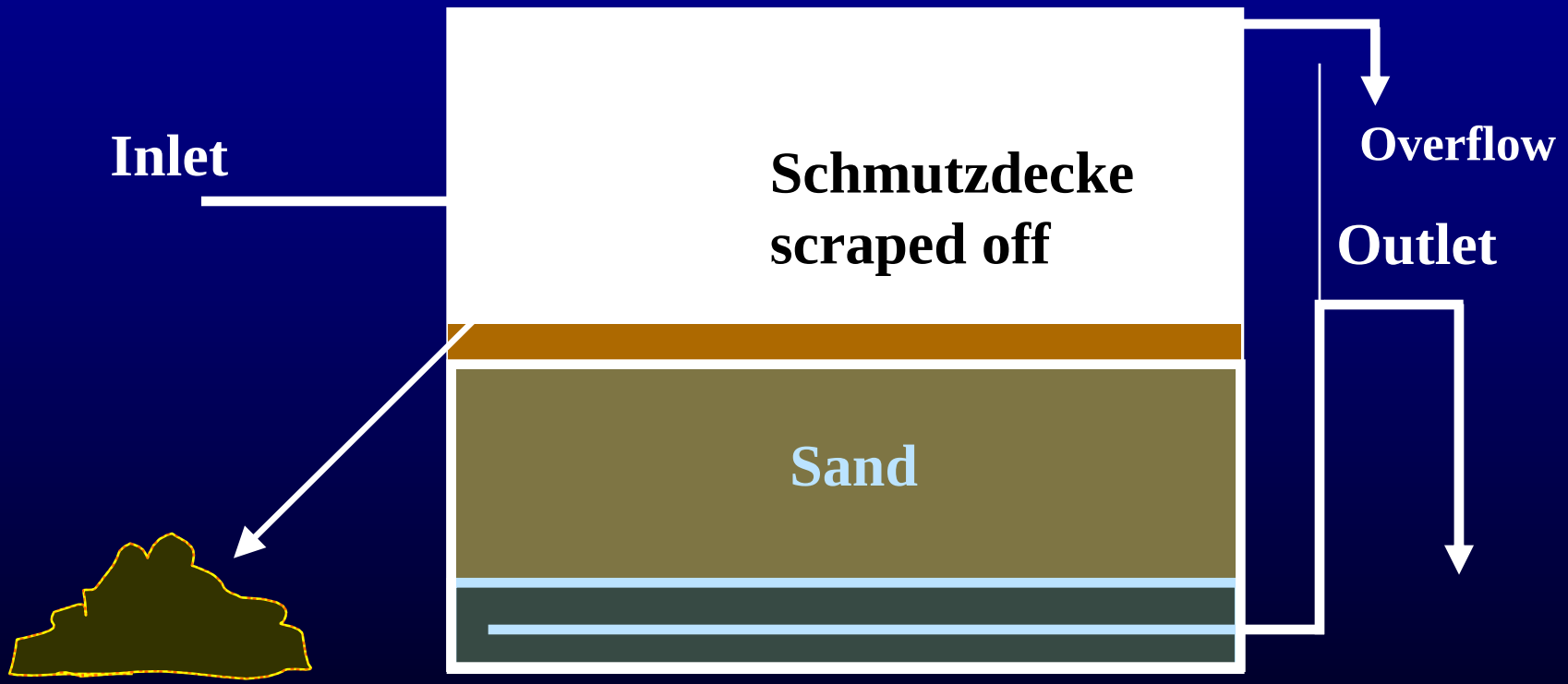
Why resurgence in popularity?

- Meets ALL regulatory requirements
- Low O & M costs / lowest life-cycle costs
- Relatively low operator skill level
- Simple process - no coagulation chemicals
- Serviceable by local trades

BASIC SLOW SAND FILTER



BASIC SLOW SAND FILTER



Modified Slow Sand Filtration

= Conventional Slow Sand Filtration

(Simple Operation – Low O & M Cost)

+

Additional Unit Processes

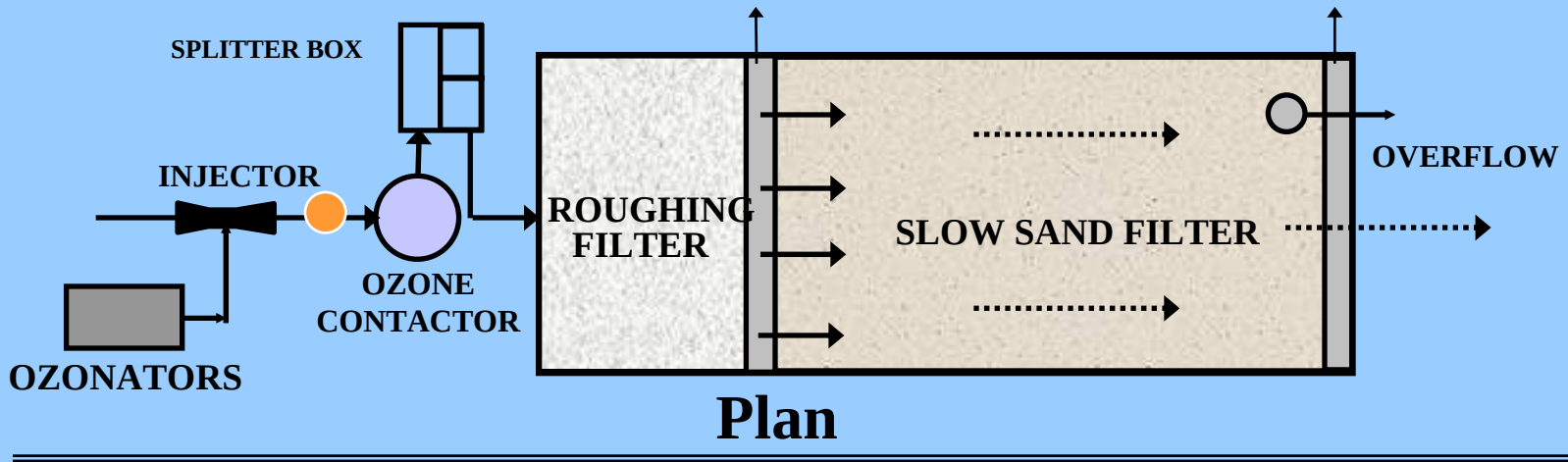
(Water Quality-Dependent)

Modified Slow Sand Filtration

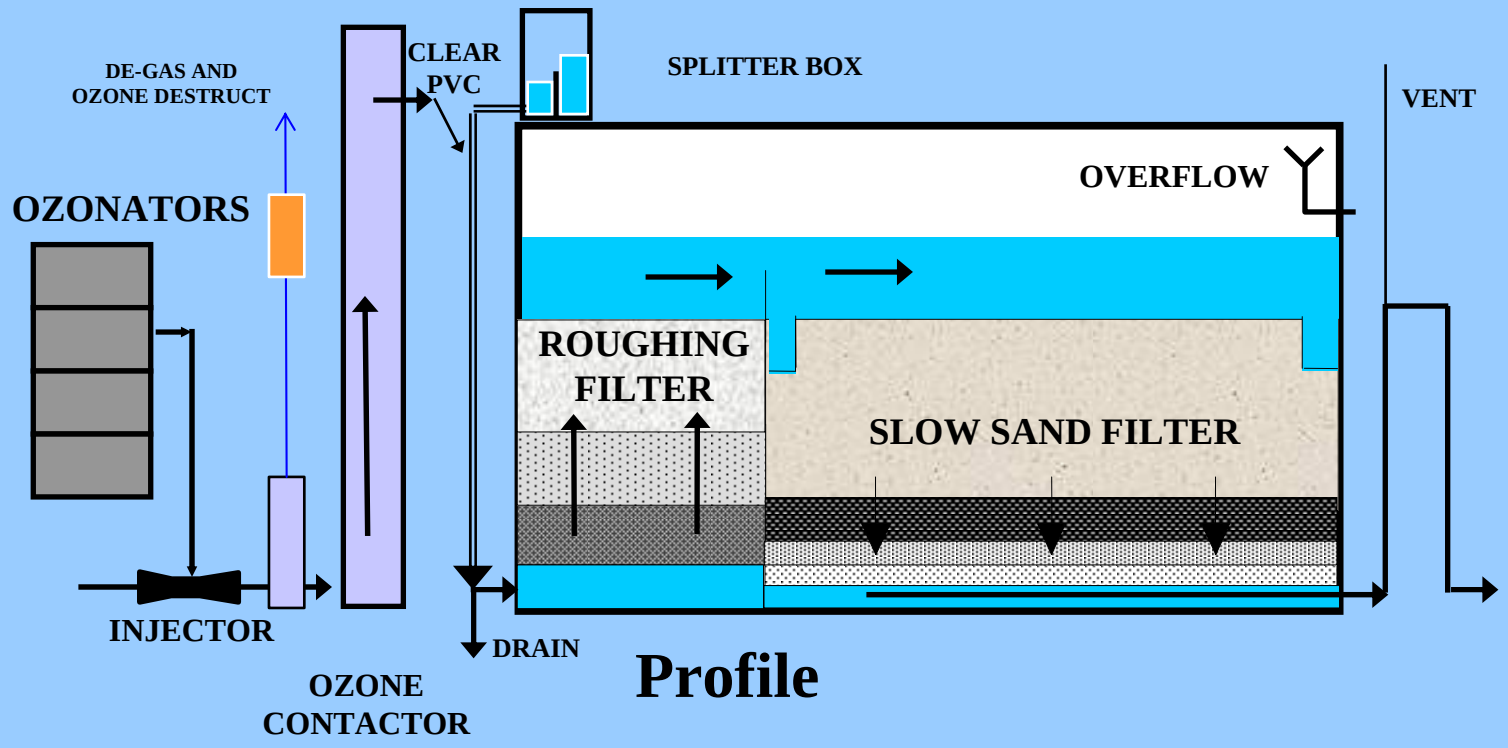
Unit Processes Can Include:

- Ozonation and/or AOP (oxidation)
- Roughing filtration (solids removal)
- Post-treatment BAC filtration (additional biofiltration stage)
- Post-treatment limestone contactor (corrosion)
- Post-treatment disinfection (required)

Modified Slow Sand Filter



Plan



Profile


Ozone Application

Modified Slow Sand Filtration

Coagulation Chemicals Not Used

- Natural Organic Colour = Large Complex Molecules - Not Biodegradable (DBP Precursors)
- Complex Organics Oxidized into assimilable organic carbon (AOC)
- Resulting "AOC" = More Bio-available Food Source for Microorganisms
- Coagulants = 80 to 95% of sludge therefore no Coagulant = far less sludge

Modified Slow Sand Filtration

Enables treatment of poor quality source water

- Pre-Ozonation
  - Converts TOC to AOC; Oxidizes Fe, Mn
  - Powerful Disinfectant
- Roughing filter with GAC cap
  - Extends range of raw water turbidity
- Package Plant with “Automated” Cleaning
- Effective for a broad spectrum of pathogens and contaminants

Slow Sand Filtration

Slow Sand Meets Regulatory Requirements

- Health Canada Treatment Guidelines
- USEPA – Slow Sand Plants Average 3-log removal of *Cryptosporidium* oocysts
- Ontario MOE: Roughing Filter + Slow Sand (No Ozone) = 2.5-log *Giardia* removal credit
- Documented ability to remove protozoan cysts and oocysts; > 5-log removal reported

Protozoan Cyst / Oocyst Removal

- Recent *Cryptosporidium* oocyst removals reported for slow sand filtration:
  - 4.0 – 4.7 log (Anderson & Huck, 2005)
  - 4.0 log (DeLoyde, 2007)
  - 4.7 log (Hijnen et al, 2007)
  - 5.3 log (Dullemont et al, 2006)
- *Giardia* cyst removal generally better than *Cryptosporidium* oocyst removal

Protozoan Cyst / Oocyst Removal

- High cyst / oocyst removals consistent with earlier literature on slow sand filtration
- Cyst / oocyst removal occurs in upper layers of the slow sand filter
- Predation and/or biodegradation
- Very low risk of delayed breakthrough

Bacteria / Virus Removal

- Minimum 4.0 log reovirus removal reported
- Poliovirus removal significantly better than MS2 bacteriophage removal
- *Bacillus* spores and *E. coli* similar; consistently >2.5 log removal reported
- Removal efficiencies organism-specific
- Required post-treatment disinfection generally effective for bacteria and viruses

REMOVAL OF:

Pharmaceuticals
Personal Health Care Products &
Endocrine Disrupting Compounds
(= “PPHCPs” & “EDCs”)

and Other Exotic Compounds

PPHCPs & EDCs

- Analytical capabilities for contaminants in drinking water are constantly improving
- Reasons for concern:
  - Pharmaceuticals often engineered to target specific organs
  - Certain EDCs and pharmaceuticals have a non-linear dose-response
    - Physiological effect becomes greater as the dose is reduced

PPHCPs & EDCs

- Biological filtration reported to remove many common compounds including:
  - Certain classes of antibiotics (tetracycline, quinolone, and macrolides)
  - Acetaminophen, caffeine, DEET, ibuprofen
- Certain polar pharmaceuticals are not effectively removed by biological filtration

Tastes & Odours
Biological Filtration Alone

- Geosmin / 2-MIB removed from 25 ng/L to threshold odour level with biologically-active GAC filters
- 100 ng/L influent concentrations of geosmin reduced by ~ 60%
- 100 ng/L influent levels of 2-MIB reduced by ~ 40%

(1 ng/L = 1 ppt)

PPHCPs & EDCs

- Ozone + biofiltration effective treatment for most PPHCPs and EDCs (80 different compounds – Westerhoff, 2003)
- Many compounds not removed by biological treatment were oxidized by ozone (synergy)
- Oxidation byproducts of EDCs and PPHCPs were removed or reduced by biological filtration

Microcystins

- Biological and slow sand filtration effective at reducing microcystin-LR
- Ozone very effective at removing moderate and high levels of microcystins
- The combination of ozone with biological (slow sand) filtration provides two levels of protection

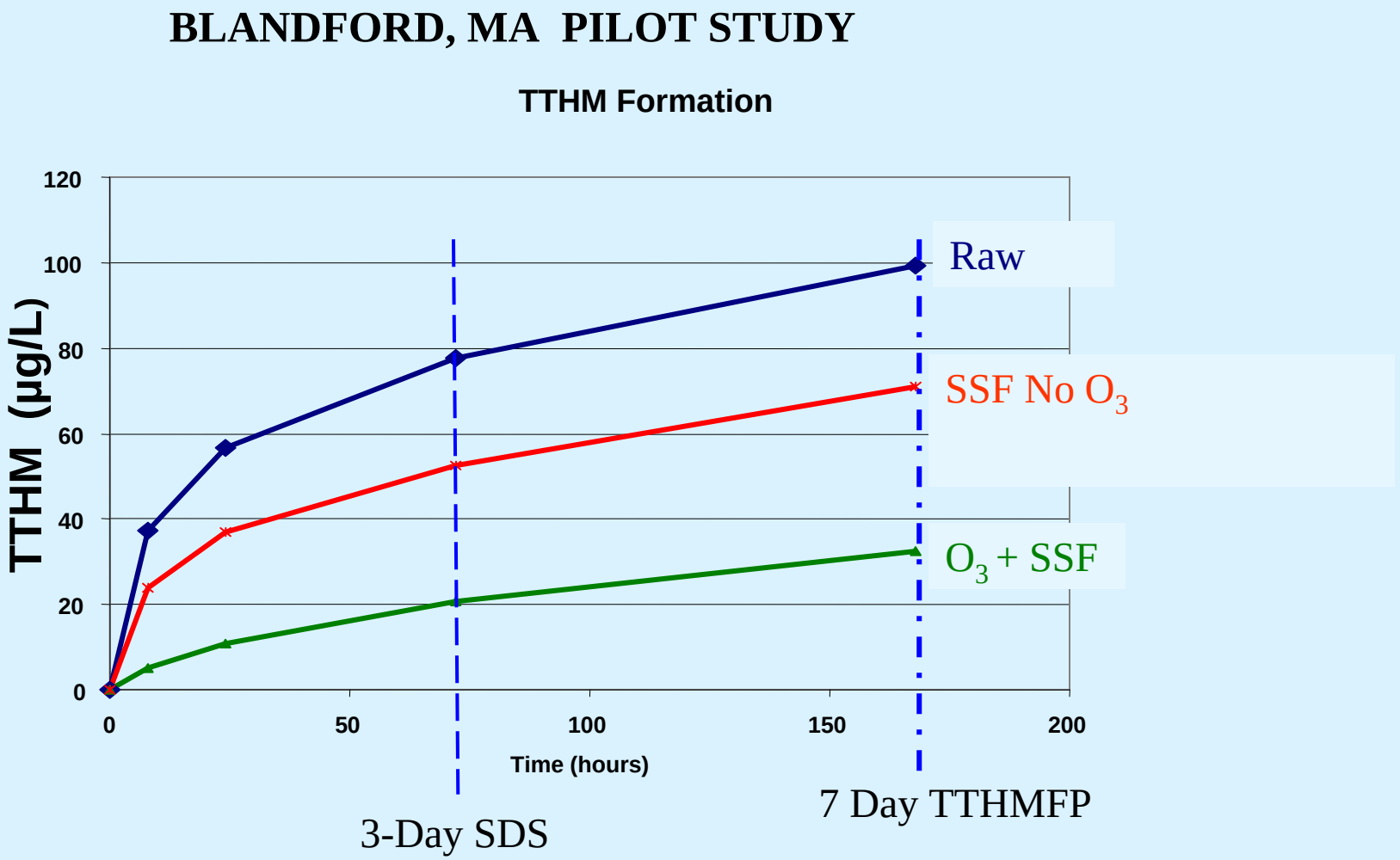
Modified Slow Sand Filtration

Removal of AOC (or BDOC) following ozonation is very important:

- Can lead to regrowth
- May increase DBPs
- Biological treatment very effective

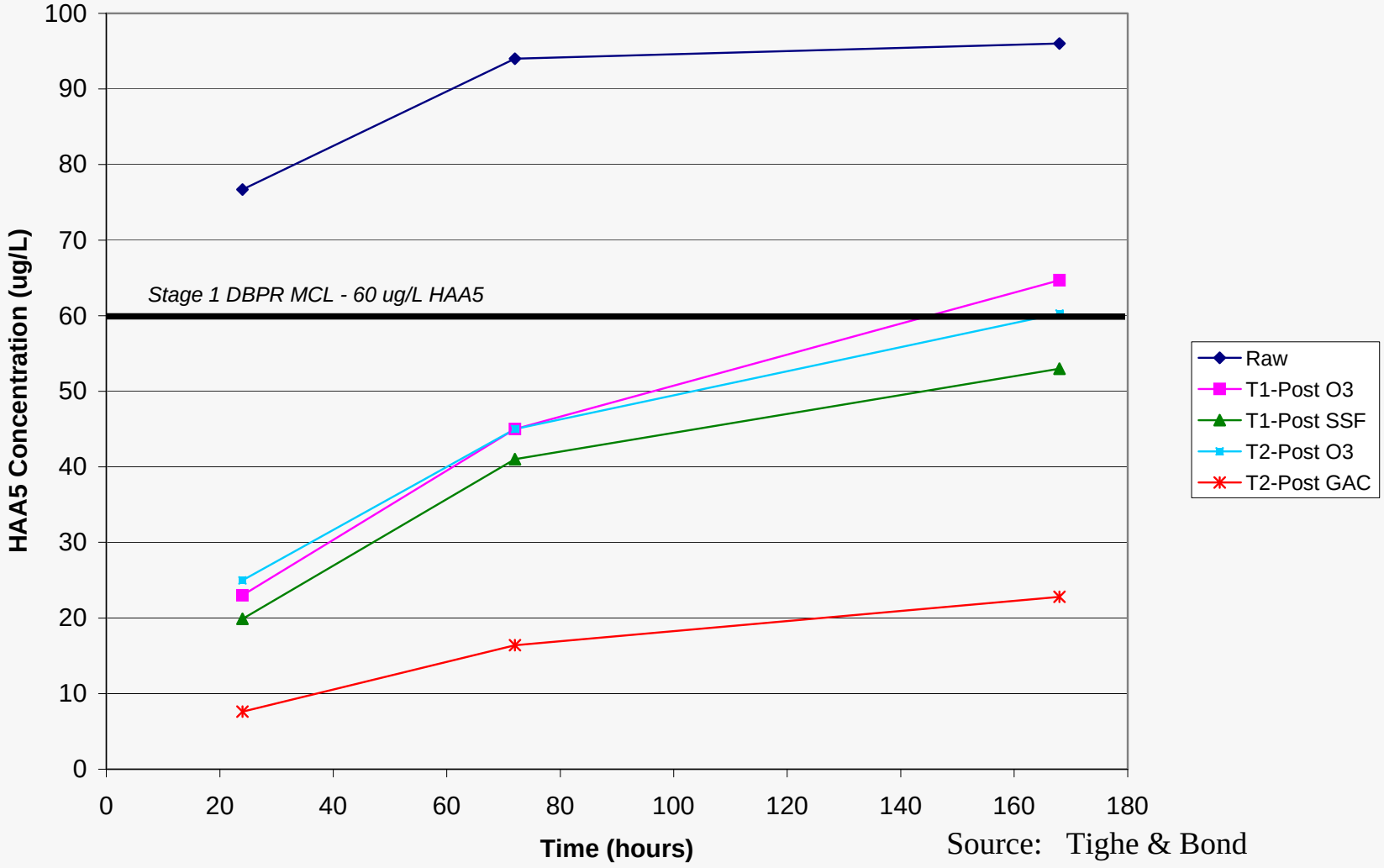
- TOC removals using O_3 + biofiltration similar to alum coagulation
- Excellent DBP precursor removal

TTHMFP Reduction



HAA_5

Blandford MA Pilot Study



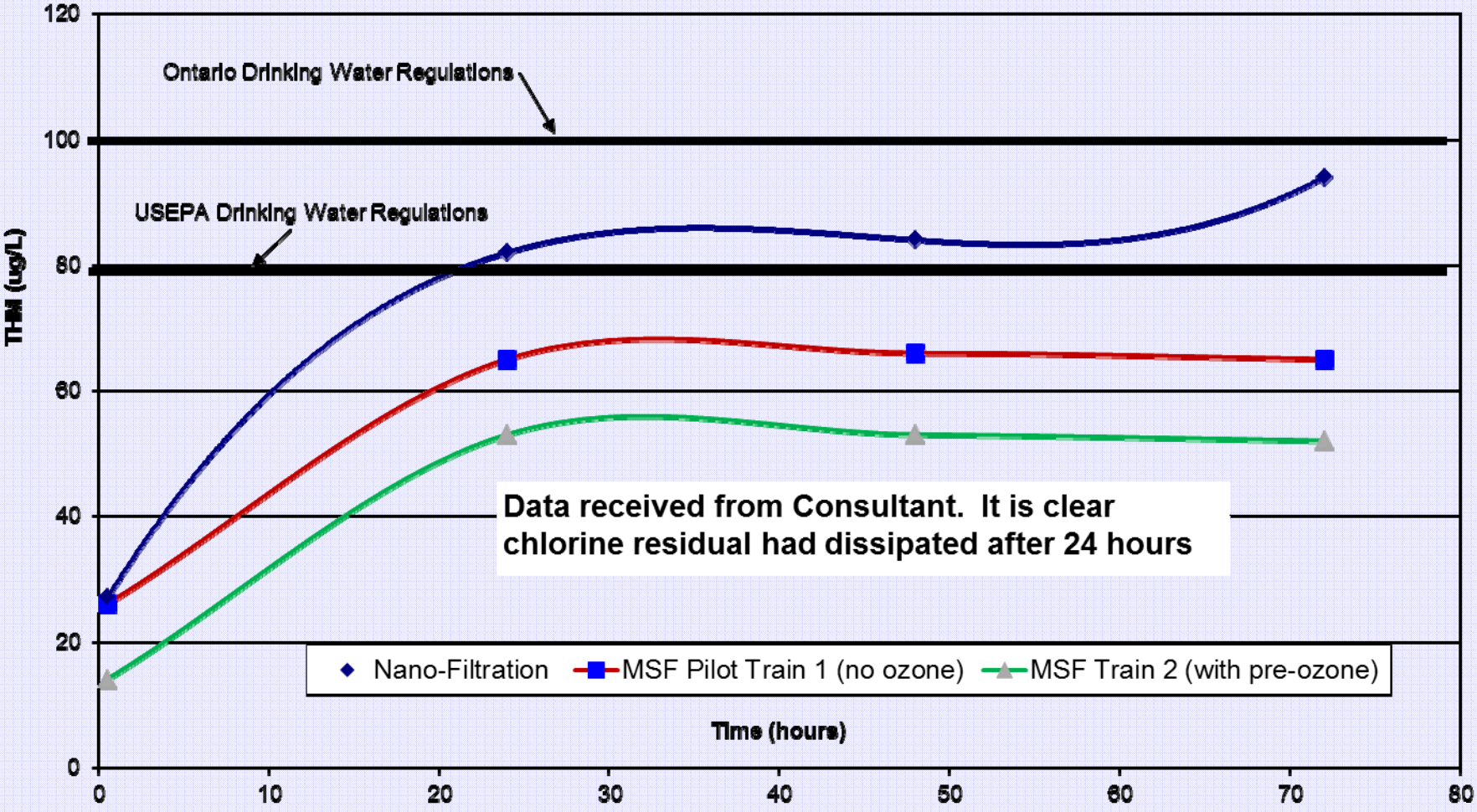
Source: Tighe & Bond

Developments in **Ozone-Assisted Biofiltration**

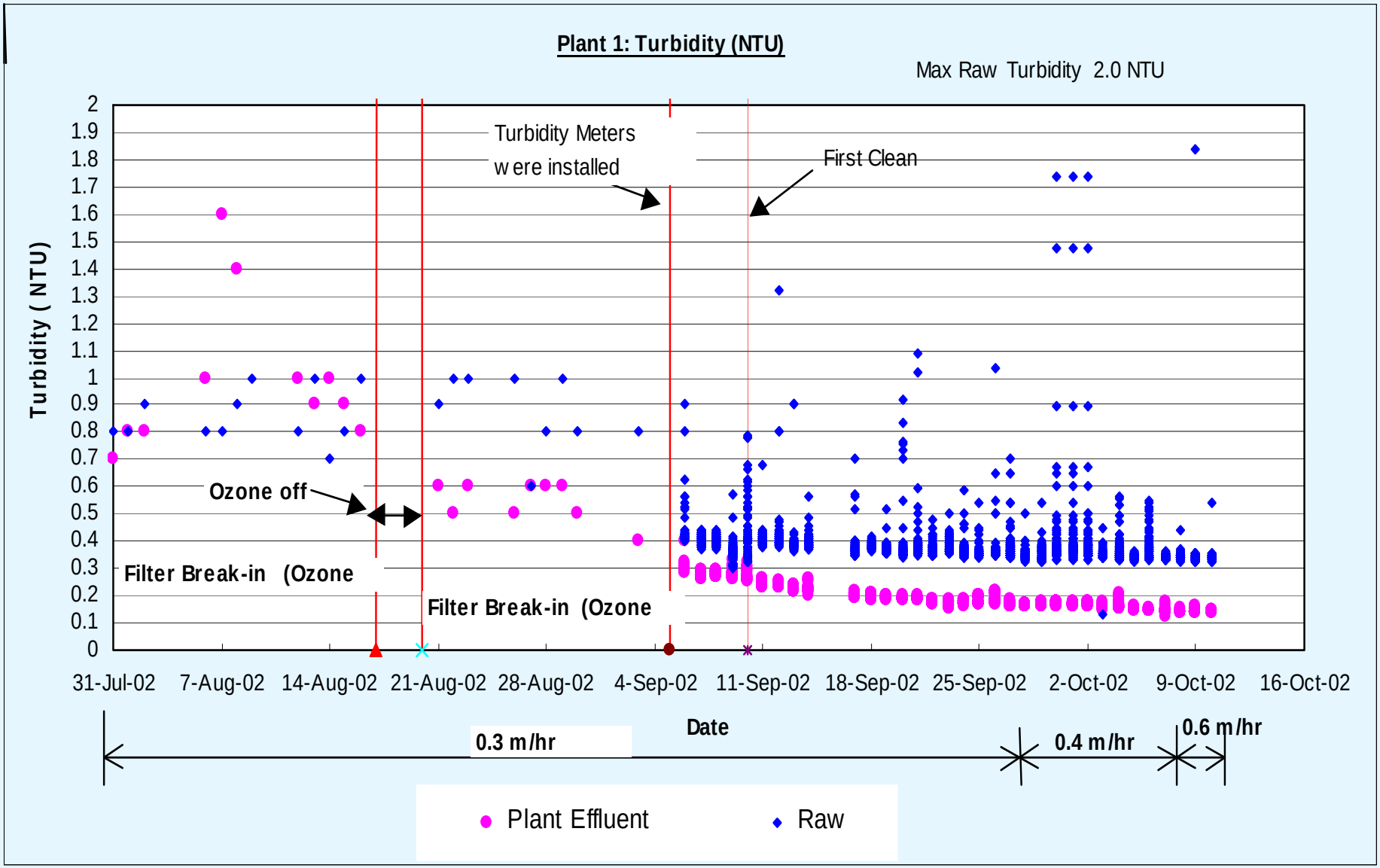
- Blandford, MA - Actual operating data, August 2007

THMs	µg/L	HAA_5	µg/L
Chloroform	27	MCAA	ND
BDCM	3.8	DCAA	0.98
DBCM	0.73	TCAA	0.58
Bromoform	ND	MBAA	ND
Total THM	**31.53**	DBAA	ND
		Total HAA_5	1.54

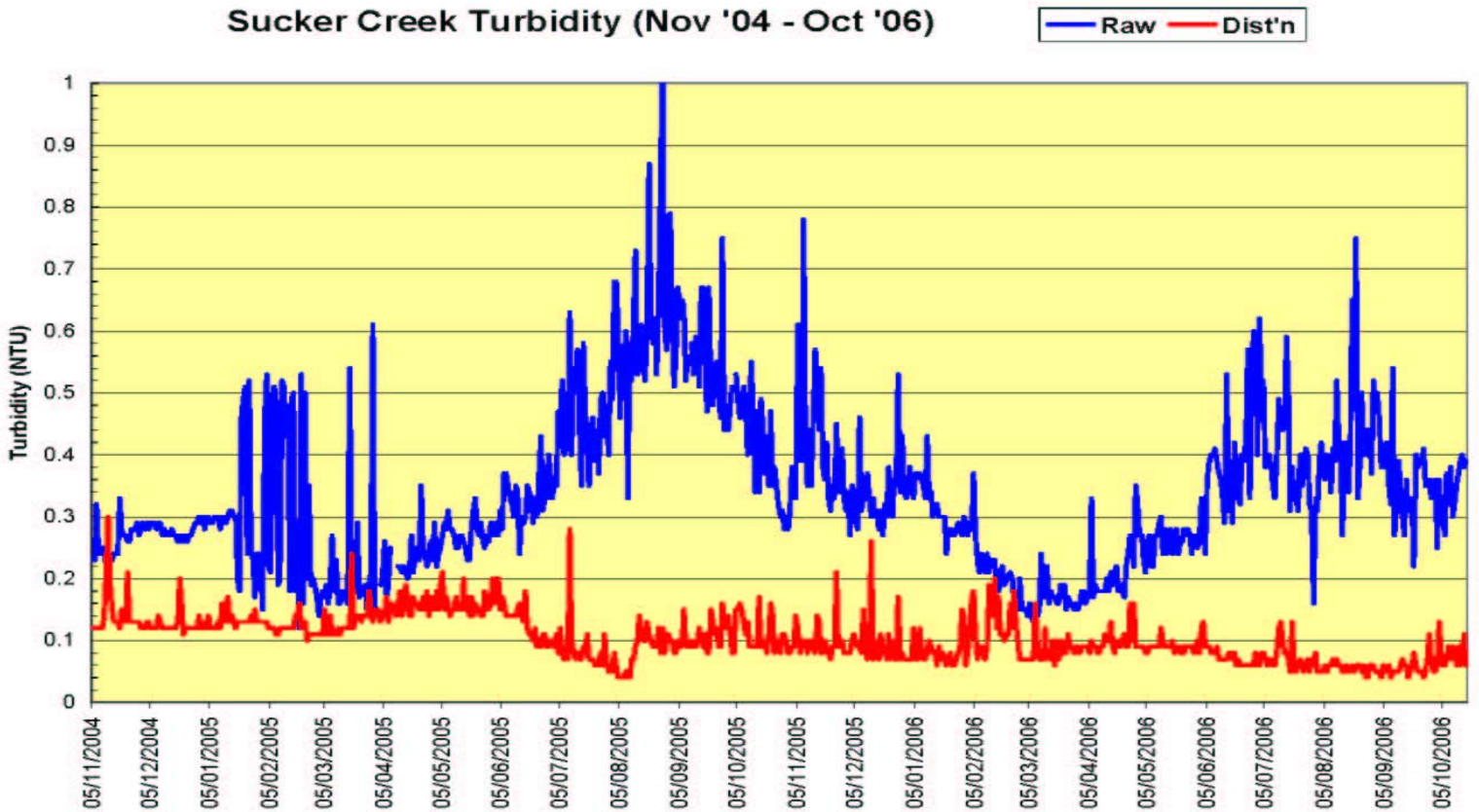
SERPENT RIVER ONTARIO PILOT STUDY
Treated Water Chlorinated



Typical Filter Ripening Period



Typical Filtered Turbidity



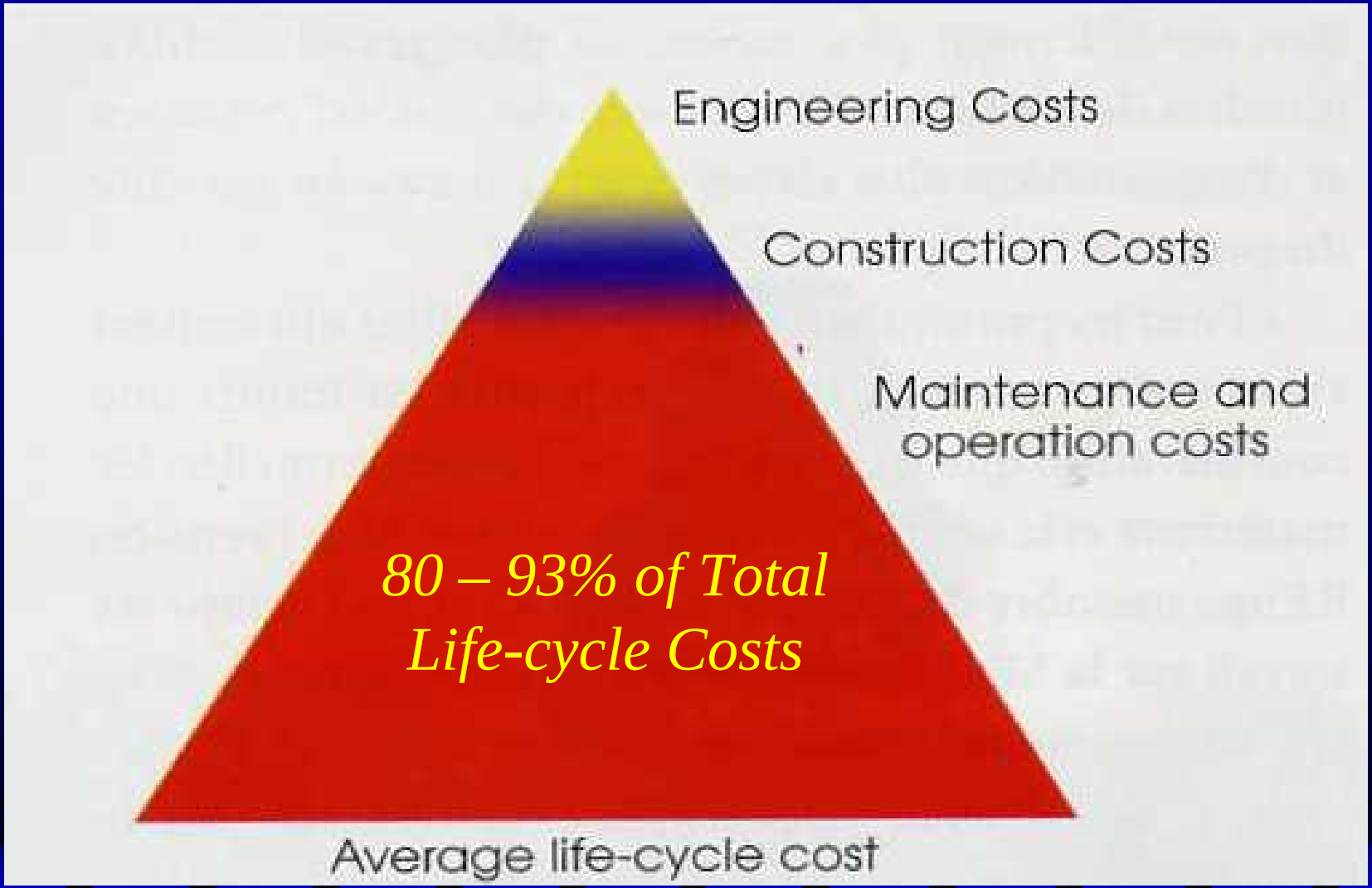

FILTER
#1
FILTER
#2

O & M / Life-Cycle Costs

Slow Sand Filtration = Low O & M Costs:

- Engineering Costs (1 - 2 % of total)
- Construction Costs (6 - 18 % of total)
- Operations and Maintenance Costs (**80 - 93%** of total life cycle cost)

LIFE CYCLE COST



Source: Consulting Engineers of Canada

O & M / Life-Cycle Costs

Common Problems for Small Systems:

- Limited Resources for O & M (Capital Cost Usually Subsidized)
- Operator has Multiple Responsibilities
- Expensive Service Calls by OEM
- Complex Treatment Chemical Systems

O & M / Life-Cycle Costs

Common Problems for Small Systems:

- Attracting and Retaining Skilled Operators
  - Overall Shortage of Qualified Operators (35% Eligible to Retire Within 10 Years)
  - With most Technologies Operators must also be Electronics Technicians
  - Comparatively Low Compensation and High Level of Responsibility

Summary- Conventional Slow Sand

- Meets Regulatory Requirements for Filtration
- Safe, Simple Operation
- Very Low O & M Costs
- No Coagulant Chemical Addition - Minimal Sludge Generation
- Passive - Operator Friendly Process

Summary- Conventional Slow Sand

- Excellent removal of cysts / oocysts
  - Mechanisms = straining and predation
  - Mainly in upper layers of filter
- Ability to remove or reduce certain common PPHCPs, EDCs, microcystins and taste and odour causing compounds
- BUT Limited to very good quality raw water sources

Summary- Modified Slow Sand

- Ozone = excellent disinfectant for pathogenic cysts, bacteria and viruses
- Ozone converts stable DOC to AOC - removed by biofiltration / slow sand filtration
- Ozone oxidizes many contaminants not removed by biological processes alone

Summary- Modified Slow Sand

Ozone + biofiltration removes or significantly reduces:

- Most PPHCPs, EDCs and pesticides
- Microcystins (Toxic Algal Metabolites)
- Geosmin / 2-MIB (Taste & Odour)
- Iron and manganese
- TOC and DBP precursors

Provides an Excellent Barrier to Pathogens and Contaminants, including DBPs

Questions?