FIXED BIOFILM WASTEWATER TREATMENT
Pathogen Reduction

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FIXED FILM WASTEWATER TREATMENT

- Wastewater treatment
  based on attached microbial growth

- Support materials
  a wide variety

- Two important factors
  - flow of wastewater
  - size of support material particles
Variety of Fixed Film Filters
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Pathogen Reduction

Fixed media

- sand
- gravel
- plastic
- activated carbon
- peat
- other
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“Trickle” Filters
- sand
- gravel
- plastic
- activated carbon
- peat
- other
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Single Pass Filters

– Peat
– Pea gravel
– Crushed glass
– Experimental media
– Sand (the best understood and most predictable)
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RMF Recirculating Media Filters

– Sand (most widely used)

– Peat

– Textiles
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Rotating Biological Contactors
Rotating cylinders with attached biofilm in wastewater flow

Submerged Filters
Downflow and Upflow
Fixed Film Filters
Their Biofilms in Relation To Pathogen Reduction
Biofilms are highly stratified with microbes and matrix

Microorganisms attach to solid materials

Microorganisms can reach high concentrations

Microbial growth rates depend upon
  – flow rates
  – size and geometric configuration of particles
    (more surface area of particles = more growth surface)
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**Biofilms**

Biofilm/Zoogleal (animal gunk) film formation

- bacteria
- fungi
- algae
- protozoa
- nematodes
- rotifers
- annelid worms (mini- aquatic earthworms)
- insect larvae/filter fly larvae
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Biofilms/Zoogloea Film Formation & Function in Pathogen Reduction

- **Bacteria**
- **Fungi**
- **Algae**
- **Protozoa**
  (grazers/predators/absorbers)

www.microscopy-uk.org.uk
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Biofilms/Zoogleal Film Formation & Function in Pathogen Reduction

Nematodes
- feed on floc
  • ingestion
  • farm biomat

Rotifers
  • (+)ingestion/filtering
  • (-)protection of pathogens

http://www.yorkcity.org/cityservices/wwtp/micro.htm

www.microscopy-uk.org.uk
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Biofilms/Zoogleal Film Formation & Function in Pathogen Reduction

 diffé Annelid worms (mini-earthworms)
  - plow through floc
  - ingest floc

http://www.yorkcity.org/
cityservices/wwtp/micro.htm

Filter fly larvae (&adults)
  - graze biomat
  - promote biomat turnover

http://www.arrowpestcontrol.com/pages/drainfly.html
As biofilms develop organisms in the deepest layers lose access to nutrition and may die-off.

Then the biofilm may/does slough off.

The fragments of biofilms carry:
- the outer attached treatment organisms
- any attached pathogens with them.
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*Biofilms/Zoogleal Film Function in Pathogen Reduction*

- **Filtration** (packed beds)
- **Adsorption to biofilm matrix**
  - (some layers polyanionic)
  - pathogens can be stuck in the “gleal goo”
- **Biofilm organisms**
  - eat/ingest/digest some pathogens
  - however the pathogens can be protected inside body
  - can overgrow and clog
- **Sloughed biofilms**
  - end up in clarifier
  - in systems without clarifier ---on to dispersal
Wastewater Pathogens
General Groups
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*Pathogens: General groupings*

☞ For this presentation all of the following are called PATHOGENS

☞ Sometimes they are divided into two groups:

– Those called Pathogens
  • Viruses
  • Bacteria
  • Fungi

– Those called Parasites
  • Protozoa
  • Helminths (Roundworms & Tapeworms)
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*Pathogens : General Size ranges*

- **Virus**
  - particles
  - particle size 20-100nm

- **Bacteria**
  - spores
  - spore size 1-3-microns

- **Fungi**
  - spores
  - spore size ~5 microns

- **Protozoa**
  - cysts
  - cyst size 10-100’s microns

- **Helminths**
  - roundworm (ova)eggs 50-100 microns
  - worm inches - 1 +ft
  - tapeworms (ova)eggs 50-100 microns
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*Pathogens : Infectious Doses*****

† Virus

Various 1-10 particles

† Bacteria

Shigella 10 - 100 spores
cholera 1,000 - 10,000,000
Campylobacter 100-1,000,000

† Protozoa

Cryptosporidium 1 oocyst
(10 in healthy volunteers)
Giardia 10-100 oocysts

† Helminths

roundworms (embryonated) 1-10 eggs
tapeworms 1-800 eggs
Wastewater Pathogen Indicators
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Criteria for Ideal Microbial Indicator

Wastewater Microbiology: 2nd edition 1999

- Member of the intestinal microflora of warm-blooded animals
- Should be present if pathogens are present, and absent in uncontaminated samples
- Should be present in greater numbers than the pathogens
- Should be at least equally resistant as the pathogens to environmental insults and to disinfection in water and wastewater treatment(s)
- Should not multiply in the environment
- Should be detectable by means of easy, rapid, and inexpensive methods
- Should be nonpathogenic
Microbial Indicators of Fecal Contaminants

- **Viral**: Bacteriophage (viruses)
- **Bacterial** (used for the rest of pathogens):
  - Total Coliforms
  - Fecal Coliform Bacteria
  - Fecal Streptococci
  - Anaerobic Bacteria
    - *Clostridium*, Bifidobacteria, etc.
VIRAL INDICATORS:
- environmental detection
- assessing pathogen removal by wastewater treatment
- F-specific bacteriophages indicator of wastewater
- Bacteriophage of *Bacterioides spp.* Chlorine resistant/some wastewater usefulness

Bacteriophage *from Cells Alive*
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Pathogen (microbial) indicators

Total Coliforms (bacteria)
- Aerobic and facultative anaerobic, gram neg, rod shaped, non-spore formers
- Include *Escherichia coli*, *Enterobacter*, *Klebsiella* etc.
- Less sensitive than viruses or protozoa to env/ disinfection
- Some may regrow (not all detected)

Fecal Coliforms (bacteria)
- All thermotolerant and ferment lactose (44.5°C)
- Vertebrate Guts
- *E. coli*, *Klebsiella*, etc.
- Survival pattern similar to path bacteria
- Less resistant than viruses or protozoan cysts to disinfection and environmental conditions
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Pathogen (microbial) indicators

☞ Fecal Streptococci
  – *Streptococcus* - 4 species
  – subgroup enterococci: *S. faecalis* and *S. faecium*
    useful for viruses, especially in sludge and seawater

☞ Anaerobic Bacteria
  – *Clostridium perfringens* (viruses & protozoan cysts)
    • useful as a tracer
  – *Bifidobacteria* fecal indicator in the environment
  – *Bacterioides* sp., fecal contamination of water
SOME EFFLUENT NUMBERS
Pathogen Concentration in Raw Wastewater / 100ml

- **Virus**
  - 100-50,000 particles

- **Bacteria**
  - **Shigella**
    - 1-1,000
  - **Salmonella**
    - 400-8,000

- **Protozoa**
  - **Cryptosporidium**
    - 1-10,000
  - **Giardia**
    - 50-10,000

- **Helminths**
  - roundworms
    - 1-1,800
  - tapeworms
    - not a good number available
Pathogen Concentration in Septic Tank Effluent / 100ml

- **Virus**  $0 - 10^5$  e.g. hepatitis, polio, coxsackie, coliphage
- **Bacteria**  $10^6 - 10^8$  e.g. *Salmonella*, *Shigella*, etc..

- **Protozoa**
- **Helminths**
  - roundworms
  - tapeworms
Pathogen Indicators
Concentration in Septic Tank Effluent / 100ml

Viruses
specific 0 - $10^7$ pfu (episodic high levels)

Fecal Coliforms
$10^5 - 10^8$ (EPA 600/2-78)

Fecal Streptococcus
$10^4 - 10^5$ (EPA 600/2-78)
FIXED FILMS
FILTERS

PATHOGEN REDUCTION
DATA
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TRICKLING FILTER SYSTEMS

- septic tanks
- fixed film reactor
- clarifier (excess biomass)
- optional recirculation of effluent
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Trickling filter

– EPA manual -
  • 1 - 2 log reduction fecal coliforms
  • says require minimum effluent disinfection for surface effluent requirements

– Bitton summarizes
  • that removal rate generally lower than activated sludge
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TRICKLING FILTERS Viruses/viral indicators

- **Viruses**
  - generally low and erratic removal
  - e.g. 59 - 91%
  - eg 0 - 20 % removal. Yet high coliform >90%
  - e.g. Efficiency of viral removal lower than coliforms

- **Bacteriophage**
  - erratic also
  - 40 - 90%
  - depends upon season
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TRICKLING FILTERS  
Pathogen removal erratic

**Virus**: 59 - 95% ;  phage 40 - 90%

† fecal coliform indicators -e.g. (0-20% viruses ; >90%fecal)
† Lewis, Austin, Loutit, Sharples (1986) no significant red. In fecal coliforms or viruses.

**Bacteria**
- vary from 20 - >90%, depending upon the operation
- **Salmonella** 73 - 95% (Feacham et al 1983)
- gen. 20-90% - some pathogenic species removal lower

**Protozoa**
- **Giardia, Entamoeba** 74-91%
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TRICKLING FILTERS - Parasites

- Protozoan *Entamoeba histolytica*
  - 71 - 91% in India

- Protozoan *Giardia lamblia*
  - similar removal rates as *E. coli*
  - 4- 44 cysts/L in the effluent
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TRICKLING FILTERS

(General according to Gabriel and Bitton 1999)

• Low and erratic removal of pathogens and parasite
• Filtration rate greatly affects the removal rate, lower rate = greater removal
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🌿 Rotating Biological Contactors
– not much is known about pathogen removal
– one study by Sagy and Kott 1990 - one log removal of fecal coliforms and *Salmonella*
– blue green algae helped? Reduce #’s

Rotating Biological Contactors (called rotating trickling filter)
- Clarke and Chang 1975 Applied Microbiology 30:223 - 228
- partially removed three types of viruses
- low flow rates - 85-94% removal
- hi flow rates - 59-81% removal
- in this system fecal coliform and fecal streptococci are appropriate for estimating some viral reductions.
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SAND FILTERS - single pass

• viruses from $0 - 10^7$ to $0 - 10^7$ pfu / 100 ml (episodic high) (Siegrist 2001) (no reduct.)
• bacteria depending upon sources/media size:
  – reduced to $10^3 - 10^4$ fecal coliform 100 ml
  – reduced to $10 - 100$ fecal coliform / 100 ml
  – from $10^6 - 10^8$ to $10 - 10^3$ FC (Siegrist 2001)
  – (under drains) reduced to < 200 cfu/100ml
  – Gustavson et al. (works with high cleaning rate)
  – June 2001 - Lake Wash and Duluth MN -
    » 4 sand filters <200 cfu/100ml
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☞ SAND FILTERS - single pass (cont)

- Protozoa (assume pore size < protozoan)
  - Use for *Giardia* in water supplies
  - Used for *Cryptosporidium* in water supplies - careful with the backwash (Milwaukee)

- Helminth eggs <1/L Mexico City study (1999)
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RMF Recirculating Media Filters

- Bitton: Because of the larger media size - does not remove fecal coliforms as effectively as single pass. Need coarse media for higher loading rates.
- Christopherson, Gustavson, Anderson. Found sand RMF reduction from $10^9$ - $10^{12}$ to $5,000$ - $10^5$ fecal coliform - still need be applied to soil infiltration systems (no biomat forms)
- recirculating sand - 2 systems MN2001 <200 fc/100ml.
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🌿 PEAT FILTERS

- Gustavson (MN) < 1,000 cfu/100ml FC
- Modular peat- Geerts, et al,2001
  - fc 94-99% reduction
  - viral 0-20% reduction
- N. Small Flows -2001 10^6 to 10^3 99%FC
- Lake Washington/Duluth 2001 4 peat <200fc/100ml
- City of Austin 2001 3-4 log reduction
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FOAM: TEXTILE FILTER EFFLUENT

- Viruses
  - 0-10^7 pfu/100ml tank
  - 0 - 10^7 pfu / 100ml filter effluent
  - episodically high

- bacteria FC -
  - 10^5 - 10^8 /100ml in tank to 10 - 10^3/100 ml in filter effluent

® Fuzzy Film for helminth eggs Mexico city study effluent <1 egg/l
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预留的单位
– 固定生物膜
– 悬浮生物膜
Some final thoughts......

- Adsorptions to solids most effective in reducing viral loads
- Larger organisms better reduced with smaller pore sizes - like sand filtration
- Minnesota as of June 2001 - developing protocols for viral pathogen surrogates and bacterial surrogates….for methods to address need more of the comparatives studies
- Need information on infectivity of pathogens after treatment, not just the numbers.
- Developing pathogen mimics for all pathogens a new study in NC.
Pooper Scooter
Highboy -->

Racing model
for the daring senior