Biofiltration: principles, biofilter types and design

Ep Eding

Aquaculture and Fisheries Group
Wageningen University
The Netherlands
1. INTRODUCTION
2. BASIC PRINCIPLES
3. FACTORS AFFECTING THE BIOFILM
4. BIOFILTER DESIGN
# INTRODUCTION

1. Production plan (maximum carrying capacity)
2. Waste production calculations (in g/kg feed)
3. Diurnal variation in waste production
4. Water quality limits ($C_{\text{limit}}$)
5. Suspended Solids control
6. Biofiltration *(principles and design)*
7. Gas control
8. Denitrification
9. RAS design concept ($Q_{\text{rec.}}, Q_e$ etc.)
10. Heat (energy) balance model
Filter questions:
- Type of biofilter?
- Size of the reactor?
- Biofilter media?
- Which processes are combined?
- Kinetics of substrate elimination?

Effect of:
- Organic material
- TAN
- Oxygen
- pH
- HSL
- Temperature

INTRODUCTION
INTRODUCTION

(Eding et al., 2006. Aquacultural Engineering 34, 234-260)
**1. Aerobic heterotrophic conversions**

**Without nitrification**

\[ C_{18}H_{19}O_9N + 17.5O_2 + H^+ \rightarrow 18CO_2 + 8H_2O + NH_4^+ \]

Microbiological oxygen consumption: 1.42 kg O\(_2\)/kg organic matter

**With nitrification (autotrophic)**

\[ C_{18}H_{19}O_9N + 19.5O_2 \rightarrow 18CO_2 + 9H_2O + H^+ + NO_3^- \]

Microbiological oxygen consumption: 1.59 kg O\(_2\)/kg organic matter

*(Henze et al., 1997)*
BASIC PRINCIPLES

2. Reaction by nitrification

1. Ammonia Oxy. Bacteria

\[ \text{NH}_4^+ + \frac{3}{2} \text{O}_2 \rightarrow \text{NO}_2^- + \text{H}_2\text{O} + 2\text{H}^+ \]

2. Nitrite Oxy. Bacteria

\[ \text{NO}_2^- + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_3^- \]

\[ \text{NH}_4^+ + 2\text{O}_2 \rightarrow \text{NO}_3^- + \text{H}_2\text{O} + 2\text{H}^+ \]

\[ 4.57 \text{ kg O}_2/\text{kg NO}_3^-\text{-N} \]

Ammonia Oxydizing Bacteria (AOB)

\[ 15CO_2 + 13NH_4^+ \rightarrow 10NO_2^- + 3C_5H_7NO_2 + 23H^+ + 4H_2O \]

Nitrite Oxydizing Bacteria (NOB)

\[ 5CO_2 + NH_4^+ + 10NO_2^- + 2H_2O \rightarrow 10NO_3^- + C_5H_7NO_2 + H^+ \]

2. Reaction by nitrification

\[
\begin{align*}
\text{NH}_4^+ + 1.86\text{O}_2 + 1.98\text{HCO}_3^- & \rightarrow \\
0.020\text{C}_5\text{H}_7\text{NO}_2 + 0.98\text{NO}_3^- + 1.88\text{H}_2\text{CO}_3 + 1.04\text{H}_2\text{O}
\end{align*}
\]

\[
\begin{align*}
- (1.86 \text{O}_2 * 32)/1.00 \text{NH}_4^+ - \text{N*14}) & = 4.25\text{gO}_2 / \text{gNH}_4^+ - \text{N} \\
- (1.86 \text{O}_2 * 32)/0.98 \text{NO}_3^- - \text{N*14}) & = 4.34\text{gO}_2 / \text{gNO}_3^- - \text{N} \\
- (2.00 \text{O}_2 * 32)/1.00 \text{NO}_3^- - \text{N*14}) & = 4.57\text{gO}_2 / \text{gNO}_3^- - \text{N}
\end{align*}
\]

3. Alkalinity destruction

\[
\text{NH}_4^+ + 1.86\text{O}_2 + 1.98\text{HCO}_3^- \rightarrow 0.020\text{C}_5\text{H}_7\text{NO}_2 + 0.98\text{NO}_3^- + 1.88\text{H}_2\text{CO}_3 + 1.04\text{H}_2\text{O}
\]

Alkalinity destruction = ±2 Eqv alkalinity/ mol N

- \(\text{NaHCO}_3\) 83 g/eqv
- \(\text{CaCO}_3\) 50 g/eqv

### Reaction by nitrification

<table>
<thead>
<tr>
<th>CONSUMES</th>
<th>STOICHIOMETRY</th>
<th>C\textsubscript{Organic} (per gN)</th>
<th>C\textsubscript{Inorganic} (g)</th>
<th>N (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH\textsubscript{4}\textsuperscript{+}-N</td>
<td>1 g N</td>
<td>-------</td>
<td>-------</td>
<td>1</td>
</tr>
<tr>
<td>Alkalinity (^1)</td>
<td>7.07 g Alk.</td>
<td>-------</td>
<td>1.70</td>
<td>------</td>
</tr>
<tr>
<td>Oxygen</td>
<td>4.25 g O\textsubscript{2}</td>
<td>-------</td>
<td>------</td>
<td>------</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>YIELDS</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VSS \textsubscript{A. bacteria}</td>
<td>0.16 g VSS</td>
<td>0.086</td>
<td>-------</td>
<td>0.02</td>
</tr>
<tr>
<td>NO\textsubscript{3}-N</td>
<td>0.98 g NO\textsubscript{3}-N</td>
<td>-------</td>
<td>-------</td>
<td>0.98</td>
</tr>
<tr>
<td>CO\textsubscript{2}</td>
<td>5.91 g CO\textsubscript{2}</td>
<td>-------</td>
<td>1.61</td>
<td>------</td>
</tr>
</tbody>
</table>

\(^1\) Expressed as CaCO\textsubscript{3} equivalents

BIOFILM MODEL

Effect of TAN limitation

(Biofilm model)

\[ S_{\text{OXYGEN}} \]

\[ S_{\text{TAN}} \]

\[ S_{\text{O}_2} = 0 \]

\[ S_{\text{TAN}} = 0 \]

x=0  x_i  x=L

L = biofilm depth

Effect of oxygen limitation

(BIOFILM MODEL)

BULK LIQUID  BIOFILM  CARRIER

$S_{OXYGEN}$

$S_{O2}=0$

$S_{TAN}=0$

$x=0$  $x_{i}$  $x=L$

$L = \text{biofilm depth}$

(Inert matrix)

BIOFILM MODEL

Effect of oxygen and TAN concentration

$\frac{1}{2}$-order/o-order model

BIOFILM MODEL

\[ \frac{C_{O2}}{C_{TAN}} = \pm 3.6 \]

\[ a \quad C_{O2} = x_1 \]
\[ b_2 \]
\[ b_1 \quad C_{O2} = x_2 \]
\[ b_1 \quad C_{O2} = x_3 \]
\[ x_1 \succ x_2 \succ x_3 \]

½-order/o-order model

(After Eding et al., 2006. Aquacult. Eng. 34, 234-260)
BIOFILM MODEL

½-order/o-order model

a. $O_2$ and NH$_4$-N, both high, number of nitrifying bacteria limits the reaction

\[ r = r_{\text{MAX}} = \text{constant (o-order reaction)} \]

b. At low concentrations of one of the substrates the reaction rate is diffusion limited

b1. Low oxygen

\[ r = \sqrt{C_{O_2}} \quad (1/2 \text{- order reaction}) \]

b2. Low ammonium

\[ r = \sqrt{C_{\text{TAN}}} \quad (1/2 \text{- order reaction}) \]

BIOFILM MODEL

Concentration ratio at which change of limiting substrate
\( \frac{C^*_{O2}}{C^*_{NH4-N}} \) is constant 3.6±0.8

\[
\frac{C^*_{O2}}{C^*_{NH4-N}} < 3.6 \quad \text{O}_2 \quad \text{limiting substrate}
\]

\[
\frac{C^*_{O2}}{C^*_{NH4-N}} > 3.6 \quad \text{NH}_4^-\text{N limiting substrate}
\]

4 type of bio-reactor performances

1. 0 - order removal kinetics in relation to \( C_{NH4-N} \) : \( C_{NH4-N} > C^*_{NH4-N} \)
2. ½ - order removal kinetics in relation to \( C_{NH4-N} \) : \( C_{NH4-N} < C^*_{NH4-N} \)
3. 0 - order and ½ - order removal kinetics in relation to \( C_{NH4-N} \)
4. ½ - order removal kinetics in relation to \( C_{O2} \) : \( C_{O2} < C^*_{O2} \)

(Bovendeur et al., 1987. Aquaculture 63, 329-353)
### BIOFILM MODEL

#### Effect of pH

<table>
<thead>
<tr>
<th>pH</th>
<th>Effect on nitrification</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk fluid (g/m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>No nitrification</td>
<td>(Wheaton, 1994)</td>
</tr>
<tr>
<td>5.6</td>
<td>No nitrification</td>
<td>(Kruner and Rosenthal 1989)</td>
</tr>
<tr>
<td>6.5-6.7</td>
<td>No nitrification</td>
<td>(Boller et al., 1994)</td>
</tr>
<tr>
<td>7.2 - 8.8</td>
<td>Optimum <em>AOB</em></td>
<td>(Chen et al., 2006)</td>
</tr>
<tr>
<td>7.2 - 9.0</td>
<td>Optimum <em>NOB</em></td>
<td>(Chen et al., 2006)</td>
</tr>
</tbody>
</table>

*Eding et al., 2006. Aquacult. Eng. 34, 234-260*
Trickling filter

Effect of pH

$r_{\text{TAN}} (\text{g/m}^2\text{day})$

$r^*$

$g \text{NH}_4\text{-N/m}^3$

(After Bovendeur, 1989 in Eding et al., 2006 Aquacult. Eng. 34, 234-260)
BIOFILM MODEL

Effect of pH

Optimal pH can be determined by three effects:

✓ Activation and deactivation of nitrifying bacteria
✓ Nutritional effect
✓ Inhibition through free ammonia and free nitrous acid
BIOFILM MODEL

Effect of Alkalinity

Nitrification: 1 g TAN oxidized \( \rightarrow \) consumes 7.1 g CaCO\( _3 \).

<table>
<thead>
<tr>
<th>Alkalinity (g/m( ^3 ))</th>
<th>Effect on nitrification</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 35</td>
<td>Reduced</td>
<td>(Swerinski et al., 1986)</td>
</tr>
<tr>
<td>&lt; 40</td>
<td>Reduced</td>
<td>(Chen et al., 1989)</td>
</tr>
<tr>
<td>&gt; 45</td>
<td>Minimum</td>
<td>(Biesterfeld et al., 2003)</td>
</tr>
<tr>
<td>75 -100</td>
<td>Maximum</td>
<td>(Gujer and Boller, 1986)</td>
</tr>
</tbody>
</table>

(Eding et al., 2006. Aquacult. Eng. 34, 234-260)
BIOFILM MODEL  Effect short term loading org. matter (3-4 hr)

\[
r_{TAN} (g/m^2/day) = -0.015 \times \text{COD (g/m}^2\text{d)} + 0.65
\]

(After Bovendeur, 1989. Dissertation Wageningen University, The Netherlands)
BIOFILM MODEL

Effect of influent COD/N ratio

FLOATING BEAD FILTER
T= 20°C
Chemically fed reactor
Sucrose as organic carbon source
TAN concentration 10 mg/L

(NAfter Chen et al., 2006. Aquacult. Eng. 34, 179-197.)
BIOFILM MODEL

Heterotrophic bacteria effect

(From Dr. J.P. Blancheton, IFREMER, FRANCE)
BIOFILM MODEL

Effect of particulate organic matter

Mineral packing media BIOGROG
Submerged filter
Particles from particle separator rearing system

(After Chen et al., 2006. Aquacult. Eng. 34, 179-197)
Effect of temperature

Comparison two pilot scale biofilters, temperature activity coefficient 1.08
van’t Hoff –Arhenius like equation

TRICKLING FILTER

\[ r_{\text{TAN}} = 0.55 \, \text{g/m}^2/\text{day} \quad (25 \, ^\circ\text{C}) \quad \text{African catfish} \]
\[ r_{\text{TAN}} = 0.25 \, \text{g/m}^2/\text{day} \quad (15 \, ^\circ\text{C}) \quad \text{Rainbow Trout} \]

*(Bovendeur et al., 1987. Aquaculture 63, 329-353)*

Study based on a Biodrum and no organic matter (BOD) supply

Prediction of relative nitrification rates (for range 7-35°C)

BIODRUM

At 15 °C a 24 % reduction is obtained of rates at 25°C

Effect of temperature

Study based on Submerged filter, internal aeration, no organic matter (BOD) supply

From 20°C -27°C:
- 1.108 % increase per °C increment (under O$_2$ limitation conditions)
- 4.275% increase per °C increment (under TAN limitation conditions)

BIOFILM MODEL

Effect of salinity

(After Nijhof and Bovendeur, 1989. Aquaculture 87, 133-143)
BIOFILM MODEL

Effect of hydraulic surface load

After Eding, 2006. Aquacultural Engineering 34, 234-260
BIOFILM MODEL

Effect of hydraulic surface load

Hypothetical Biofilm (trickling filter)

Removal rate (g TAN m\(^{-2}\)d\(^{-1}\))

Start up

‘Full grown’ biofilm

TAN concentration (g m\(^{-3}\))

Removal rate (g NO\(_2\)-N m\(^{-2}\)d\(^{-1}\))

‘Full grown’ biofilm

Start up

NO\(_2\)-N concentration (g m\(^{-3}\))

Effect of ageing

Trickling filter biofilm

(BIOFILM MODEL)

BIOFILM MODEL

Effect of Nitrite

(Based on Brett and Zala, 1975).

- Feeding and feed composition
- Harvesting & grading & restocking
- Continuous water treatment processes
BIOFILTER DESIGN

Safety factor

1. Low safety factor
2. Intermediate safety factor
3. High safety factor

\( r_{\text{TAN}} \) (g/m\(^2\)/day)

\( r_2 \)

\( r_3 \)

\( g \) TAN/m\(^3\)

(Bovendeur et al., 1987. Aquaculture 63, 329-353)
BIOFILTER DESIGN

Effect of diurnal variation

\[ P_{TAN}(g\ TAN) \]

\[ r_{TAN} (g/m^2/day) \]

Peak

Feeding

\[ r_d^* \]

Metabolism limitation

\[ g\ NH_4-N/m^3 \]

**BIOFILTER DESIGN**

Effect of diurnal variation

- **Feeding**
  - $P_{TAN}(g\ TAN)$
  - $r_{TAN}\ (g/m^2/day)$
  - $r_d^*$

- **Waste production dynamics**
  - Metabolism limitation

- **Waste removal kinetics**
  - $g\ NH_4-N/m^3$

BIOFILTER DESIGN

Effect of diurnal variation

- Feeding
- Peak
- \( r_{TAN} \) (g/m²/day)
- Metabolism limitation
- \( r_d^* \)
- \( r_p \)
- \( g \text{ NH}_4^-\text{N/m}^3 \)

3. High safety factor

BIOFILTERS USED IN RAS

- Trickling filter
- Rotating biological contactors
- Bead filter
- Moving bed biofilm reactors
- Submerged filter
- Fluidized bed filter
African catfish RAS

Trickling filter

Filter pac
Crossflow
Bionet

Trickling filter

African catfish RAS

Courtesy Fleuren & Nooijen BV, Someren, The Netherlands (http://www.fleuren-nooijen.nl/Home.html)

(From Eding and Schneider, 2005. RAS-Short course, Trondheim)
Trickling filter

African catfish RAS

Trickling filter

Lamella sedimentation

Sump

(Courtesy Fleuren & Nooijen BV, Someren The Netherlands, [http://www.fleuren-nooijen.nl/Home.html](http://www.fleuren-nooijen.nl/Home.html))

Trickling filter sizing

Determine:

Step 1. Peak feed load (kg feed/day)
Step 2. Feed protein content (%)
Step 3. Temperature (°C)
Step 4. TAN production rate ($P_{TAN} = g \text{ TAN/day}$)
Step 5. Desired TAN (g/m³)
Step 6. In situ nitrification reduction $P_{TAN}$ (%)
Step 7. Passive denitrification (%)
Step 8. Allowable Nitrate-N (g/m³)
Step 9. Water exchange for Nitrate-N control reduction $P_{TAN}$ (%)
Step 10. Treatment Efficiency (TE) (%)

Trickling filter sizing

Determine:

Step 10. Flow for TAN (m³/day) control

\[
Q_{\text{TAN}} = \frac{P_{\text{TAN}}}{(C_{\text{TAN,IN}} - C_{\text{TAN,OUT}})} = \frac{P_{\text{TAN}}}{(1-\text{TE}/100) \times C_{\text{TAN,OUT}}}
\]

Step 11. Required surface area (A) & filter volume (V)

TAN removal rate \(r_{\text{TAN}}\) in g TAN/m²/day

\[
A \ (m^2) = \frac{P_{\text{TAN}} \ (g \ TAN/day)}{r_{\text{TAN}} \ (g \ TAN/m^2/day)}
\]

\[
V \ (m^3) = \frac{A \ (m^2)}{SSA \ (m^2/m^3)}
\]

Trickling filter sizing

Determine:

Step 13. Cross-sectional filter area ($\phi$ in m$^2$) and filter diameter ($\Phi$)
Fixed media depth (H in m)

$$\phi \ (m^2) = \frac{V \ (m^3)}{H \ (m)}$$
$$\Phi \ (m) = 2 \times \sqrt[3]{\phi \ (m^2) / 3.1416}$$

Fixed: Desired TAN conc., Treatment efficiency, TAN removal rate, Filter height
Trickling filter design

If $C_{\text{TAN,IN}} \geq 2 \text{ g/m}^3$
then

$$C_{\text{TAN,IN}} = C^*_{\text{TAN}} = 2 \text{ g/m}^3$$

$$r_i = a \sqrt{[C_{\text{TAN,IN}}]-0.1} \quad \text{(g/m}^2/\text{day)}$$

$$a = 7.81 \times 10^{-4} H^* + 0.2 \quad \text{(m/day)}$$

$H$ = hydraulic surface load (m/day)

*(correction for filter media)*

Eding et al., 2006, Aquacult Eng. 34, 234-260

Determine filter performance

Biofilter

Efficiency $E$

$R_{\text{TAN}}$

$Q_f$

$C_{\text{TAN,IN}}$

$C^*_{\text{TAN,OUT}}$

$C^*_{\text{Limit}}$

Trickling filters

Spec. surface area : 150-234 m²/m³
TAN removal rate : 0.1-1.0 gTAN/m²/day
Hydraulic surface load : 100-750 m³/m²/day
Height : 2-4 m

(Bovendeur et al., 1987; Nijhof, 1995; Kamstra et al, 1998)

Characteristics:
- Simple design/construction
- Aeration /degassing CO₂
- High stability
- Cooling tower in summertime
- No maintenance
- Continuous
- Low volumetric removal rate (g TAN/m³/day)
- Large biofilters
- Biofilm sheared off
- Moderate capital costs
- Foam production
- Head loss
Rotating biological contactor (RBC)

Air or water driven

**RBC-600,**

- **Surface area:** 600 ft²
- **Surface density:** 92 ft²/ft³
- **Rotation:** Air injection or water injection
- **Rotation velocity:** 2-3 rpm
- **Support rack:** PVC
- **Floor space:** 12 ft² (with staging unit)

**RBC-10000,**

*(Fresh-Culture System Inc., Breinigsville, USA  Website: www.fresh-culture.com)*
Commercial Aquaculture systems using RBC’s

Air or water driven RBC’s

(Fresh-Culture System Inc., Breinigsville, USA  Website: www.fresh-culture.com)
Rotating biological contactor sizing

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compartimentalization:</td>
<td>specialization bacteria</td>
</tr>
<tr>
<td>Max. hydraulic loading:</td>
<td>300 m³/m²/day</td>
</tr>
<tr>
<td>Peripheral velocities:</td>
<td>0.18- 0.39 m/s</td>
</tr>
<tr>
<td>Submergence:</td>
<td>40%</td>
</tr>
<tr>
<td>Reduction in CO₂ conc.:</td>
<td>39%</td>
</tr>
</tbody>
</table>

*(Brazil, 2006. Aquacult. Eng. 34, 261-274)*
Rotating biological contactor sizing

(Brazil, 2006. Aquacult. Eng. 34, 261-274.)
Rotating biological contactor sizing

Determine:

Step 1. Calculate oxygen requirement (kg O₂/day)
Step 2. Calculate water flow requirement for DO (L/day)
        Check the number of tank exchanges per hour (N/hour)
Step 3. Calculate TAN production (kg TAN/day)
Step 4. Determine TAN removal rate (g/m²/day)
Step 5. Calculate biofilter surface area (A_{media} = m²)
        (Timmons and Ebeling, 2007)

Rotating biological contactors

Characteristics:

- Passive aeration
- Low head loss
- Non clogging
- Reliable performance
- Degassing
- Modularization
- Low operation costs
- Self cleaning

- Relative high purchase price
- Mechanically more complex (e.g. Motor driven types)
- Relative high foot print

(See also Wheaton, 1994; Timmons and Ebeling 2007)
Biofiltration by floating beadfilters

Polygeyser

A. Inlet
B. Water outlet
C. Filter chamber
D. Buffer area for air
E. Air inlet
F. Air outlet
G. Funnel in which beads are rinsed
H. Sludge collection chamber
H. Sludge discharge valve
I. Window
Biofiltration by bead filters

Beadfilter

Biofilm carrier: Floating beads

After Malone et al., 1998

Plastic Bead

Heterotrophic biofilm

Embedded nitrifiers

BOD decay

O₂
Org. Wastes

CO₂

NH₃
O₂

Bicarbonates

NO₂

CO₂
Nitrate

Nitrification

Wageningen University
University for Life Sciences
Agriculture and Fisheries
Biofiltration by bead filters

Propeller Bead filter  Filtration mode  Mixing mode

 Courtesy Dr. Malone
Biofiltration by bead filters

Propeller Bead filter  Settling mode  Sludge removal

Figure 2.C: Settling mode
Figure 2.D: Sludge removal

Courtesy Dr. Malone
Biofiltration by bead filters

Propeller Bead filter

Bead filter

Fysical filtration

Biological filtration

Courtesy Dr. Malone
Bead filter sizing

Determine:

Step 1. System volume ($V_s$ in $m^3$)
Step 2. Max. fish load (L in kg)
Step 3. Peak feed load (kg feed/day)
Step 4. Feed protein content (%) 
Step 5. Operating temperature ($^\circ$F)
Step 6. Salinity (ppt)
Step 7. Determine TAN production /kg feed ($E_{TAN}$)
Step 8. Correct TAN production for feeds with higher protein ($P2$, %)

$$E_{TAN} = P2 \left( \frac{30 g TAN/kg feed}{35\% \text{ protein}} \right)$$
Step 9. Correct for in situ nitrification ($Is = 30\%$)

(Drennan et al., 2006. Aquacult. Eng. 34, 403-416)
Bead filter sizing

Determine:

Step 10. Correction TAN$_{Total}$ for water exchange

\[
\text{TAN}_{\text{Biofilter}} = \text{TAN}_T - (1.5\text{mg/L})(Q_{\text{exchange}} \text{ (in L/Day)}) \times (10^{-3})
\]

Step 11. Volume biofilter ($V_b$ in m$^3$)

Enhanced filter media

\[
V_{\text{Biofilter media}} = \frac{\text{TAN}_{\text{Biofilter}}}{530 \text{ g TAN/m}^3} = \ldots \text{m}^3
\]

Recommended model ........

Step 12. Flow rate ($Q$) through biofilter

Hydraulic loading rate = 806 L/min./m$^3$ of beads

\[
Q = (806 \text{ L/min./m}^3 \text{ beads})(\text{m}^3 \text{ beads})/\text{kg feed} = \ldots \text{L/min/kg feed}
\]

(Drennan et al., 2006. Aquacult. Eng. 34, 403-416)
Bead filter characteristics

Propeller Bead filter

Characteristics

- Combines solids removal with nitrification
- Fine particle removal
- Easy to install and operate
- Biofilm management important! (backwashing frequency)
- Modularization
- No degassing
- Leaches nutrients
- No internal aeration
- Head loss

Courtesy Dr. Malone

Aquaculture Systems Technologies, (New Orleans, LA, USA)
Moving bed biofilter

Moving bed biofilm reactor
Moving bed biofilm performance

TAN removal rate for Kaldness type K1, SSA = 500 m²/m³, 24 °C

\[
R_{\text{TAN}}(\text{g TAN/m}^2/\text{day})
\]

(REACTOR EFFLUENT (g TAN/m³))

(After Drennan et al., 2006. Aquacult. Eng. 34, 403-416)
Submerged biofilters

4 Biofilters in series

Schematic overview
Fluidized sandbed filter

Fluidized sand beds

Biofilm carrier: Sand

Spec. surface area
  : sand 4000-45000 m²/m³

TAN removal rate
  - Cold water
    : 0.2-0.4 kg/m³ expanded bed/day
  - Warm water
    : 0.6-1.0 kg/m³ expanded bed/day

PrAqua Technologies,
Nanaimo, British Colombia)
Fluidized sandbed filter

Fluidized sand beds

Biofilm carrier: Sand

Design steps:

- Determine the TAN load
- Determine the sand volume
  Based on TAN removal rate per m$^3$ sand
- Select design depth of sandbed
- Determine cross-sectional area filterbed
- Select a sand size in relation to flow rate
- Determine fluidization velocity
- Compare flow rates for water quality control in the fish tanks, adjust cross-sectional area of the bed if necessary
- Check mass balance on oxygen
- Design water delivery system

\[ Q \ (m^3/min) = \text{Fluidization velocity} \ (m/s) \times A(m^2) \times 60 \ s/min \]

(For design see Timmons et al, 2001)
Fluidized sandbed filter

Fluidized sand bed

Biofilm carrier: Sand or Plastic media
(Artic Charr culture)

- Easier start up
- No pipes and orifices
- 1/3 less pressure

(Freshwater Institute, Sherperdstown, West Virginia)

(The CycloBio(R))
Manufacturer: Marine Biotech
Fluidized sandbed characteristics

Biofilm carrier: Sand

Characteristics

- High specific surface area
- Uniformity of buoyancy
- Easy media containment
- Relative low investments
- Sand size is related to temperature
- High TAN removal efficiency
- Need for CO$_2$ stripping
- Controlled flow
- Head loss
- Oxygen supply from water
- More difficult to operate
- Can have maintenance problems
- Sand loss
  - bed growth management
Questions?

Aquaculture and Fisheries group (AFI)
Wageningen University The Netherlands
E-mail: Ep.Eding@wur.nl
Aquaculture and Fisheries group (AFI)
Wageningen University, The Netherlands
E-mail: Ep.Eding@wur.nl