ENERGY SAVING in RAS

Investment and functioning cost of low energy treatment systems

optimal size of the treatment devices for minimal consumption of energy

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Energy in RAS is used mainly for gas transfer (and combined nitrification in some cases) through water & air pumping.

Treatment
- Oxygen supply
- CO₂ removal
- Nitrification
- Solid filtration
- Denitrification
- pH control
- Temperature control
- Photoperiod
- Disinfection

Action
- Water Pumping
- Air pumping
- Mechanical energy gas transfer, rotating & agitation
- Heating
- Illumination

Production cost breakdown (avg. of 3 pilot systems 100ton)
- Feed 26%
- Investment return 25%
- Energy + oxygen 13%
- Water 2%
- Work 8%
- Miscellaneous 8%
- Materials, packing, Insurance 6%

Investment breakdown (avg. of 3 pilot systems 100ton)
- Rearing structure 45%
- Water treatment 22%
- Farming equipment 1%
- Auxiliary 2%
- Feeding & control 3%
- Miscellaneous 8%
- Infrastructure 7%
Water pumping (for recirculation)

\[ P = \frac{\gamma \cdot Q \cdot H}{\eta} \]

- \( P \) = Pumping power (W)
- \( \gamma \) = Specific gravity of water (N/m\(^3\))
- \( Q_W \) = Flow rate of water (m\(^3\)/sec)
- \( H \) = Total pumping head (m)
- \( \eta \) = Pumping efficiency (%)

Fish rearing volume

\[ H = \sum \{H_Z, H_L, H_V, H_P\} \]

- \( H_Z \) - water level difference
- \( H_L \) - head loss due to friction
- \( H_V \) - velocity head
- \( H_P \) - pressure head

In Low Head RAS – minimize all and each of \( H \) components
**Head loss**

\[ H_L = K_L \times \frac{V^2}{2g} \]

- \( H_L \) = local head loss due to friction on pipes, fittings, valves

- Low water velocity
- Wide cross sections
- Minimum parts (valves)

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**Pumping height \( H_Z \)**

- **High Head \( H_Z \) (m)**
- **Low Head \( H_Z \) (m)**

- 6-10m
- 0.2m

<table>
<thead>
<tr>
<th></th>
<th>Pumping head ( H_Z ) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.H.</td>
<td>0.2</td>
</tr>
<tr>
<td>H.H</td>
<td>6</td>
</tr>
<tr>
<td>Ratio LH/HH</td>
<td>1:30</td>
</tr>
</tbody>
</table>
Pumping Efficiency

- HH water pump efficiency ≈ 75% – 90%
- LH water pump efficiency is low
- Air Lift water pumping efficiency ≈ 25% – 30%

Air lift pumping efficiency:
Air pumping energy = 10 w/m³ air
G/L = 20%
Lifting H = 0.2 m
Water pumping power = 2.8 w/m³ water
Pumping efficiency = 28%

Advantage of scale

- Improved efficiency of engines as size increase
- Scaling up and aggregation of power sources (engines)
Flow rate of water (recirculation) – Q

- Water flow rate is designed to treat metabolites and gas exchange according to fish requirements.

Removing of CO₂ by stripping

HH systems
Low flow rates

CO₂ removal vs. water flow rate
(one pass, feeding= 1kg/d/m³ rearing volume)

- Dissolved:
  - 30-50 gr
- Gases
  - 500-850 gr

High flow rates
LH systems
Flow rate of water (recirculation)

- Supplying DO by oxygenation & aeration

**Low flow rate**
- Pure oxygen
  - High pressure oxygenation
  - Direct oxygenation
  - LHO
  - U Tube

**High flow rates**
- Aeration is feasible
Summary of flow rate of water (recirculation)

Power summary table (for gas exchange)

<table>
<thead>
<tr>
<th></th>
<th>Pumping head $H_z$</th>
<th>Pumping efficiency $\eta$</th>
<th>Water flow rate $Q$ (or ER)</th>
<th>Production rate</th>
<th>Energy consumption (for gas exchange)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m</td>
<td>%</td>
<td>m$^3$/h/m$^3$ rearing vol. or (1/h)</td>
<td>kg fish /m$^3$/y</td>
<td>kWh/kg fish</td>
</tr>
<tr>
<td>L.H.</td>
<td>0.1-0.4</td>
<td>25-40</td>
<td>20-30</td>
<td>80-100</td>
<td>4-5</td>
</tr>
<tr>
<td>H.H</td>
<td>6-12</td>
<td>75-90</td>
<td>1-2</td>
<td>100-150</td>
<td>4-5 *</td>
</tr>
</tbody>
</table>

* Not including pure oxygen additional cost $\approx 0.5$ $$/kg fish
System configuration

**High Head system**
One main cycle treatment

**Low Head system**
Multi cycle treatment

- **TAN removal + solid filtration**
- **Solids, Nitrate, & P removal**
- **DO supply**
- **CO₂ removal**

**High Head system**

- **Solid filtration**
- **TAN removal**
- **CO₂ removal**

**Low Head system**

- **DO supply CO₂ removal**
- **TAN removal + solid filtration**
- **Solids, Nitrate, & P removal**

**Qₜreatment**
RT ≈ 1 h

**Q₂₉ gas exch.**
RT ≈ 2-3 min

**QₜAN removal**
RT ≈ 1 h

**Q₂₉AN removal**
RT ≈ 1 D

Images and descriptions are present, illustrating the flow and treatment processes for each system.
Cycle I – Air lift performances

Results on “Kora”的 Airlift model MK21

CO₂ stripping results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CO₂/DO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kₖₐ</td>
<td>0.3–0.4</td>
</tr>
<tr>
<td>CTR/OTR</td>
<td>≈2</td>
</tr>
</tbody>
</table>

CTR = CO₂ transfer rate (@ 8 mg/l = 1600% saturation)

OTR = Oxygen transfer rate (at 80% saturation)

SOTR = Standard Oxygen Transfer Rate

SAE = Standard Aeration Efficiency

Q = Water flow rate

Aeration improvements – back aeration

“Mega-Flow” system – patented by “Kora”
Cycle II – Nitrification & Solid removal

Nitrification biofilter

- Water flow rate ≈ 1–2 vol/h (in HH & LH systems) is sufficient.
- Biofilter size:

<table>
<thead>
<tr>
<th></th>
<th>Typical Nitrification Biofilter</th>
<th>Media specific surface area</th>
<th>Media volume</th>
<th>Pumping Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH</td>
<td>Submerged</td>
<td>(m²/m³)</td>
<td>(m³/kg feed/d)</td>
<td>(m)</td>
</tr>
<tr>
<td>HH</td>
<td>Trickling</td>
<td>200</td>
<td>0.5</td>
<td>6</td>
</tr>
</tbody>
</table>

- Nitrification rate of 0.5 gTAN/m²/d

Solid filtration

- Low head up-flow bead filter – head loss of 1–2 cm.

Fine solid removal

- Low head foam fractionation, using water flow at low pressure or other low energy methods
Construction costs of fish tanks & heat loss per unit volume (related to wall surface area) reduces as fish tank size increases.
Open questions

1. Design DO (& CO\(_2\)) concentration at different temperature and its effect on oxygen supply.

2. High levels of CO\(_2\) in HH (oxygen enriched) system versus limited DO gradient in LH (aeration based) systems.

3. Importance of fine solid filtration vs. fish requirements.

4. Ways of significant reduction in capital \ investment costs.

Seginer & Mozes, in prep.