Treating gill diseases in freshwater – water chemistry in tarps and well boats

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Bathing

Table 1
Definition of gross AGD gill scores as used by TASSAL

<table>
<thead>
<tr>
<th>Infection level</th>
<th>Score</th>
<th>Gross signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td>0</td>
<td>gills appear clean, healthy red colour</td>
</tr>
<tr>
<td>Very light</td>
<td>1</td>
<td>1 mucoid spot, light mucus</td>
</tr>
<tr>
<td>Light</td>
<td>2</td>
<td>2–3 mucous spots, some paling of colour</td>
</tr>
<tr>
<td>Medium</td>
<td>3</td>
<td>established thickened mucous patch</td>
</tr>
<tr>
<td>Heavy</td>
<td>4</td>
<td>&gt; 3 mucous patches or single large patch</td>
</tr>
</tbody>
</table>

Table 2
Difference in the gross signs, gill smear results, presence of live *Paramoeba* on smears and presence of gill lesions and *Paramoeba* in histological sections before and after freshwater bathing

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence of mucoid patches (%)</td>
<td>93.3 (1.9)</td>
<td>55 (7.9)</td>
</tr>
<tr>
<td>Gross appearance—clear (%)</td>
<td>6.7 (1.9)</td>
<td>44.9 (7.9)</td>
</tr>
<tr>
<td>Gross appearance—very light (%)</td>
<td>18.9 (4.8)</td>
<td>18.0 (5.7)</td>
</tr>
<tr>
<td>Gross appearance—light (%)</td>
<td>26.7 (1.9)</td>
<td>24.4 (1.7)</td>
</tr>
<tr>
<td>Gross appearance—medium (%)</td>
<td>24.4 (1.7)</td>
<td>9.1 (0.9)</td>
</tr>
<tr>
<td>Gross appearance—heavy (%)</td>
<td>23.4 (1.7)</td>
<td>3.5 (1.9)</td>
</tr>
<tr>
<td>DiffQuick positive gill smears (%)</td>
<td>77.6 (5.4)</td>
<td>27.1 (2.6)</td>
</tr>
<tr>
<td><em>Paramoeba</em> live on fresh smear (%)</td>
<td>86 (n = 50)</td>
<td>27 (n = 11)</td>
</tr>
<tr>
<td>Number of <em>Paramoeba</em>/lesion</td>
<td>0.4 (0.11)</td>
<td>0.07 (0.02)</td>
</tr>
<tr>
<td>Number of AGD lesions/filament</td>
<td>0.23 (0.04)</td>
<td>0.21 (0.02)</td>
</tr>
<tr>
<td><em>Paramoeba</em> within cysts (%)</td>
<td>31.9 (5.6)</td>
<td>71.2 (15.8)</td>
</tr>
</tbody>
</table>

Parsons et al. 2001 Aquaculture 195:205-210

Clark et al. 2003 Aquaculture 219: 135-142
Effects of freshwater bathing of AGD affected Atlantic salmon

Effects of experimental freshwater exposure on mean (± SE) respiratory variables of Atlantic salmon under normoxic (100% saturation) or hyperoxic (200% saturation) conditions. Like symbols are significantly different from each other.

<table>
<thead>
<tr>
<th>Variable</th>
<th>100% Before</th>
<th>100% After</th>
<th>200% Before</th>
<th>200% After</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO&lt;sub&gt;2&lt;/sub&gt; (mm Hg)</td>
<td>110.2 (5.9)</td>
<td>118.5 (5.0)*</td>
<td>123.3 (14.1)</td>
<td>154.2 (13.9)*</td>
</tr>
<tr>
<td>pH</td>
<td>7.756 (0.017)</td>
<td>7.799 (0.039)</td>
<td>7.706 (0.015)</td>
<td>7.716 (0.043)</td>
</tr>
<tr>
<td>CO&lt;sub&gt;2&lt;/sub&gt; (ml/100 ml)</td>
<td>11.19 (1.36)</td>
<td>8.22 (0.96)</td>
<td>9.34 (1.38)</td>
<td>9.61 (1.02)</td>
</tr>
<tr>
<td>Hct (%)</td>
<td>25.2 (1.9)</td>
<td>26.3 (1.2)</td>
<td>23.3 (0.98)</td>
<td>23.6 (1.7)</td>
</tr>
<tr>
<td>Hb (g/100 ml)</td>
<td>7.16 (0.63)</td>
<td>6.72 (0.51)</td>
<td>7.23 (0.47)</td>
<td>5.98 (0.90)</td>
</tr>
<tr>
<td>MCHC</td>
<td>0.28 (0.03)</td>
<td>0.25 (0.02)</td>
<td>0.31 (0.02)</td>
<td>0.25 (0.03)</td>
</tr>
<tr>
<td>O&lt;sub&gt;2&lt;/sub&gt;/Hb (ml/g)</td>
<td>1.25 (0.16)</td>
<td>1.01 (0.15)</td>
<td>1.01 (0.18)</td>
<td>1.32 (0.16)</td>
</tr>
</tbody>
</table>

Powell et al. 2001 Aquaculture 199: 259-266

Roberts and Powell 2003 Journal of Fish Diseases 26: 591-599
Comparison of treatment approaches

**Tarpaulin**
- Tow infected cage from production to bathing site
- Pump fish from Production cage into bathing cage lined with tarpaulin
- Treatment period
- Pull away tarpaulin fish in «new» cage
- Tow «clean» cage back to production site

**Wellboat**
- Well boat loads with FW
- WB pull along side infected cage
- Fish pumped from cage into wellboat well
- H₂O₂ added to water
- Treatment period
- Fish pumped back into cage
- Water «treated/disinfected» and discharged

**Infected cage in situ**
- Tarpaulin slung under cage or skirt around cage
- H₂O₂ added to water
- Treatment period
- Tarpaulin/skirt pulled away
Factors affecting freshwater abstraction and use

- Legal frameworks
  - SEPA
  - Environmental impact assessment legislation
  - Water framework directive
  - Conservation legislation
- River type
- Season
- Prevailing flow
- Abstraction intake points
- Storage reservoirs
- Pipelines
- Road/boat transport
- **Water chemistry**
Freshwater availability

Gill amoeba survival in freshwater: implications for freshwater bathing

![Graph showing amoeba numbers (% seawater controls) after 3 hour exposure in vitro with different ion concentrations.](image)

**Amoeba numbers (% seawater controls)**

- **3 hour exposure in vitro**
- **Ion concentration (mg L\(^{-1}\))**
  - NaCl
  - CaCl\(_2\)
  - MgCl\(_2\)

**Relative survival (% SW control)**

**Ratio of ionic concentrations (NaCl/CaCl\(_2\) mg L\(^{-1}\))**

Powell and Clark 2003 Aquaculture 220: 135-144
Effects of water hardness on efficacy of freshwater bathing

Roberts and Powell 2003 Journal of Fish Diseases 26: 591-599

Powell et al. 2005 FRDC project report 2001/205
Norwegian freshwater (WQ 99-06)

- Low major ion concentrations
- Norwegian WQ is expected to give good treatment efficacy (AGD)
Norwegian freshwater (WQ 99-06)

- Generally low pH and buffering capacity
- Closed FW treatment systems with high biomass will generate high degree of \( \text{CO}_2 \) (g) accumulation and pH drop
- Aeration and oxygenation may result in steady-state conditions
Sensitivity of CO₂ concentration to alkalinity and pH

Figur 6. Sensitiviteten av beregnede CO₂ verdier i forhold til endret total alkalitet ved tre ulike pH-nivåer: pH 5 (grønn), pH 6 (rød) og pH 7 (blå).

Figur 7. Sensitiviteten av beregnede CO₂ verdier ved ulik pH og to alkalitetsnivåer (blå – 20 μmol/kg, grønn – 400 μmol/kg). Sensitiviteten øker ved lavere pH og ved høyere alkalitet.

Source: NIVA report 2015
Behavior av amóbegellesykdom i brønnbåt
...but remember

CO$_2$ is a weak acid in solution

\[
\begin{align*}
H_2O + CO_2 & \rightleftharpoons H_2CO_3 \\
H_2CO_3 & \rightleftharpoons HCO_3^- + H^+ \\
HCO_3^- + H^+ & \rightleftharpoons CO_3^{2-} + 2H^+
\end{align*}
\]

NH$_3$ is a weak acid in solution

\[
\begin{align*}
NH_3 + H_2O & \rightleftharpoons NH_4^+ + OH^-
\end{align*}
\]
Modeling the accumulation of CO₂ during high density, re-circulating transport of adult Atlantic salmon, *Salmo salar*, from observations aboard a sea-going commercial live-haul vessel


**Henderson-Hasselbalch equation:**

\[
P_{\text{CO}_2} = \frac{\text{TCO}_2}{\alpha \times 10^{pH - pK_1} + 1}\]

- \(P_{\text{CO}_2}\): partial pressure of CO₂ (mmHg)
- \(TCO_2\): total CO₂ in solution (mmol L⁻¹)
- \(pK_1\): first dissociation constant of CO₂

\[
P_{\text{CO}_2} = \frac{\text{TCO}_{\text{res}} + \text{TCO}_{\text{bg}}}{\alpha \times 10^{pH - pK_1} + 1}
\]

- \(TCO_{\text{res}}\): moles of accumulated total CO₂ from respiration (mmol L⁻¹)
- \(TCO_{\text{bg}}\): moles of background total CO₂ (mmol L⁻¹)

The amount of CO₂ created through respiration is calculated from the equation:

\[
\text{TCO}_{\text{res}} = \frac{(\text{MO}_2 \times \text{RER} \times \text{mass}) \times t}{V_r}
\]

- \(\text{MO}_2\): O₂ consumption rate (input as mg O₂ min⁻¹ kg⁻¹), converted to mmol O₂ min⁻¹ kg⁻¹
- \(\text{RER}\): respiratory exchange ratio (mol CO₂ excreted per mol O₂ consumed)
- \(V_r\): respiratory quotient (RQ)
- \(t\): time

**Fig. 3.** Modeled changes in water quality during various closed-hold transport scenarios. Simulated \(P_{\text{CO}_2}\) accumulation at routine MO₂ (2.5 mg O₂ min⁻¹ kg⁻¹, solid lines) and maximum MO₂ (8.0 mg O₂ min⁻¹ kg⁻¹, dashed lines) across a range of loading densities: low density (70 kg m⁻³), medium density (120 kg m⁻³) and high density (170 kg m⁻³). (A) Under low stress conditions, low loading density allows a recirculation time of up to 150 min while at a high density this time is reduced to 56 min. (B) Under high stress conditions, low loading densities allow recirculation time of 48 min while high loading densities further reduce the time to reach the 10 mmHg CO₂ threshold to 19 min. The associated water pH changes at routine MO₂ (C) and maximum MO₂ (D) at low, medium and high loading densities show that water pH decreases with increasing water \(P_{\text{CO}_2}\). The arbitrary threshold \(P_{\text{CO}_2}\) of 10 mmHg is reached at a water pH of 6.6 (dotted lines) under all scenarios. All trips were modeled using the same water conditions: temperature = 10°C, salinity = 30 ppt, starting water pH = 7.8.
CO$_2$ prediction of salmon at different temperatures
CO₂ predictions for salmon at different stocking densities (12C)

AGD affected from Jones (2008).

Source: NIVA report 2015
Behandling av amøbegjellesykdom i brønnbåt
Effects of DOC and water hardness on AGD bathing efficacy

**Figure 3** The percentage of viable amoebae present on the gills of Atlantic salmon bathed in freshwater for 2.5 h with varying levels of dissolved organic carbon and total water hardness when compared with pre-bath numbers (mean ± SE). Different letters indicate significant differences between treatments ($P > 0.05$).

**Figure 4** The percent of gill filaments with amebic gill disease (AGD)-type lesions post bath (mean ± SE). Different letters indicate significant differences between treatments ($P > 0.05$).

Green et al 2005 Aquaculture Research 36: 398-404
Simplified illustration of water chemistry interactions during freshwater bathing

How are all of these parameters interacting?
What is the effect on:
 Treatment efficacy?
 Fish welfare?
 Amoeba survival?
Efficacy of chemical additives to freshwater baths

Chlorine dioxide and chloramine-T
• Significantly reduce gill amoeba numbers

Hydrogen peroxide < 100 mg l\(^{-1}\)
• Results were equivocal

Interactive effects:
• DOC, water chemistry?
• Reactive oxygen based agents are active through the generation of toxic oxy radicals
• The generation of oxy radicals depends in reactive metal concentrations and organic compounds to enhance breakdown

Key points for consideration

• Water availability
• Water compostion and chemistry
• Effects of fish metabolism
• Additives to freshwater
• Alternatives to freshwater
• Alternatives to bathing
Thank you for your attention

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