Issues in Shrimp Pond Water and Sediment Quality Management

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Objectives

The purpose of this presentation is to consider several topics as follow:

- **Effectiveness of amendments – liming materials, disinfectants, zeolite, etc.;**
- **Liming pond bottoms for disinfection;**
- **Liming pond water: calcium carbonate saturation index;**
- **Minimum acceptable dissolved oxygen concentration;**
- **Estimating aeration rate based on oxygen demand.**

Liming materials and shrimp production.

Amendment	n	Amount (t/ha/yr)	Production (t/ha/yr)
		Thailand	
Lime	13	1.86	5.92
Ag limestone	17	4.04	6.13
Both	10	6.43	5.37
None	12	---	10.45
		Vietnam	
Lime	26	1.92	5.08
Ag limestone	12	1.32	4.96
Both	10	3.23	5.64

Disinfectants and shrimp production.

Amendment	n	Amount (t/ha/yr)	Production (t/ha/yr)
		Thailand	
Chlorine	19	0.72	8.75
Other*	7	(?)	7.62
None	8	---	5.70
		Vietnam	
Chlorine	10	0.33	5.85
Other**	11	(?)	6.73
None	7	---	1.32

*Copper sulfate, potassium permanganate, iodine, and BKC.
**Iodine, BKC, glutaraldehyde, and hydrogen peroxide.

Saponin, minerals and shrimp production in Thailand.			
	n	Amount (t/ha/yr)	Production (t/ha/yr)
Saponin	9	1.02	7.12
None	22	---	8.08
Minerals	17	(?)	9.97
None	14	(?)	5.62

Saponin, zeolite and shrimp production in Vietnam.

	n	Amount (t/ha/yr)	Production (t/ha/yr)
Saponin	6	0.29	4.42
None	22	---	5.28
Zeolite	17	0.80	5.06
None	11	---	5.21

Microbial Amendments (Probiotics)

- All farms in Thailand and Vietnam used them, so cannot compare production with and without probiotics.
- No evidence from research that these products improve water or bottom soil quality.

Conclusions about Amendments

- Ninety products – including liming materials, fertilizers, probiotics, vitamins, antibiotics, minerals, and disinfectants – were used in Thailand and Vietnam.

- The cost of amendments ranged from $170 to $2,262/t shrimp in Vietnam and from $0 to $654/t shrimp in Thailand.

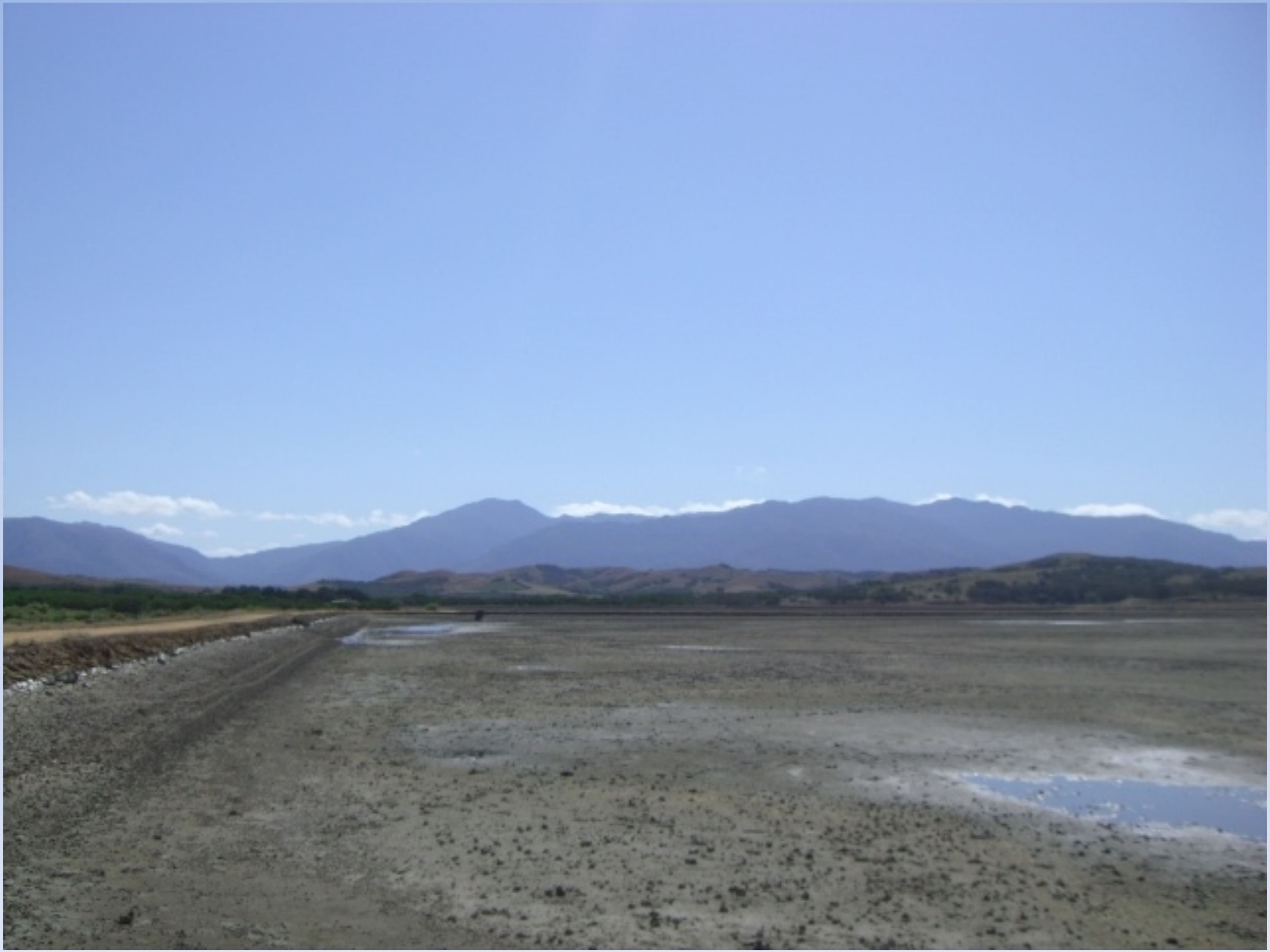
- Considerable reduction in production cost could accrue from applying only effective amendments and only when necessary.

Common Liming Materials

- **Agricultural limestone – crushed limestone (usually a mixture of $CaCO_3$ and $MgCO_3$).**
- **Burnt lime – limestone burned in a kiln (usually a mixture of CaO and MgO).**
- **Hydrated lime – burnt lime treated with water [usually a mixture of $Ca(OH)_2$ and $Mg(OH)_2$].**
- **Sodium bicarbonate – $NaHCO_3$ (often used in biofloc systems. Initially highly soluble.**

Liming and Disinfection

- To kill organisms in soil, and raise pH above 10.
- Two soils, acidic (pH 5.3) and alkaline (pH 7.6):
  - to maintain pH above 10 for 12 hr; 4,500 kg/ha in acidic soil; 3,000 kg/ha in alkaline soil.
  - to maintain pH above 10 for 24 hr; 7,500 kg/ha in acidic soil; 4,500 kg/ha in alkaline soil.
- Could restrict liming to areas of bottom that will not dry.



Liming pond bottom

Liming for Water Quality Improvement

- One purpose: avoid low alkalinity and low pH water in ponds with acidic soils or acidic source water.

- Other purpose: provide alkalinity to serve as a reserve source of carbon for phytoplankton and to buffer water against large daily pH fluctuation resulting from phytoplankton photosynthesis.

- Solubility of liming materials is controlled by pH, salinity, alkalinity, temperature, and calcium concentration in water.

Carbon Sources for Phytoplankton Photosynthesis

- Water with pH below 8.3 contains carbon dioxide and bicarbonate, and phytoplankton use carbon dioxide in photosynthesis – causes pH to rise.

- When pH reaches 8.3 there is no carbon dioxide; bicarbonate and carbonate are present.

- Phytoplankton can use bicarbonate as a carbon source for photosynthesis above pH 8.3 – causes pH to rise further.

Use of Bicarbonate by Phytoplankton (pH above 8.3)

$2HCO_3^-$ → Phytoplankton (carbonic anhydrase)

Phytoplankton → $CO_3^{2-} + H_2O$

Phytoplankton → CO_2 (for photosynthesis)

$CO_3^{2-} + H_2O$ —(Ca^{2+})→ $CaCO_3$ (suspended in water)

$CO_3^{2-} + H_2O$ —(H_2O)→ $HCO_3^- + OH^-$ (causes pH to increase)

$CaCO_3$ (suspended in water) → Precipitates

$CaCO_3$ (suspended in water) → Dissolves at night ($CaCO_3 + CO_2 + H_2O = Ca^{2+} + 2HCO_3^-$)

Respiration → Dissolves at night

Calcium Carbonate Saturation Index

- When a water reaches saturation with respect to calcium carbonate, no more calcium carbonate will dissolve in it.
- Seawater usually is near saturation with calcium carbonate.
- The pH for calcium carbonate saturation in water often is determined to ascertain whether calcium carbonate is likely to precipitate or dissolve.
- The most popular $CaCO_3$ saturation Index probably is the Langelier Saturation Index.

Langelier Saturation Index

$$LSI = pH = pH_{sat}$$

(1) If LSI = 0 ($pH = pH_{sat}$), water is saturated with $CaCO_3$.

(2) If LSI is positive ($pH > pH_{sat}$), $CaCO_3$ will precipitate.

(3) If LSI is negative ($pH < pH_{sat}$), $CaCO_3$ will dissolve.

pH_{sat} for Langelier Saturation Index

$$pH_{sat} = (9.3 + A + B) – (C + D)$$

$A = [\log_{10}(TDS) – 1]/10$

$B = [-13.12 \times \log_{10}(°C + 273)] + 34.55$

$C = \log_{10}(Ca^{2+} \times 2.5) – 0.4$

D = log10(TA)

TDS = total dissolved solids (or salinity) (mg/L)

°C = water temperature

Ca^{2+} = concentration (mg/L)

TA = total alkalinity as $CaCO_3$ (mg/L)

pH at calcium carbonate saturation in water of different compositions.

Water	TDS (mg/L)	Ca^{2+} (mg/L)	TA (mg/L as $CaCO_3$)	pH_{sat}
Seawater	34,500	400	116	7.02
Pond water	20,000	232	67.3	7.47
Pond water	5,000	60	50	8.12
Pond water	5,000	50	20	8.60
Pond water	34,500	400	10	8.08

Conclusions about Liming Materials

1. Farmers often add too little burnt lime to disinfect pond bottoms effectively. Because of large amounts required for effectiveness, use on areas that will not dry.

2. Most of the liming material applied to shrimp ponds does not dissolve. Limit use to ponds that actually need to be limed, i.e., bottom soil pH below 7, water pH below 7.5, and alkalinity below 75 mg/L.

Minimum Dissolved Oxygen Requirements of Shrimp

- **The dissolved oxygen concentration should not fall below 40-60% of saturation.**
- **Critical dissolved oxygen concentrations at 50% saturation:**

Salinity (ppt)	26°C	28°C	30°C	32°C
5	3.9	3.8	3.7	3.5
10	3.8	3.7	3.6	3.4
20	3.6	3.5	3.4	3.3
30	3.4	3.3	3.2	3.1
40	3.2	3.1	3.0	2.9

Effect of average early morning DO concentrations on shrimp survival, yield, and FCR in ponds stocked at 33 postlarvae/m^2 (three replications/treatment). Source: McGraw et al. (2001).

Early morning dissolved oxygen (mg/L)	Survival (%)	Shrimp yield (kg/ha)	FCR
2.32	42	2,976	2.64
2.96	55	3,631	2.21
3.89	61	3,975	1.96

Aeration Requirement

- Usually based on experience.
- Common rates:
  - 1 hp each 350-500 kg shrimp
  - 1 hp for each 8-10 kg/ha/day of feed input
- Can be calculated from feed BOD, hourly oxygen demand, minimum acceptable dissolved oxygen concentration, and aerator performance rating.

Feed BOD

- Organic C + O_2 🎭 CO_2; 2.67 kg oxygen used to oxidize 1 kg organic carbon in feed.
- NH_4 + $2O_2$ 🎭 NO_3^- + $2H^+$ + H_2O; 4.57 kg oxygen used to oxidize 1 kg nitrogen in feed.
- The feed BOD is the amount of oxygen needed to oxidize all carbon and nitrogen in feed not recovered in shrimp at harvest.
- Most shrimp feeds have BOD of 0.9 to 1.1 kg O_2/kg feed.

Hourly Oxygen Demand Assumptions

- Phytoplankton are basic oxygen neutral – they use as much oxygen as they produce.
- The daily oxygen demand of feed reaches an equilibrium with feed input in the later part of the crop.
- The oxygen demand is rather constant over a 24-hr period.
- The fact that phytoplankton actually produce more oxygen than they use provides a safety factor.

Hourly Oxygen Demand

$$\text{Hourly } O_2 \text{ demand} = \frac{\text{Feed BOD} \times \text{Daily feed input}}{24}$$

Example:

Feeding rate of 200 kg/ha/day,

$$\text{Hourly } O_2 \text{ demand} = \frac{(1.05 \text{ kg } O_2/\text{kg feed})(200 \text{ kg/ha/day})}{24}$$

$$= 8.75 \text{ kg } O_2/\text{hr.}$$

Aerator Performance Ratings

- The most common rating is the standard aeration efficiency (SAE). The SAE is given in kg O_2/kW·hr or kg O_2/hp·hr (1 hp = 0.746 kW). The SAE is for the standard test conditions of clean freshwater, 20°C, and 0 mg/L dissolved oxygen.

- The actual aeration efficiency (AAE) is for the performance of the aerator under actual operating conditions, and AAE is less than SAE.

Aerator Performance Ratings (continued)

- An equation is available for AAE, and most shrimp pond aerators operating at 28 to 32°C in water of salinities of 15-30 ppt will have AAE values around 0.3 to 0.6 kg O_2/hp·hr at the lowest acceptable dissolved oxygen concentration.

Aeration Requirement

- **Example:**

  Feed input = 200 kg/ha/day

  AAE of aerator – 0.45 kg O2/hp·ha

  Feed BOD = 1.05 kg O2/kg feed

Aeration requirement (hp/ha) =

$$\frac{(200\ \text{kg feed/ha/day} \times 1.05\ \text{kg } O_2/\text{kg feed})}{24\ \text{hr}} \div 0.45\ \text{kg } O_2/\text{hr}\cdot\text{hr}$$

= 19.4 hp.

- **Using the equation and specific data on FCR, feed BOD, and water quality, more exact determination can be made.**

$$\mathbf{A}\boldsymbol{AE} = \mathbf{SAE}\left[\frac{\boldsymbol{C_s} - \boldsymbol{C_a}}{\mathbf{9.09}}\right]\mathbf{1.024}^{\boldsymbol{t}-\mathbf{20}}\boldsymbol{\alpha}$$

where:

AAE = aeration efficiency in pond (kg O_2/kW·hr);

SAE = standard aeration efficiency (kg O_2/kW·hr);

C_s = dissolved oxygen concentration at saturation in pond water (at existing temperature and salinity) (mg/L);

C_m = minimum, desired dissolved oxygen concentration in pond water (mg/L);

9.09 = dissolved oxygen concentration in clean freshwater at 20°C (mg/L);

1.024 = empirically determined factor relating aeration rate to temperature;

t = water temperature (°C);

20 = standard temperature for reporting SAE (°C);

α = ratio of oxygen transfer coefficients of water being aerated:clean water (at same temperature and salinity). Use α = 0.94 for aquaculture ponds.