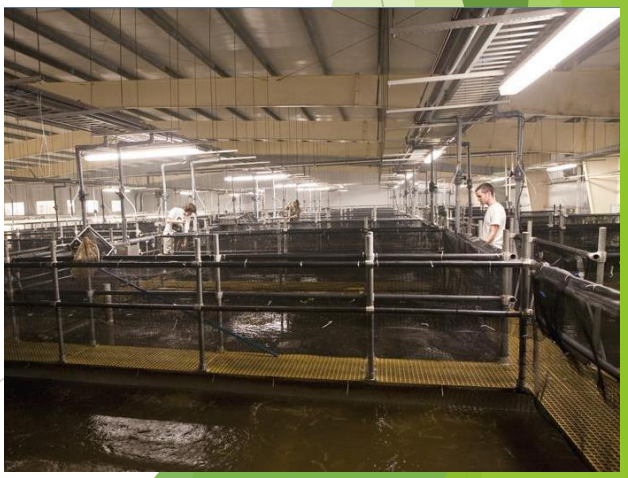
Accumulation of Toxic Metals in Bioflocs for Shrimp Culture

David Kuhn, Addison Lawrence, Jack Crocket

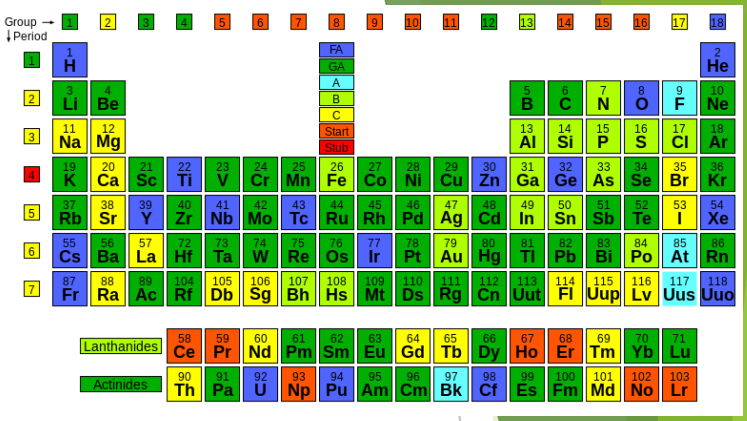
Shrimp culture in RAS

- Attracting considerable economic interest because:
  - Environmentally friendly
  - Bio-secure
  - Can be located inland in temperate climates
  - Year around production
- Two types of RAS
  - (1) Clear-water and (2) Biofloc
- Often conducted in lower salinity (brackish water)
- Very low water exchange rates

What are the challenges related to element/mineral accumulation or loss over time?



Elements and shrimp

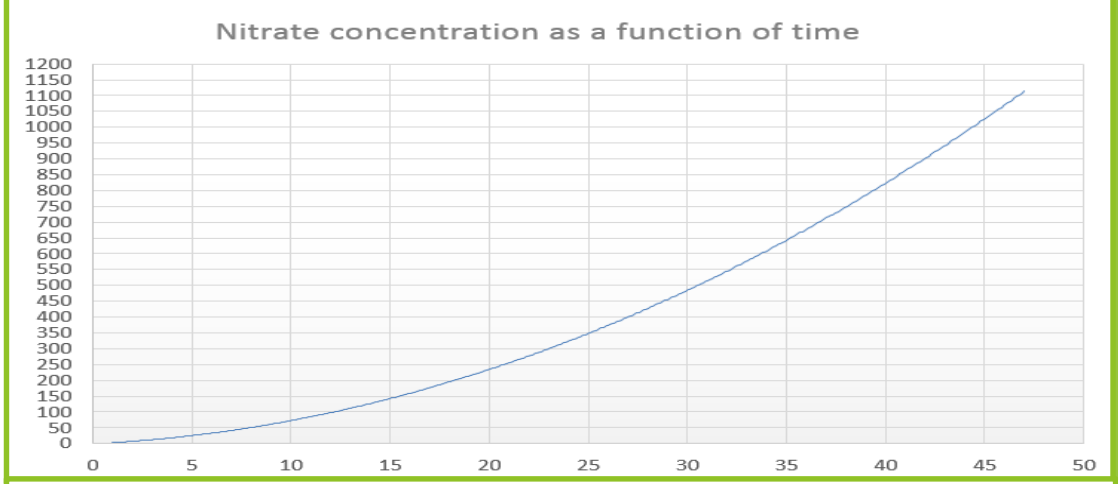


- Beneficial elements in water
  - Calcium:
    - Exoskeleton, enzyme activator, etc.
  - Chloride
    - Regulation of osmotic pressure and acid-base balance, etc.
  - Magnesium
    - Exoskeleton, enzyme activator, etc.
  - Phosphorus
    - Exoskeleton, phospholipids, ATP, energy and cell metabolism, etc.
  - Potassium
    - Osmotic pressure, acid-base balance, muscles, and glycogen and protein syn., etc.
  - Sodium
    - Osmotic pressure, acid-base balance, transport of O2 and CO2 in hemolymph, etc.
  - Sulfur
    - Amino acids, vitamins, detox of aromatic compounds, etc.
  - Others

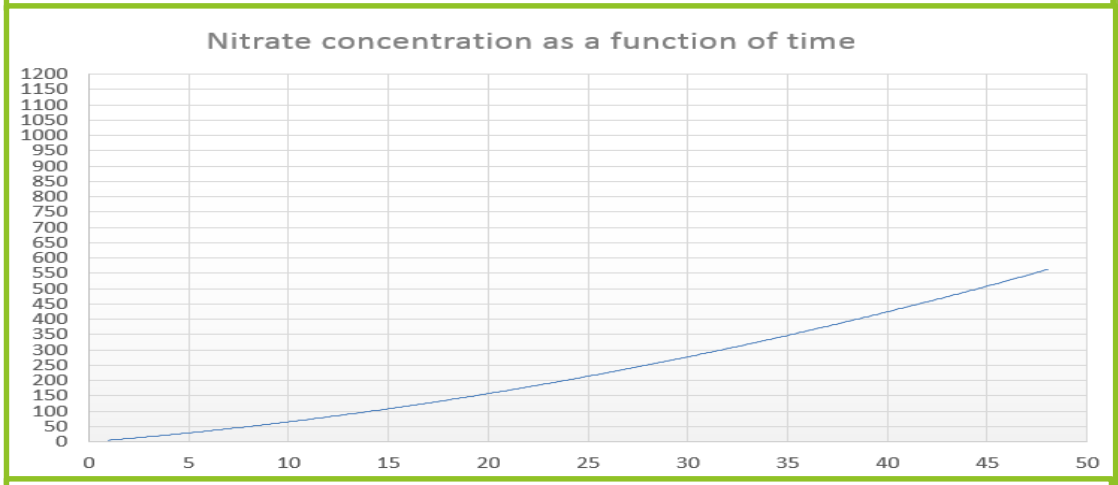
- Toxic elements
  - Copper
  - Cadmium
  - Chromium
  - Lead
  - Mercury
  - Manganese
  - Selenium
  - Zinc

Note: many of these are required at very low levels (micronutrients), typically delivered in the feed as part of the mineral mix

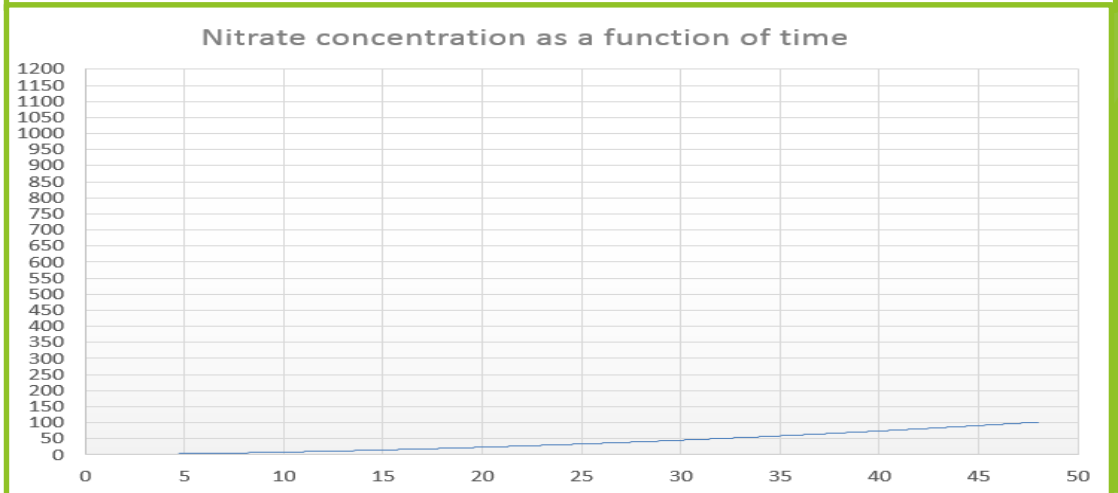
Low water exchange rate
(e.g. 0.5% a day) →



Moderate water exchange rate
(e.g. 10% a day) →



High water exchange rate
(e.g. 30% a day) →



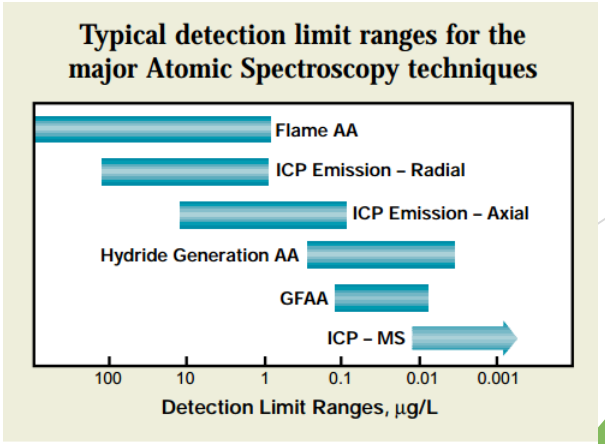
Methods for Analyzing Elements

Onsite option

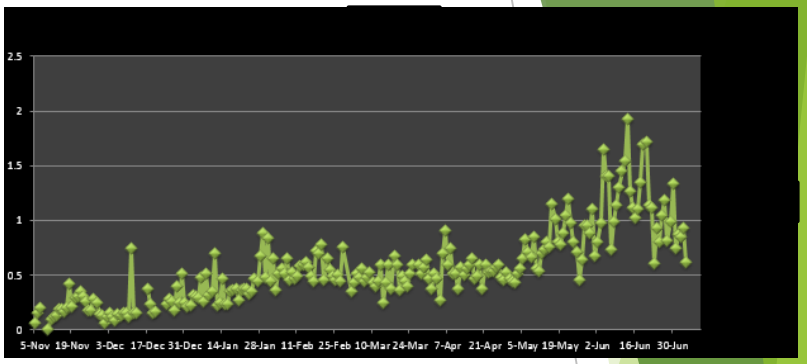
- Colorimetric methods
- HACH methods
- Meters
- Inexpensive
- Convenient
- Not accurate for some test methods

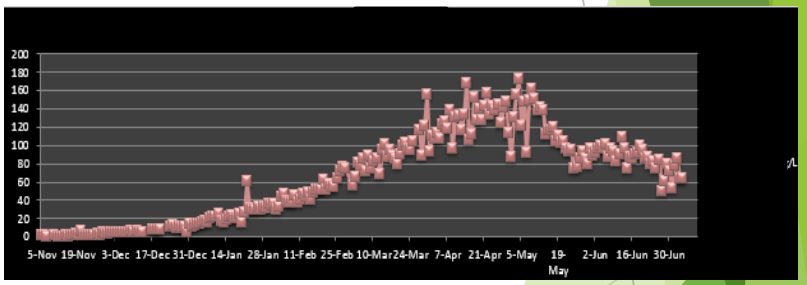
Offsite options

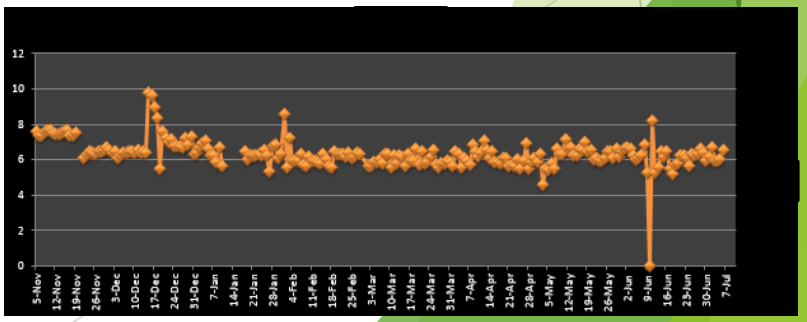
- Flame Atomic Absorption Spectrophotometry (FAA)
- Graphite Furnace Atomic Absorption Spectrophotometry (GFAA)
- Inductively Coupled Plasma Atomic Emission Spectrophotometry (ICP-AES; ICP Emission-Radial)
- Inductively Coupled Plasma Mass Spectrophotometry (ICP-MS)
- More expensive
- Less convenient
  - Universities or certified commercial labs usually required
- Extremely accurate



Record keeping







Target levels

Concentration of element or ion at given salinity

	Salinity 35 g/L	Salinity 15 g/L	Salinity 7.5 g/L	Salinity 0.5 g/L
Calcium	411 mg/L	176	88	6
Chloride	19,353	8,294	4,147	276
Magnesium	1,284	550	275	18
Potassium	399	171	86	6
Sodium	10,781	4,620	2,310	154
Sulfate	2,712	1,162	581	39
Na:K	27:1	27:1	27:1	27:1
Ca:K	~1:1	~1:1	~1:1	~1:1

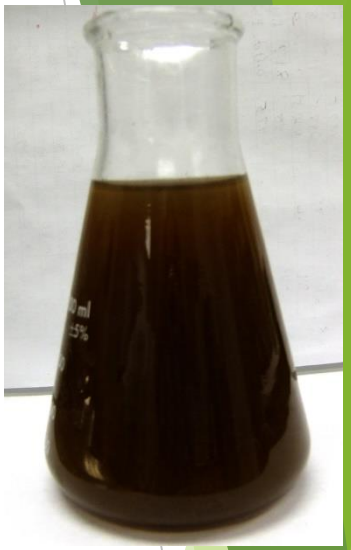
How to manage

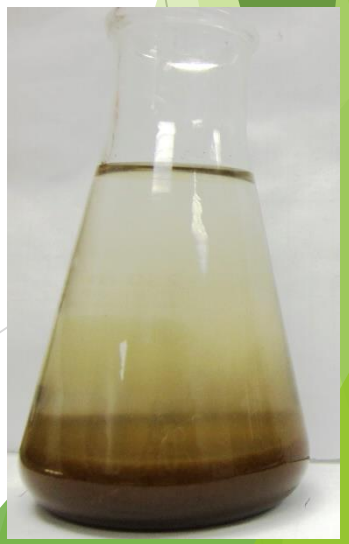
- Adjust salt and mineral levels in **feed**
- Adjust salt and mineral levels in **water**

Salt/mineral	Chemical formula	Common name	Approx. cost 50 pound QTY
Calcium chloride	$CaCl$	-	$20
Calcium sulfate	$CaSO_4$	Gypsum	$25
Magnesium sulfate	$MgSO_4$	Epsom salt	$25
Potassium chloride	KCl	Muriate of potash	$60
Potassium magnesium sulfate	K_2SO_4-$MgSO_4$	K-mag	$50
Potassium sulfate	K_2SO_4	-	$85
Sodium chloride	$NaCl$	Salt	$10
Synthetic sea salt	Mix	Sea Salt	$30 to $40 ($12 in bulk)

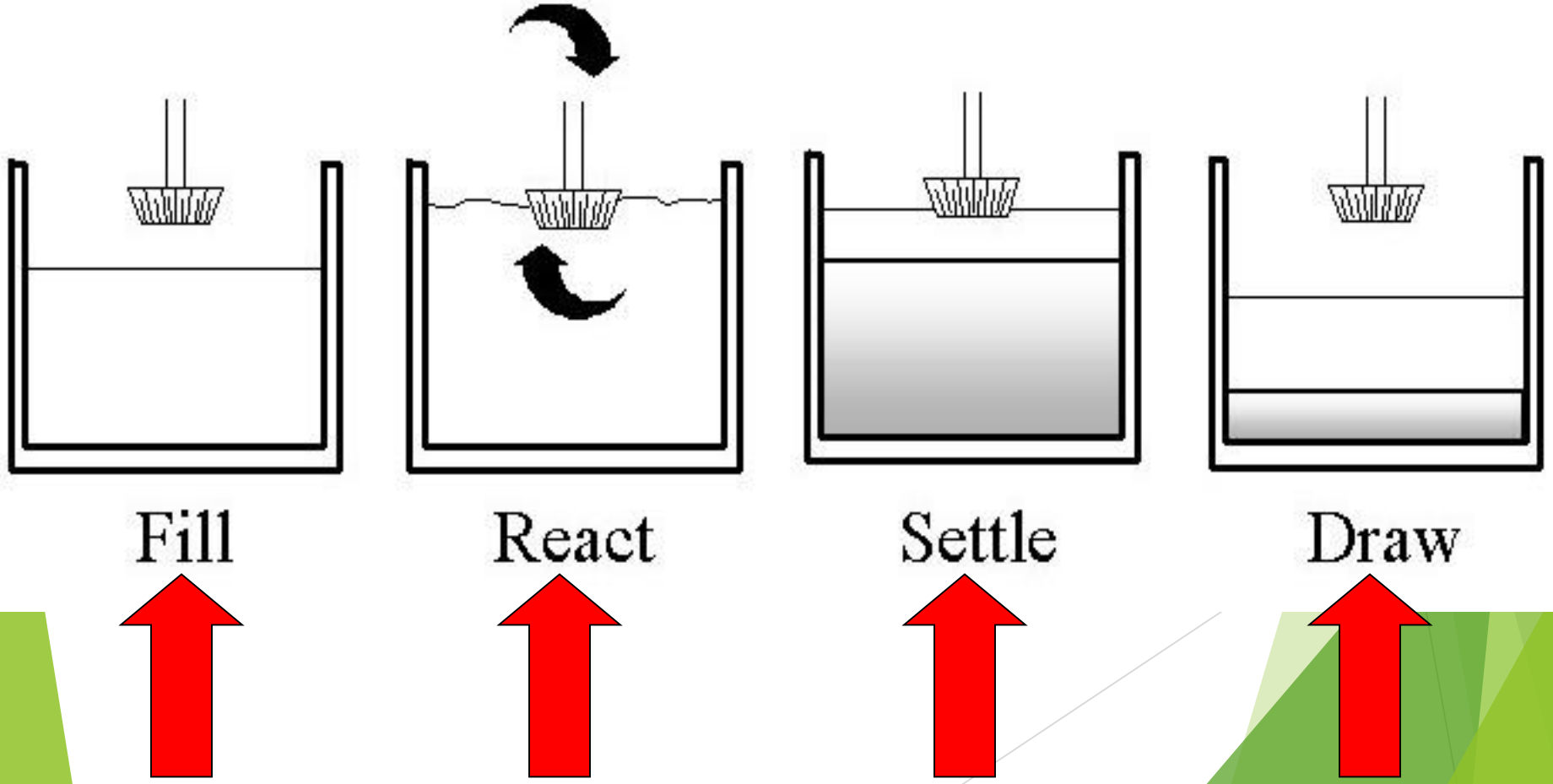
Case Study

- Bioflocs
  - Are bacteria, algae, other microorganisms, multivalent cations, exocellular polymers, uneaten feed, etc..
  - Removes nutrients (e.g. nitrogen) from the water by assimilating it into bacteria protein
  - Bioflocs serve as a food to shrimp
- Two types of biofloc technology
  - In-situ biofloc technology (common)
    - Bioflocs are produced in water with shrimp
    - C:N increased by carbon addition or using low protein feed
  - Ex-situ biofloc technology (emerging technology)
    - Bioflocs are produced externally in bioreactors
    - Carbon source not often required
    - Bioflocs can be used a feed ingredient

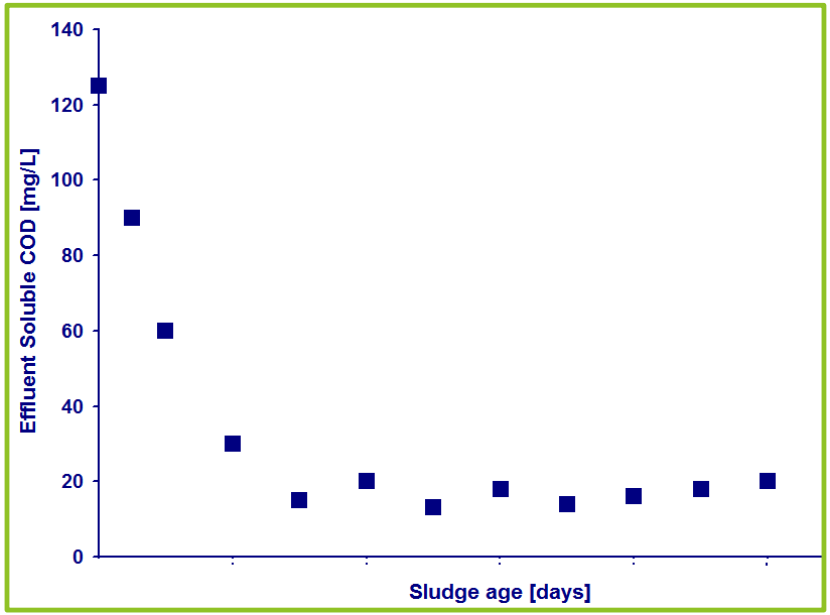


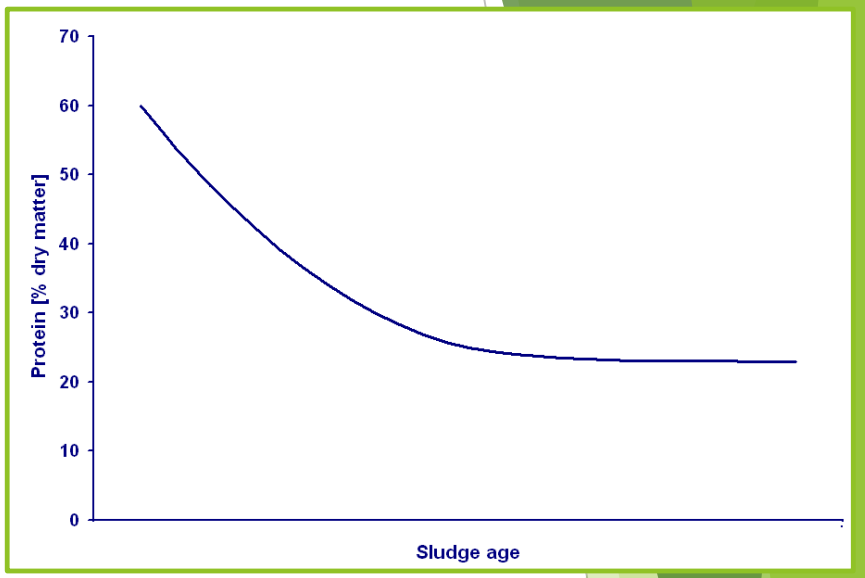


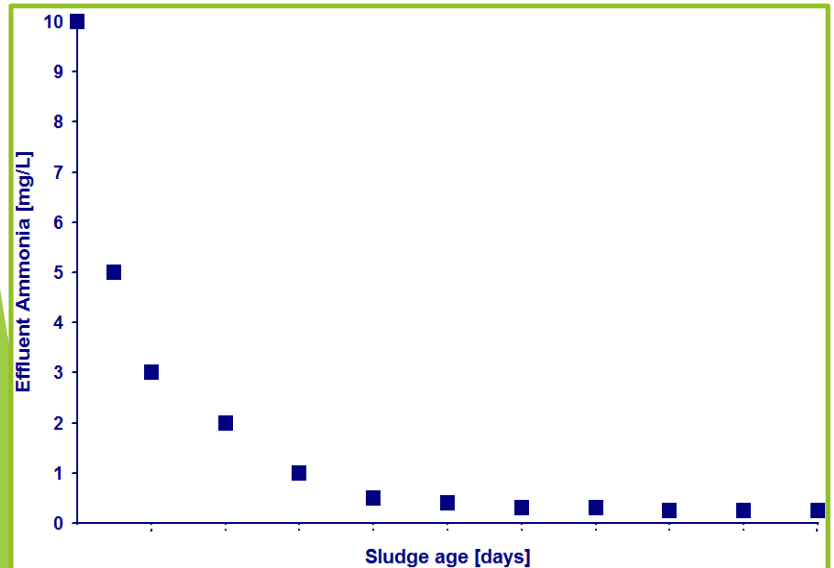
Biological reactors (e.g. SBR)

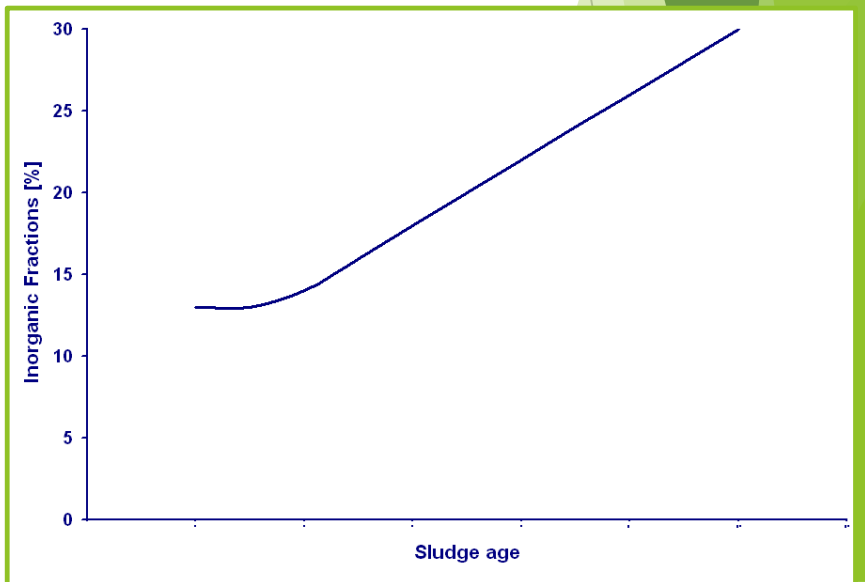


- Sludge age: average age of biofloc particle in bioreactor
  - Higher biofloc removal = younger sludge age
  - Less biofloc removal = older sludge age

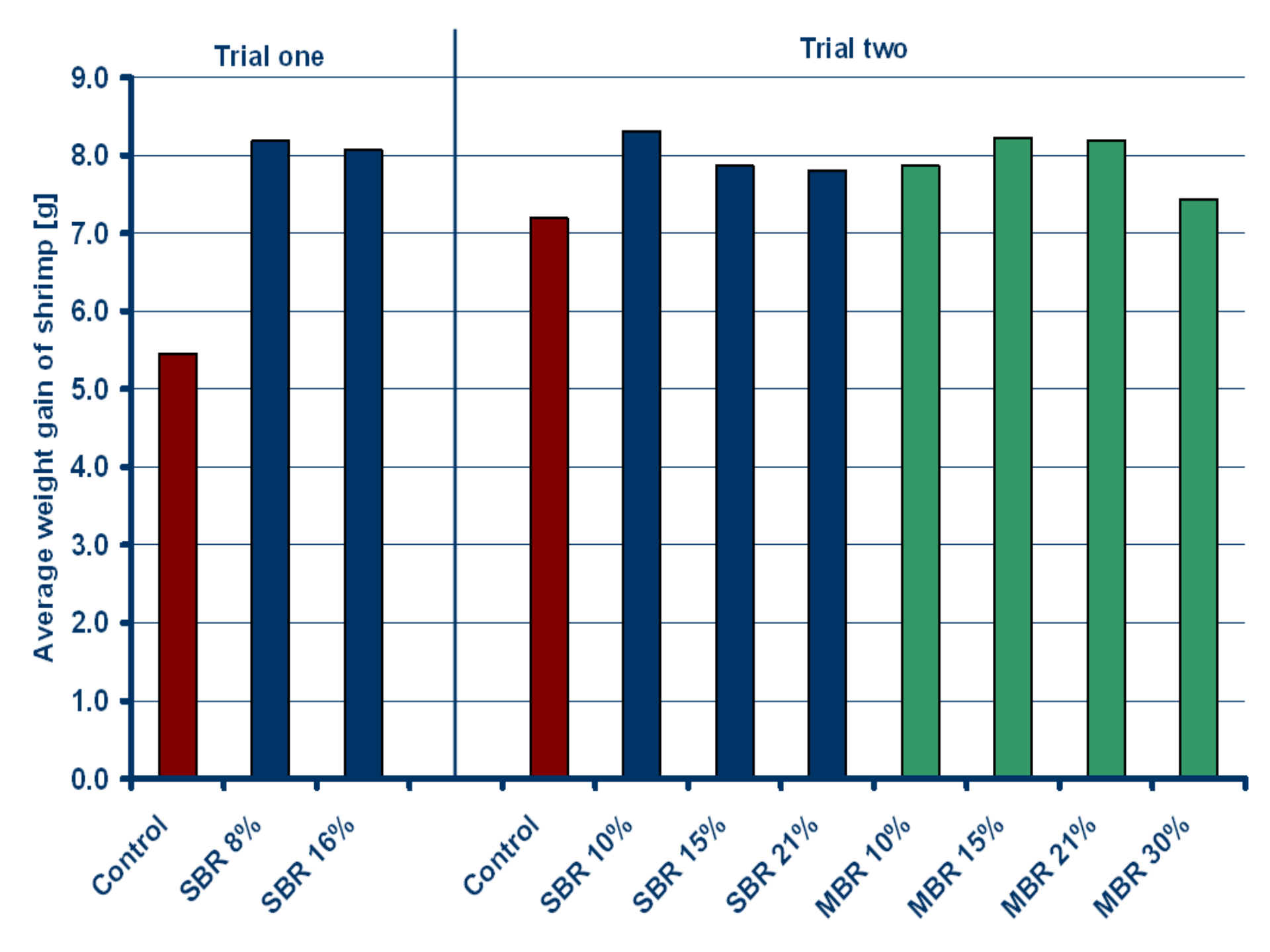








- Typically operate SBR with sludge age <30 days
  - Good performance of SBR
  - Harvested bioflocs to include in shrimp feed
  - Replacing fishmeal/soybean protein with bioflocs in feed always resulted in **equal or significant better growth of shrimp**
    - **Six replicates per diet, with five shrimp per tank**
    - **Shared water quality**
    - **Isonitrogenous, isocaloric diets**


Trial one
Trial two
Average weight gain of shrimp [g]
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Control
SBR 8%
SBR 16%
Control
SBR 10%
SBR 15%
SBR 21%
MBR 10%
MBR 15%
MBR 21%
MBR 30%

- Operated SBRs with high sludge age (> 60 days)
  - SBR cleaned the wastewater extremely efficiently
  - Great biofloc material from an operation standpoint (settled out well)
  - Used in growth trial. Shrimp growth was suppressed by nearly 30%!
  - WHY?
    - Conducted mineral analysis. Mn was between 0.9 and 1.1% in biofloc
    - Translated to approximately 0.1 to 0.3% Mn in the shrimp diet (depending on biofloc inclusion level)

- Laboratory trial
  - 5 different diets (0.02, 0.05, 0.10, 0.20, and 0.30% Mn)
    - 6 replicates per diet
  - 6 week study
  - 8 shrimp per 24-L tank