Challenges and opportunities in Aquaponics

Solids control in aquaponics systems

Introduction

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What are solids?

- Faeces
- Biofloc (dead and living bacteria)
- Uneaten food

- Size range from centimeters to microns
  - Settlable solids (>100 µm)
  - Suspended solids (<100 µm)
  - Fines (<30 µm)

Solids – why are they important?

- ± 30% of fish feed becomes solid waste
- Mostly organic matter
- Feed source for heterotrophic bacteria
- Oxygen competition between bacteria and fish
- Competition between autotrophs (nitrifiers) and heterotrophs
- Negatively affect water quality
- Source of nutrients for plants
- Negatively affect fish health

Removal mechanisms

- Gravity
  - Sedimentation basins
  - Lamella settlers
  - Swirl separators/vortex
  - Radial flow settlers
- Screening
  - Static screen
  - Drum filters
  - Belt filters
- Floatation
  - Foam fractionation
- Granular/Depth filtration
  - Sand filters (slow and rapid)
  - Bead filters
- Oxidation
  - Ozonation
  - Chlorination
  - AOT

Solids in RAS

- Normal RAS: majority of solids

  <100 µm

- Intensive RAS: majority of solids

  <30 µm

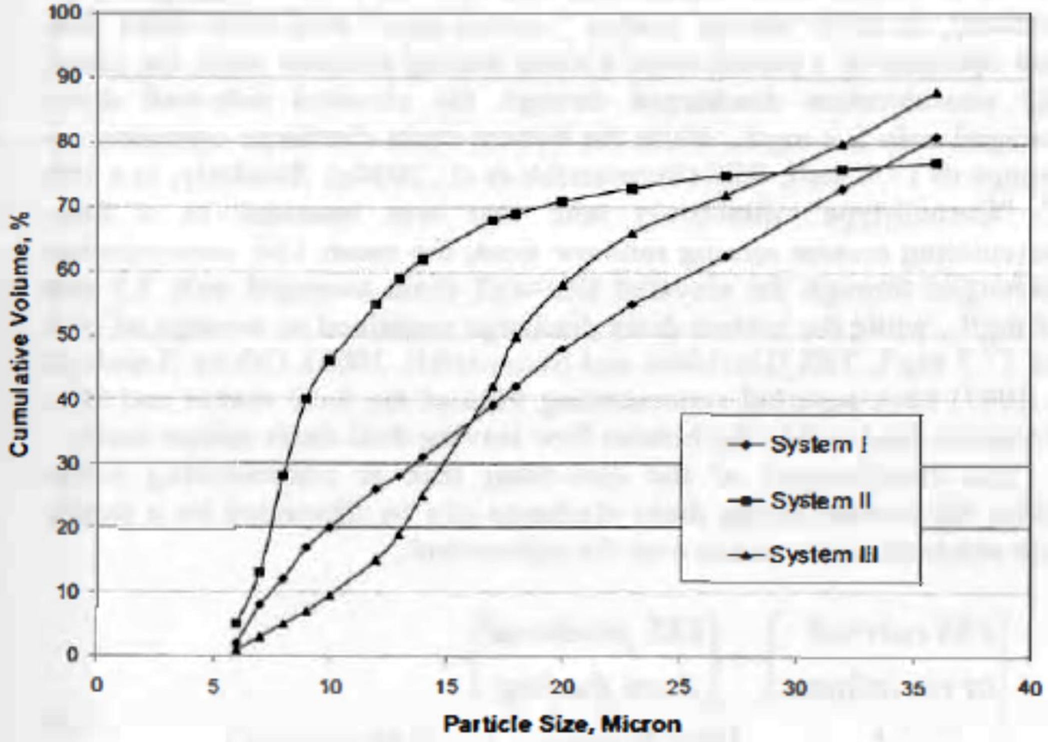


Figure 5.2 Cumulative distribution of particle volume in three recirculating high density aquaculture systems (Chen et al., 1993b). (Systems I and III were rainbow trout and System II was brook trout. Feeding rates were approximately 0.75% BW per day. Water exchange was 5% per day. System III used ozone.)

Source: Timmons & Ebeling, 2010

Safe concentrations

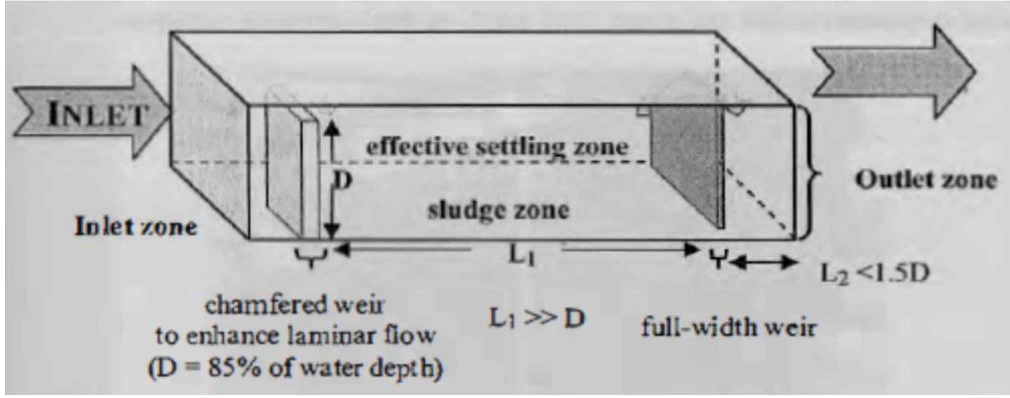
- Species dependent
- Typical RAS < 25mg/l (Alabaster and Lloyd, 1982)
- Sensitive species < 15 mg/l (EIFAC, 1980)
- Resistant species > 25mg/l

Criteria for solids control processes

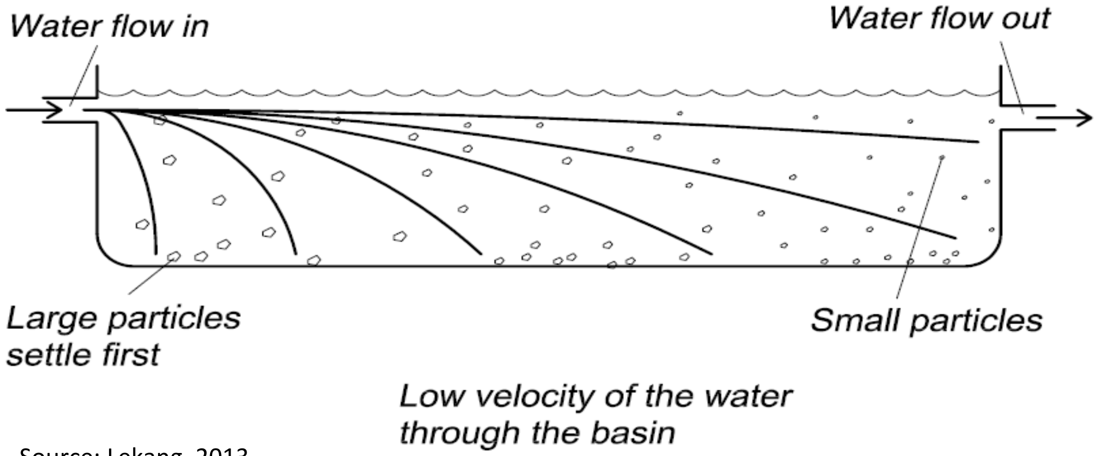
- Hydraulic loading rate (flow per unit cross sectional area)
- Fine solids removal capability
- Head loss
- Water loss during filter backwash
- Resistance to biofouling
- Ease of operation / maintenance
- Cost
- Footprint

Gravity separation - sedimentation basins

- Depends on particle settling velocity (0.01 – 4.3 cm/s)
- HRT 15 – 30 mins
- HLR: 1.66-14 m3/m2 per hour
- Turbulence should be avoided!
- Can be used in-line or off-line
- Easy to construct, but large footprint and water volume



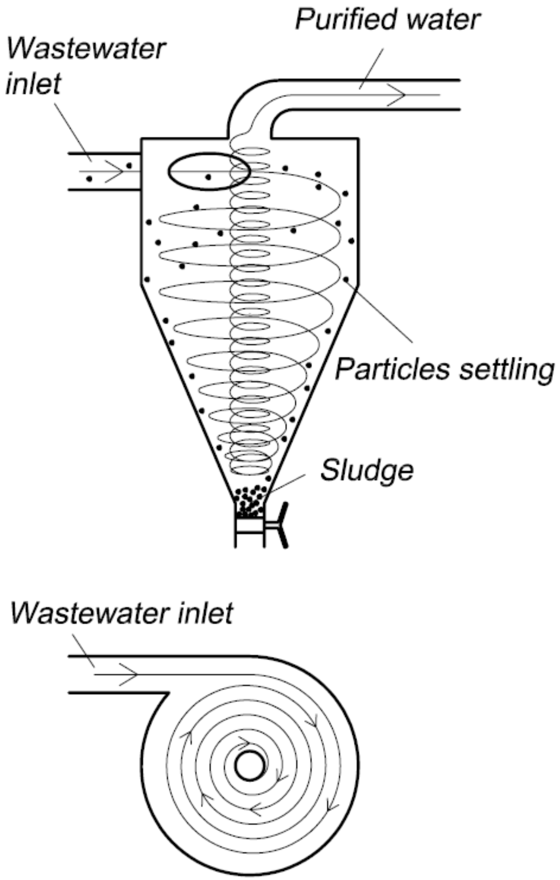
Source: Timmons & Ebeling, 2010



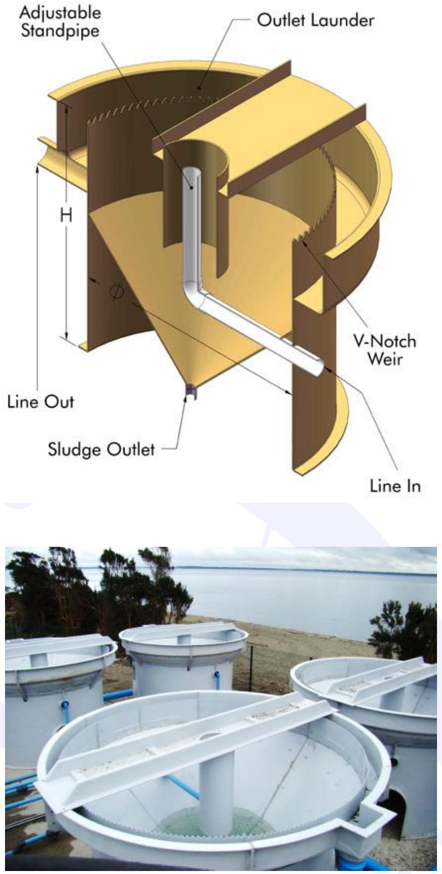
Source: Lekang, 2013

Gravity separation – swirl and radial flowseparators

- HRT >30s
- HLR: 7-14 m3/m2 per hour
- Turbulence should be avoided!
- Can be used in-line or off-line
- Radial flow twice as efficient as swirl separator



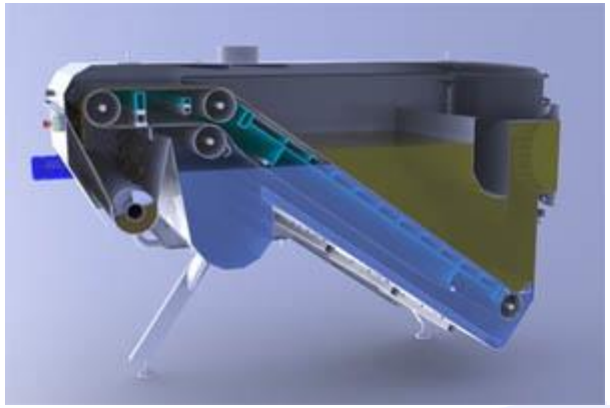
Source: Lekang, 2013



Source: Water Management Technologies, LA (US)

Microscreens: drum, disc and belt filters

- Minimal floor space
- Automatic operation – minimal labor
- Low head loss
- Fast removal of solids from water – no leaching
- Higher capital cost
- Drum filters are a prefered option



Source: Salsnes (NO)

Source: Veolia (Se)

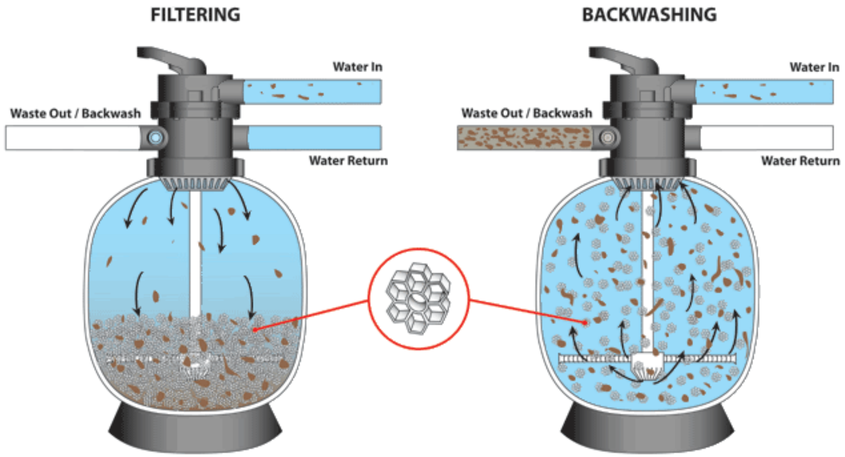
Source: Kurger Inc (US)

Source: LandIng Aquaculture

Granular media/depth

- Sand filters and bead filters
- Removal of fine solids (up to 5 µm)
- Higher head loss
- No filtration during backwash
- Solids remain in water → leaching
- Biological activity (good or bad)


Source: Aquaculture Systems Technologies, LO (US)



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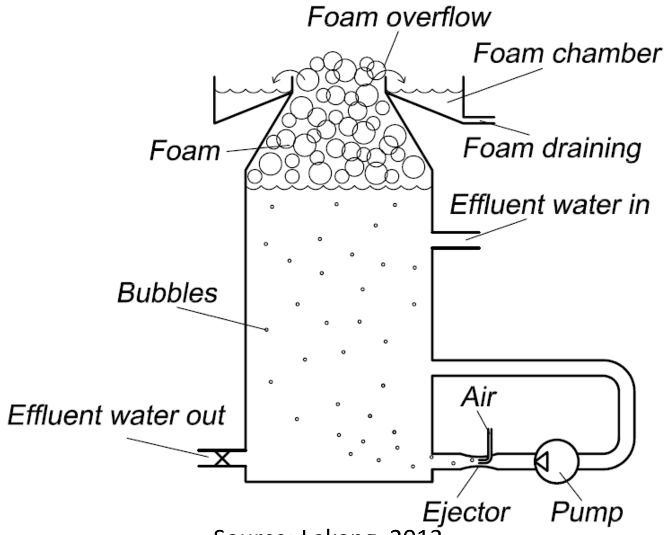
Foam fractionation

- Effective for fine solids (<30 µm)
- Removes surfactants (proteins)
- Air bubbles collect organic material, dissolved organic and proteins
- Produces large foam volumes
- Air and water must be mixed
  - Difussers, venturis, spray nozzles or trickling through media
- Can be coupled with ozone



Source: Lekang, 2013


Source: Coral Vue


Source: Clarity (NO)

Solids removal techniques characteristics

Table 5.1 Characterizations of Solids Removal Techniques for Recirculating Aquaculture Systems (Chen & Malone, 1991).

Technique	Solids Size Removed (micron)	Head Loss (m)	Hydraulic Loading m^3/d per m^2	TSS Removed (%)	Reference
Sedimentation	>100		24–94	40–60	EPA 1975
Settling tank			24–61		Liao 1980
Tube Settler			30–90		Muir 1978
Granular Media	>20	0.1–3	175–430	20–60	Muir, 1982; EPA 1975
Rapid sand filter			94–351	67–91	EPA 1975
			285	70–90	Mayo 1976
Pressure sand filters		2–20	115–700	50–95	Muir 1982; EPA 1975
Floating bead filter		0.8–6	1935		Wimberly 1990
Screen	>75	Negligi-ble	100–2,200		
Porous Media	>0.1		40–130		Muir 1982
Dissolved Earth	>0.1		29–59	>90	Muir 1982; EPA 1975
Cartridge	1–10	~5	1–10 gpm		
Hydrocyclones	1–75	14–35			Huguenjn & Colt 1989; Wheaton 1977
Foam Fractionation	<30		290–280		Chen 1991
Ozonation	<30		see Chpt 11		

Source: Timmons & Ebeling, 2010

Solids removal design tips

- Each particle size range must be addressed with the correct technique
  - Mix & Match±

    Example: drum filter + foam fractionation

    OR: radial flow separator + bead filter

    OR: etc etc

    “Large” and “fine” solids should be covered!
- DO NOT compromise on capacity:
  - Settling techniques don’t settle
  - Microsieves backwash too often
  - Nutrients leach
  - Solids accumulate, compromising your system
  - ...and you will have to start all over again

Think about:

head loss → energy use/costs

maintenance → labor costs

purchase price vs footprint

water use

Solids removal design tips (cont...)

- Some HP systems can control solids to certain degree
  - Media beds: natural solids traps, but not enough empirical data
- Ensure correct solids transport to your filters
- Tank design / hydrodynamics for rapid flushing of solids
- Water transport: avoid tight corners, check slopes and ensure correct water velocities
- In general, transport the solids out of the system as quickly and gently as possible!

Solids removal example

- Round tanks

  → hydrodynamics
- Soft bends
- Correct velocity in pipes
- Slope in central drain
- Drumfilter for large solids
- Foam fractionator for

  small solids

Thank you for your attention!