RAS Design and Engineering Principles with Aquaponics Integration

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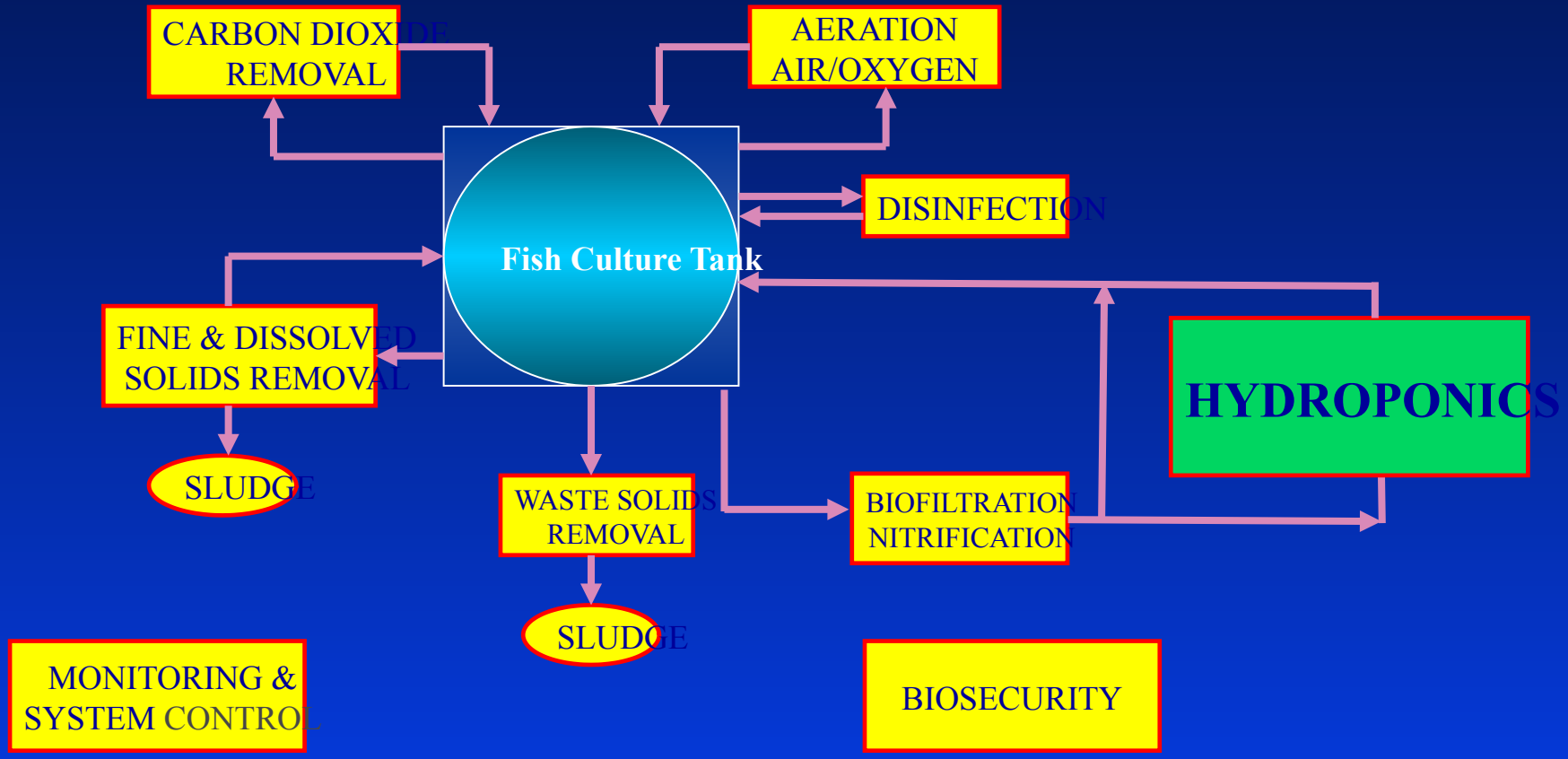
"Closed Environmental Life Support System for Fish"

Overview of Unit Operations



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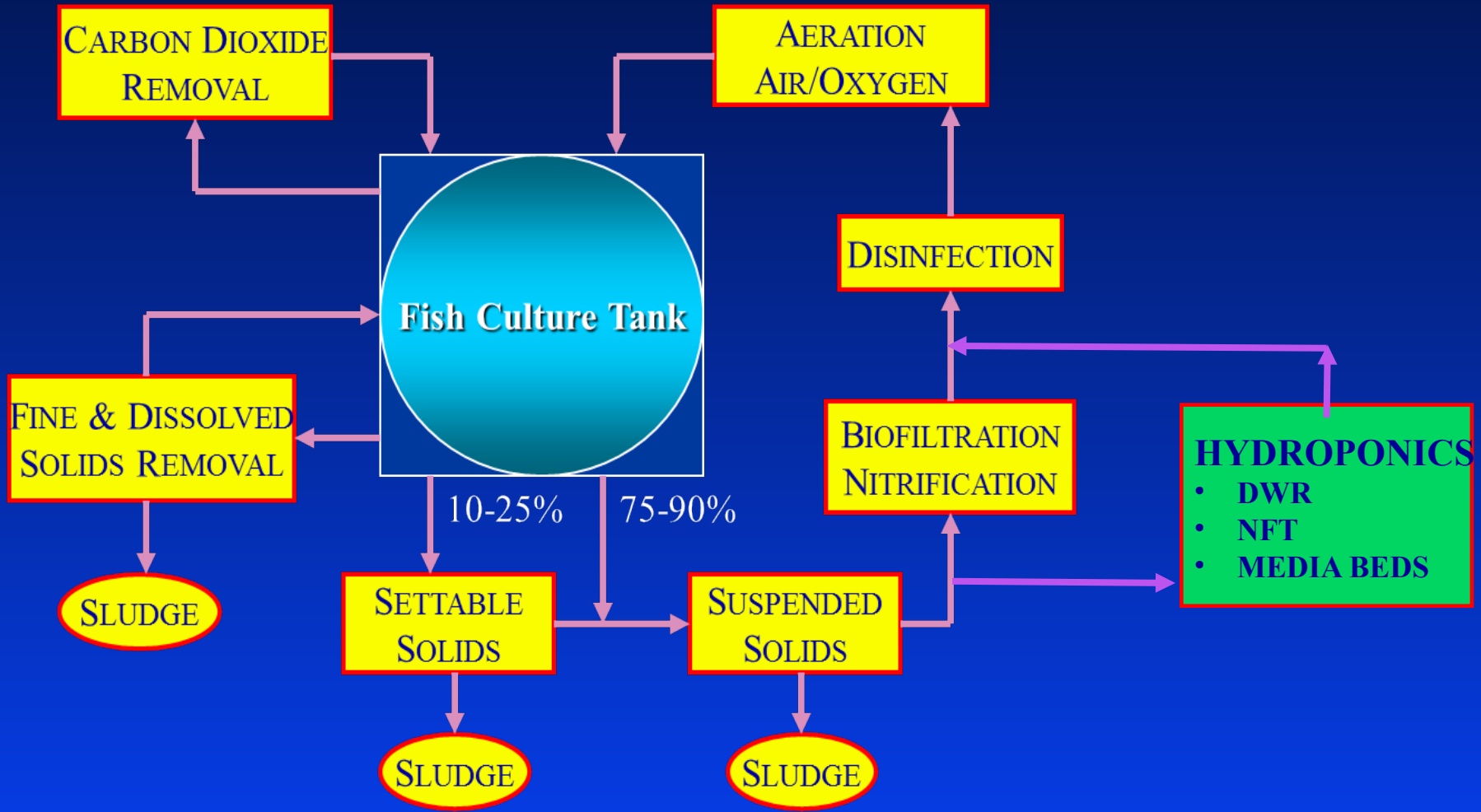

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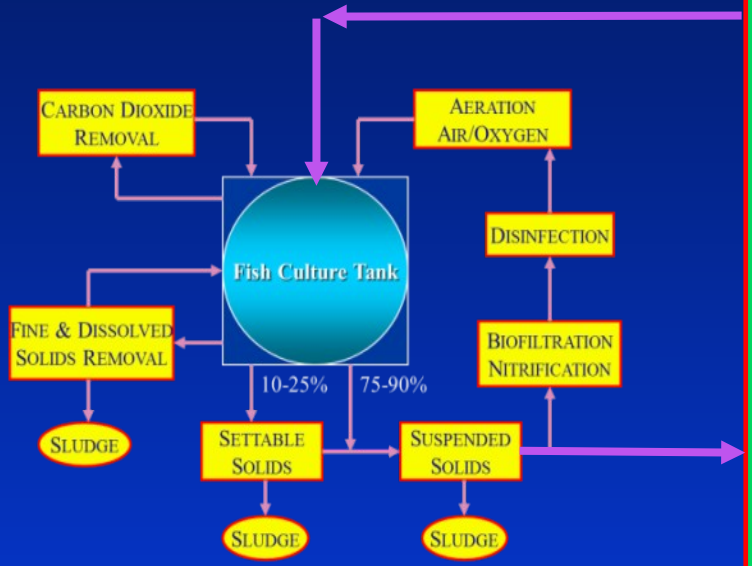


HYDROPONICS

- **DEEP WATER RAFTS**
- **NFT**
- **MEDIA BED**
- **DRIP**

Why Reuse Water?

Minimize Water Use

- conserve heat
  - Note, heat gain can also be a problem in some coldwater systems.
- decrease water demand
- decrease wastewater discharge volume
- reduce regulated TMDL discharged

Why Reuse Water?

Increase Biosecurity

- locate on smaller “pathogen-free” ground water or municipal resources
- smaller inlet flows are cheaper to disinfect
- smaller discharge flows are easier to screen and prevent escapement
- locate farm away from regions with known pathogen problems

Culture Tank

"Anything that holds water"

Polyethylene Tanks/Fiberglass Tanks

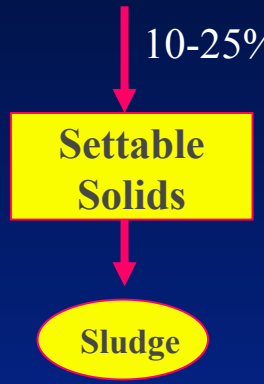
Plywood/Wood Tanks & Raceways

Fish Culture Tank

Aquarium & Algae Systems

Fish Culture Tank

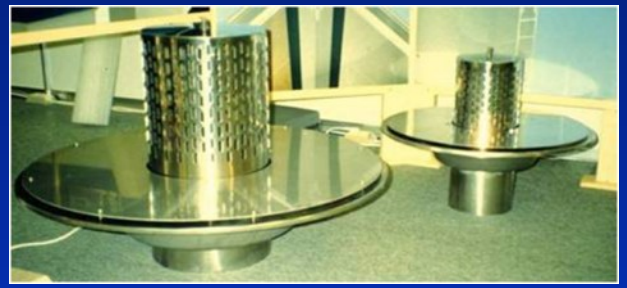
Settable Solids Removal



- Cornell Dual Drain System
  - Bottom center drain/ Upper sidewall discharge
- Settling basins
- Swirl separators/ Radial Flow Clarifers

"RULE OF THUMB"
1 kg of feed ⇒ 0.30 kgs of solids

"Cornell" Dual-Drain System

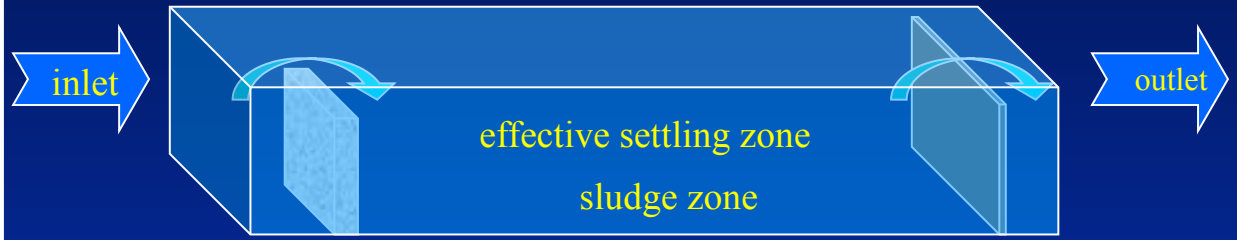


"RULE OF THUMB"

Dual-Drain Design

- Dia:Depth = 3:1 to 6:1
- 15 to 25% through center drain
- 75 to 85% through sidewall discharge

Settling Basins



Raceway Quiescent Zone

"Rule of Thumb"

Settling Basin Design

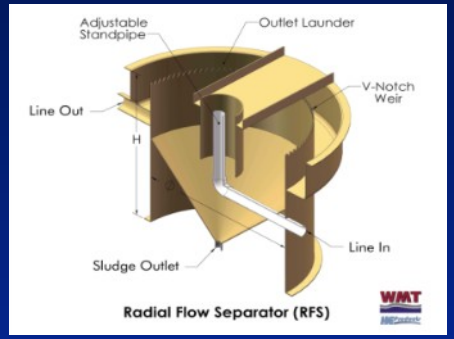
- basin floor area of 40 Lpm/m^2 of flow
- 250 to 410 Lpm per m width of weir for outflow
- submerge inlet weir 15% of basin water depth
- use 25 cm wide weirs and use rounded edges
- maximize length of settling chamber as much as possible

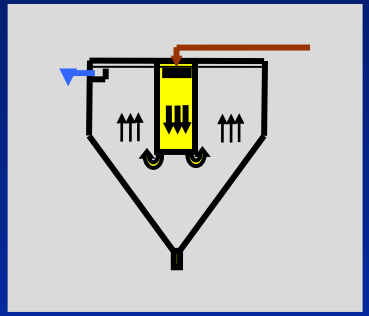
Swirl Separator / Radial Flow Clarifiers

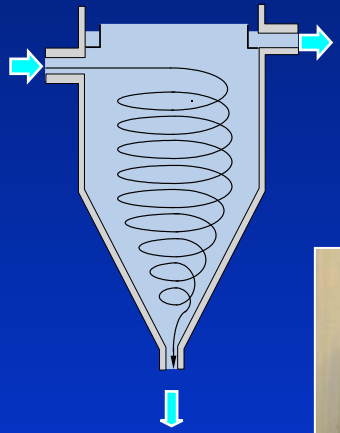
10-25%
Settable Solids
Sludge

$$V_s = \frac{g(\rho_p - \rho)D_p^2}{18\mu}$$

Stokes Law



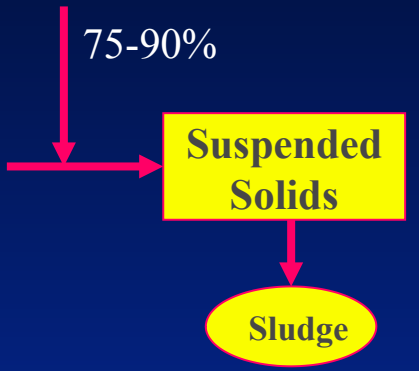


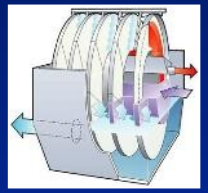


"RULE OF THUMB"
Radial FlowDesign

Surface-loading rate for the radial-flow clarifier 187 Lpm/m² (4.6 gpm/ft²) of settling area

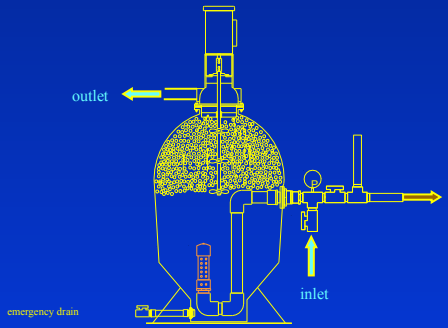
Suspended Solids Removal



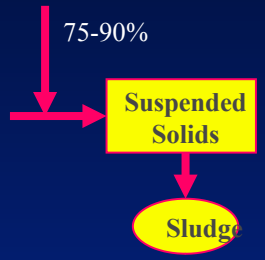


- Screen filtration
  - rotating microscreens
  - horizontal screen
  - vertical screen

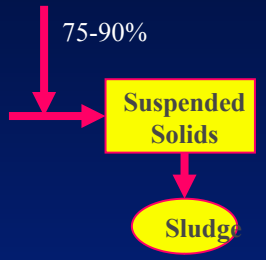
- Pressurized bead filters
- Pressurized sand filters
- Bag filters



Rotating Microscreen Filter



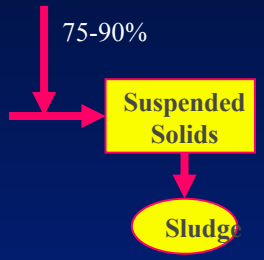
Pressurized Bead Filters



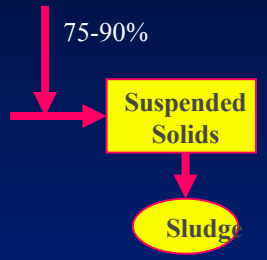
"RULE OF THUMB"
Suspended Solids Capture Design

Bead Filter – 5 to 6 lbs of feed per ft^3 of media

Pressurized Sand Filters

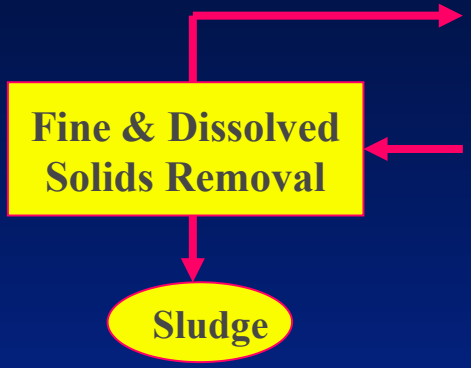


Bag Filters



Fine & Dissolved Solids

- Foam Fractionation
- Protein Skimmers



"RULE OF THUMB"
Foam Fractionation

Tank Volume every 2 to 4 hour

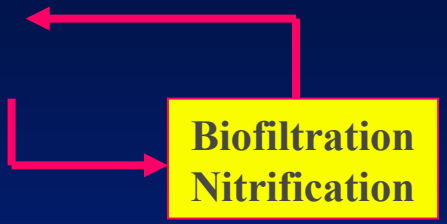
Solids Disposal

Sludge

By-Product
NOT a Waste Stream

- GeoTextile Bags
- Land application
- Composting
- Aquaponics

Biofiltration /Nitrification



Ammonia Oxidizing Bacteria Ammonia → Nitrite

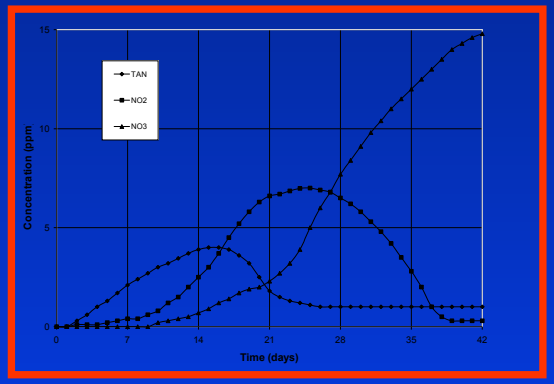
$$2\,NH_4^+ + OH^- + 3\,O_2 \Rightarrow 2\,H^+ + 2\,NO_2^- + 4\,H_2O$$

Nitrite Oxidizing Bacteria Nitrite → Nitrate

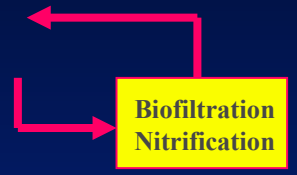
$$2\,NO_2 + 1\,O_2 \Rightarrow 2\,NO_3^-$$

"RULE OF THUMB"

1 KG FEED ⇒ ABOUT 0.03 KG AMMONIA



Biofiltration / Nitrification



- Trickling Biofilters
- Fluidized sand biofilters
- Moving bed BioReactors
- Media Bed - Hydroponics

"RULE OF THUMB"

MBBR Design

- 17.14 g TAN/ft^3 /day curler media @ 25 to 30 Deg C
- 13.26 g TAN/ft^3 /day @ 15 to 20 Deg C
- 10.14 g TAN/ft^3 /day @ 5 to 10 Deg C
- 3 to 5 min HRT
- 50% fill factor – max 65%
- Air flow: 0.125 scfm/ft^3 of reactor

Aeration / Oxygenation

Aeration Systems

Air Stones, Packed Towers

Oxygenation Systems

Micro-Diffusers, Speece Cones

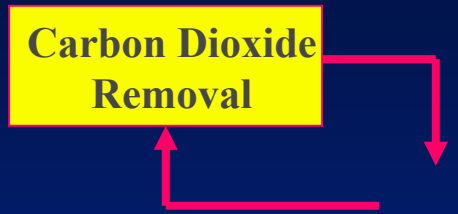
"RULE OF THUMB"

1 KG FEED $\Rightarrow$ 0.65 TO 1.00 KG OF O_2

Emergency Backup Oxygen

Normally Open Soleniod
Opens on Power Failure

Carbon Dioxide Removal

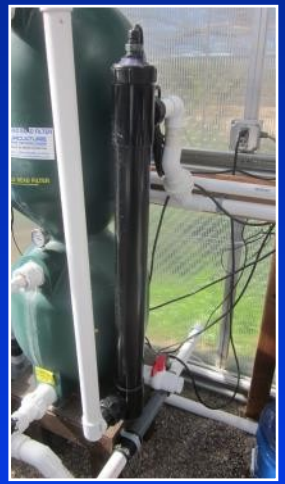


- Packed column degassing units

Disinfection

Disinfection

- Ultraviolet radiation



"RULE OF THUMB"
UV

- 30 mW-sec/cm^2
- 10-30 second contact times

- Ozone

"RULE OF THUMB"
Ozone

0.025 and 0.045 kg O_3 per kg feed

Monitoring & System Control

Monitoring & System Control

Continuous

- DO
- Level
- Flow
- Temperature
- Air pressure

Phone Dialer

Periodically

- pH
- EC
- NH_3
- NO_2
- NO_3
- CO_2
- Alkalinity

The most sophisticated monitoring and alarm system is an attentive human operator!

It takes only one mistake to KILL EVERYTHING IN YOU FACILITY!!!!

Continuous Monitoring

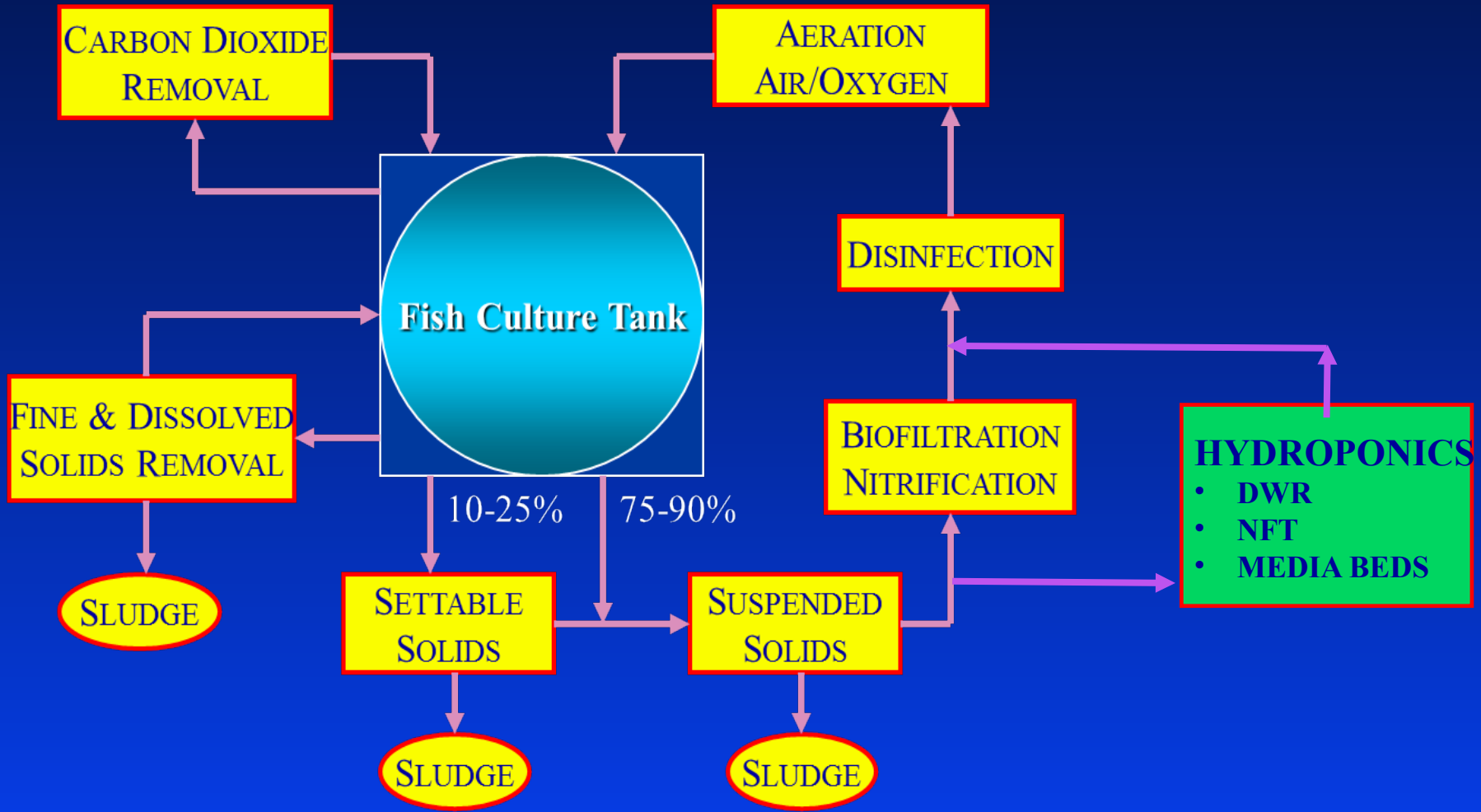
Monitoring & System Control

BioSecurity

Support Components

- Water Quality Lab
- Storage - Feed, Chemicals, Product
- Equipment Storage
- Staff Support
- Back-up Generator
- Quarantine Area
- Waste Disposal

Overview of Unit Operations



Aquaponics

Aquaponics: the integration of aquaculture and hydroponics

Advantages of Aquaponics over RAS systems

- plants recover a substantial percentage of the traditionally discharged nutrients
- minimizing water exchange reduces operating costs of aquaponic systems
- secondary plant crop improves overall system profit potential
- savings in construction and operation by sharing operational and infrastructural costs
- opportunity for sustainable, localized, small-scale production

Disdvantages of Aquaponics over RAS systems

- large ratio of plant growing area to fish rearing area
- new set of skills – aquaculturist and horticulturist
- limits use of treatment options for both fish and plants

RAS Aquaponics -Compromises

Compromise of Aquaculture and Hydroponics

pH: 6.5 to 7.0

- Raise pH – Calcium Hydroxide or Potassium Hydroxide
- Lower pH – nitric, phosphoric or acetic acid

Temperature: 21 to 23 °C (70 to 74 °F)

- Tilapia usually: 25 to 28 °C (78 to 84 °F)
- Plants over 23°C (75°F) – slow growth & susceptible to funus and phthium

RAS Aquaponics -Compromises

Compromise of Aquaculture and Hydroponics

Ammonia: < 3.0

- Species dependent
- High ammonia concentrations toxic to both plants and fish

Dissolved Oxygen: 80% saturation

- Tilapia: > 3.0 mg/L
- Plants just as important!!

Alkalinity: > 100 mg/L as $CaCO_3$

- 90 to 200 mg/L
- Never use Sodium Bicarbonate (Baking Soda), high sodium levels

RAS Aquaponics -Compromises

Compromise of Aquaculture and Hydroponics

Electrical Conductivity: lower than hydroponics systems

- Hydroponics: 1500-1800 ($\mu S \cdot m^{-1}$)
- Aquaponics: 300 to 800 ($\mu S \cdot m^{-1}$)
- Continuous generation of nutriens
- Organic nature of nutrients results in a lower concentration of salts

Common Deficiencies:

- Potassium – potasium hydroxide
- Calcium – calcium hydroxide
- Iron – chelated iron

Hydroponic/Aquaponic Systems

Water Based Culture:

- Floating Hydroponic Technique
  (Raft Culture, Deep water Culture)
- Nutrient Film Technique (NFT)

Media Based Culture:

- Reciprocating Systems
- (Ebb & Flow, Flood & Drain)
- Dutch Bucket
- Drip System – Rockwool Slabs

Air Based Culture:

- Aeroponics
- Vertical Gardens

Hydroponics /Aquaponics

Hydroponics – Raft System

Friendly Farm Hawaii.

Lettuce Factory, Ithica, NY

Nelson & Pade, Inc.

Hydroponics /Aquaponics

Raft System – Deep water

Advantages

- Significant buffering due to large volume of water
- Well adapted for the production of short stature crops
- pH and EC maintained at constant levels
- Temperature of root zone optimized
- Dissolved oxygen maintined with airstones
- Ease of handling/harvesting
- Maximized greenhouse floor space

Disadvantages

- Limited to crops like lettuce/basal/herbs
- Plants low to ground

Aquaponics

Hydroponics – NFT System

Nelson & Pade, Inc.

E&T Farms Aquaponics.

Continental Organics

Aquaculture Systems Tech., LLC

Hydroponics /Aquaponics

NFT System

Advantages

- Low capital start-up costs
- Ease of handling/harvesting
- Maximized greenhouse floor space
- Plants are typically at waist level

Disadvantages

- Limited buffering due to small volume of water
- Difficult to control root temperature
- Disruption in water flow leads quickly to dehydration and wilting

Hydroponics /Aquaponics

Reciprocating System (flood and drain)

To ensure adequate aeration of plant roots, gravel beds are operated in a reciprocating (ebb and flow) mode, where the beds are alternately flooded and drained.

Hydroponics /Aquaponics

Reciprocating System (flood and drain)

Advantages

- Lowest capital start-up costs
- Ease of handling/harvesting
- Grow a wide variety of crops
- Maximized greenhouse floor space
- Media beds at waist level

Disadvantages

- Media is can be very heavy & expensive
- Disruption in water flow leads to dehydration and wilting

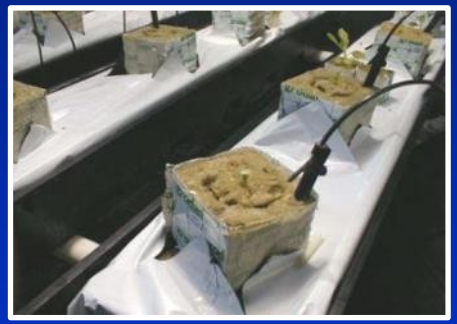
Hydroponics /Aquaponics

Dutch Bucket System (bato buckets)

Dutch Bucket is basically a 2.5 to 3 gallon bucket with a special drain fitting that maintains a small reserve of nutrient at the bottom as a precautionary measure.

Hydroponics /Aquaponics

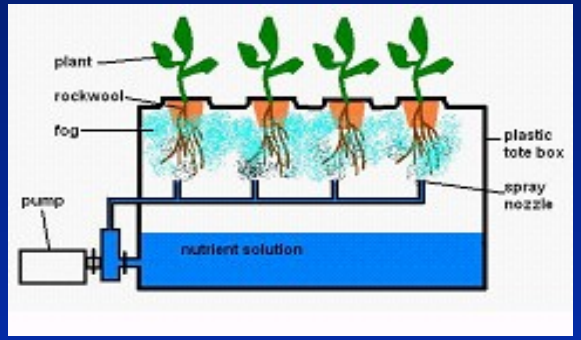
Drip System – Rockwool Slabs



These cucumbers are being grown in a slab-drip-irrigation system. The nutrient solution is delivered via drip irrigation lines.

Hydroponics /Aquaponics

Aeroponics



In an aeroponics environment the plants grow with the roots suspended in a misted solution of nutrients.

Hydroponics /Aquaponics

Vertical Gardens

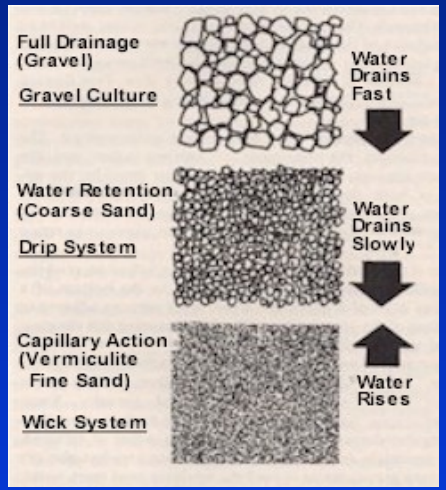
In an aeroponics environment the plants grow with the roots suspended in a misted solution of nutrients.

Hydroponic Mediums

Perfect Medium

- Holds a even ratio of air to water
- Helps to buffer pH changes with time
- Is easily flushed and re-wets easily after being dehydrated
- Is reusable or biodegradable
- Is inexpensive and easy to obtain
- Lightweight and easy to work with.

Sometimes the Perfect Medium is NO medium



Hydroponic Mediums

Commonly Used Mediums:

Rockwool

Coconut Coir

Coco Peat

Perlite

Lightweight Expanded Clay Pellets

Common Pea Gravel

Engineering Design Details

Hydroponics – Raft System

Design Crieria: daily feed input/plant growing area

(Hydroponics makes up 75% of the system water volume)

Raft System: channel (raceway) with a 1 ft depth, usually 4 to 8 ft wide covered by a floating sheet of polystyrene (4 ft x 8 ft x 1 ½ inches) for plant support.

"RULE OF THUMB???"

60 to 100 g of fish feed/day m^2 of raft area
60 to 90 min water turnover rate
Aeration – airstones or diffusers

Engineering Design Details

Hydroponics – NFT System

Design Crieria: daily feed input/plant growing area
(Hydroponics makes up small fraction of the system water volume)

NFT System: shallow flow of water, 1 lpm with 1% slope

"RULE OF THUMB"
Waste Treatment

15-25 g of fish feed/day m^2 of raft area
1 lpm for rate
1% slope

Engineering Design Details

Hydroponics – Reciprocating System (flood and drain)

Design Crieria: daily feed media volume

(Hydroponics makes up small fraction of the system water volume)

Volume ratio of 1 ft^3 of fish-rearing to 2 ft^3 of media

"RULE OF THUMB"

Waste Treatment

1 ft^3 of fish fish rearing volume to 2 ft^3 of media (1/4 to ½ inch in diameter)

Engineering Design

Design Crieria: daily feed input / plant growing area?

Golden Rule of Engineering Mass Balance

Production = Consumption + Accumulation

Nutrients from Fish | Plant Growth | Excess or Deficit in Nutrients

Water Quality

Plant Nutrients

Free Macronutrients

(90 to 95% dry weight)

carbon (C): 30 to 50%
oxygen (O): 30 TO 48%
hydrogen (H): 6%

Micro-nutrients

(less than 1% dry weight)

chlorine (Cl)
iron (Fe)
manganese (Mn)
boron (B)
zinc (Zn)
copper (Cu)
molybdenum (Mo)

Macro-nutrients

(5 to 10% of dry matter)

nitrogen (N): 22%
phosphorus (P): 6%
potassium (K): 29%
calcium (Ca): 21%
magnesium (Mg): 6%
sulfur (S): 11%

pH Control
Calcium hydroxide
Potassium hydroxide
(Never Baking Soda)

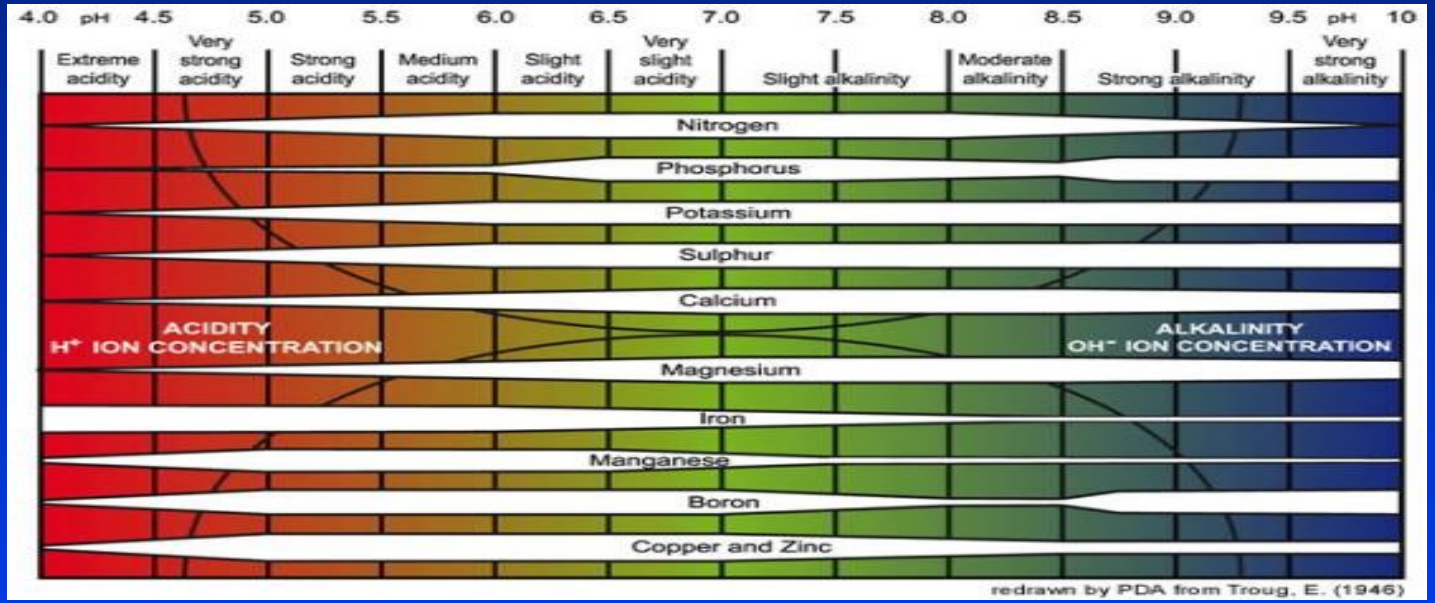
Nutrient Availability and pH

High pH:

Decreases the availability of Iron, Manganese, Boron, Copper, Zinc and Phosphorous

Low pH:

Decreases the availability of Potassium, Sulphur, Calcium Magnesium and Phosphorous



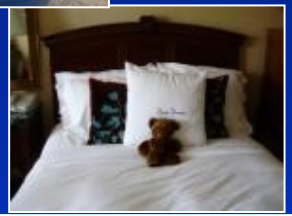
Questions?











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