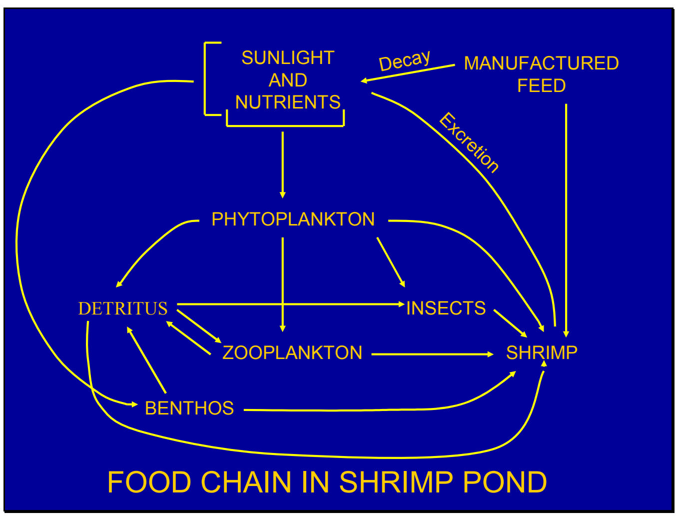
Workshop 1: Best Management Practices for water and soil management in shrimp farming

The workshop on the management of soil and water quality was delivered by Doctor Claude Boyd (University of Alabama) on June 23 to June 25, 2003 in Mazatlán, México. The following slides are the intellectual authorship of Dr. Claude Boyd and were used during this 3 day training event.

Taller 1: Buenas Prácticas para el Manejo de Aguas y Suelos en el Cultivo de Camarón

El taller "Buenas Prácticas para el Manejo de Aguas y Suelos en el Cultivo de Camarón" fue impartido por el Doctor Claude Boyd de la Universidad de Alabama los días 23 al 25 de Junio del 2003 en Mazatlán, México. Las gráficas que se muestran a continuación son propiedad intelectual del Dr. Claude Boyd y fueron usadas durante los tres días de duración de este taller.



FOOD CHAIN IN SHRIMP POND

LIGHT-DARK BOTTLE MEASUREMENT OF PHOTOSYNTHESIS

INITIAL BOTTLE (IB) - INITIAL OXYGEN CONCENTRATION
LIGHT BOTTLE (LB) - RESPIRATION AND PHOTOSYNTHEISIS
DARK BOTTLE (DB) - RESPIRATION ONLY

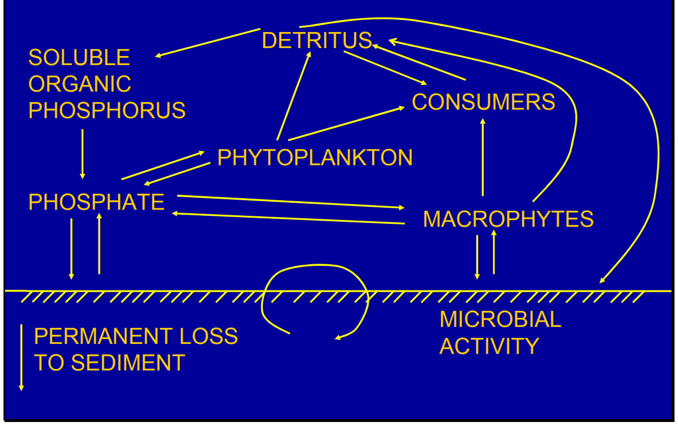
LB - IB = NET PHOTOSYNTHESIS (NP)
IB - DB = RESPIRATION (R)
NP + R = GROSS PHOTOSYNTHESIS
OR
LB - DB = GROSS PHOTOSYNTHESIS

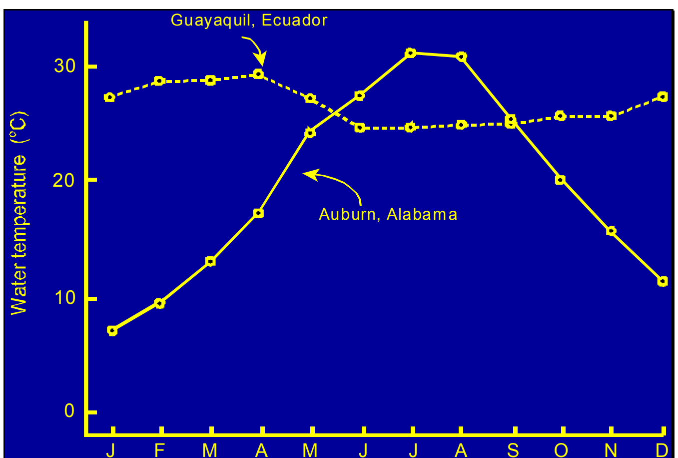
ESSENTIAL MINERAL NUTRIENTS FOR PLANTS

Macronutrients	Micronutrients
Nitrogen	Iron
Phosphorus	Manganese
Sulfur	Copper
Calcium	Zinc
Magnesium	Boron
Potassium	Molybdenum
Sodium*	Cobalt*
Silicon*	Chlorine*

*Not all required by all species. There is evidence that certain algae and some higher plants need one or more of these elements

PHOSPHORUS CYCLE IN A FERTILIZED AQUACULTURE POND





Average monthly water temperatures at two sites

pH OF PURE WATER

$$H_2O = H^+ + OH^-$$

$$(H^+)(OH^-) = 10^{-14}$$

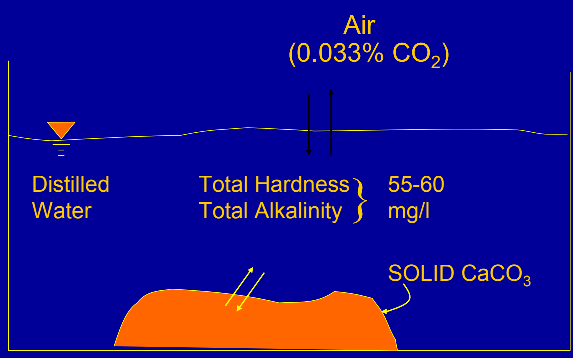
$$(H^+) = (OH^-)$$

$$(H^+)(H^+) = 10^{-14}$$

$$(H^+) = 10^{-7}$$

$$pH = -\log(10^{-7}) = 7$$

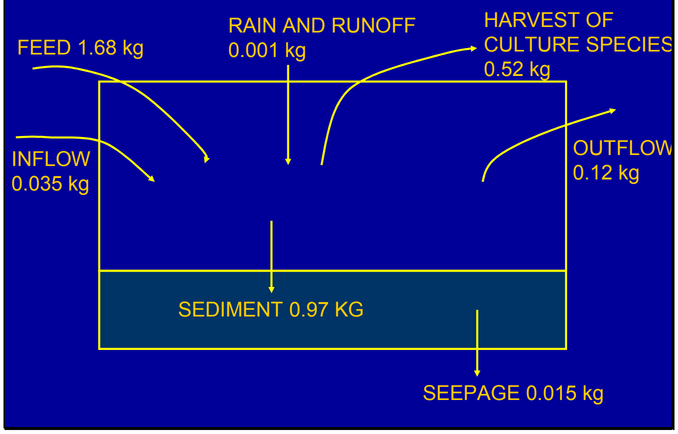
Dissolution of Calcium Carbonate



CARBON DIOXIDE IS AN ACID

$$CO_2 + H_2O = H^+ + HCO$$

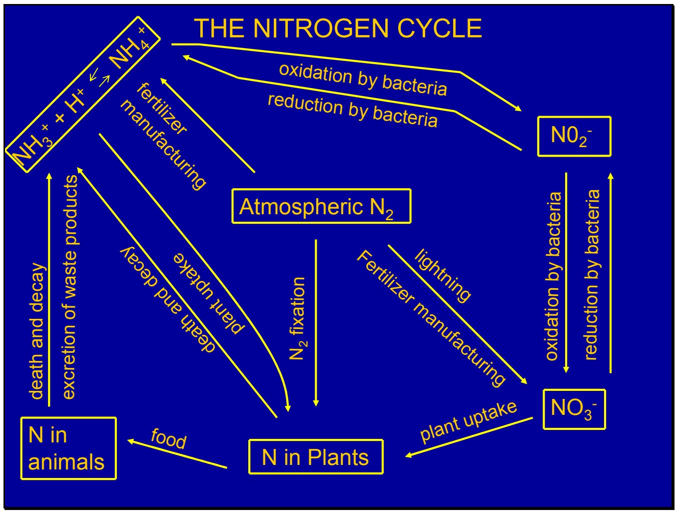
PHOSPHOROUS BUDGET FOR A 0.04-HECTAR AQUACULTURE POND



DISTRIBUTIONS OF PHOSPHORUS WITHIN DIFFERENT POOLS AND FRACTIONS FOR A 400-m^2 BY 1 m DEEP POND

Phosphorus pool	Phosphorus fraction	(g)	(% of total)
Pond water	Total phosphorus	100.8	0.19
	Soluble reactive phosphorus	7.6	0.01
	Soluble non-reactive phosphorus	10.4	0.02
	Particulate phosphorus	82.8	0.16
Soil	Total phosphorus	53,040.0	99.81
	Loosely-bound phosphorus	512.0	0.96
	Calcium-bound phosphorus	104.0	0.20
	Iron and aluminum-bound phosphorus	6,920.0	13.02
	Residual phosphorus	45,404.0	85.63
Pond	Total phosphorus	53,140.8	100.00

THE NITROGEN CYCLE



Nitrification

$NH_4^+ + 2O_2 = NO_3^- + 2H^+ + H_20$

3.5 mg DO/mg NH_4^+

DENITRIFICATION

To atmosphere ↗

$4\ NO_3^- = 5\ CH_20 + 4\ H^+ \longrightarrow 2\ N_2 + 5\ CO_2 + 7\ H_20$

MAJOR IONS IN WATER

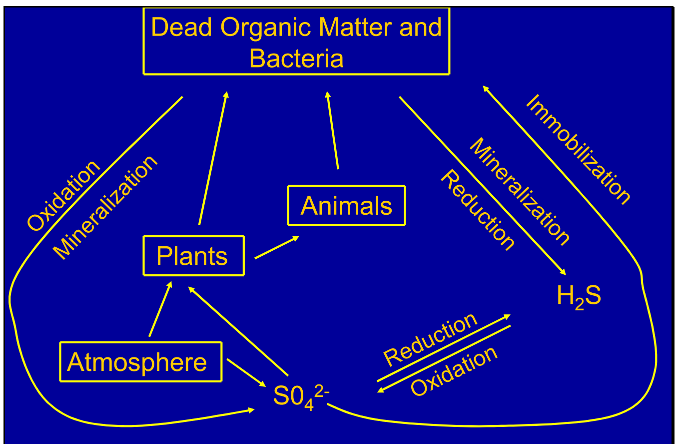
ANIONS	CATIONS
BICARBONATE (HCO_3^-)	CALCIUM (Ca^{2+})
CARBONATE (CO_3^{2-})	MAGNESIUM (Mg^{2+})
SULFATE (SO_4^{2-})	SODIUM (Na^+)
CHLORIDE (Cl^-)	POTASSIUM (K^+)

MEQ / LITER ANIONS = MEQ/LITER CATIONS

MAJOR MINERAL COMPONENTS OF SEAWATER

CATIONS		ANIONS	
SODIUM	10,500 mg/l	CHLORIDE	19,000 mg/l
MAGNESIUM	1,350 mg/l	SULFATE	2,700 mg/l
CALCIUM	400 mg/l	BICARBONATE	142 mg/l
POTASSIUM	380 mg/l	CARBONATE	0 mg/l
			(at pH > 8.3)

SALINITY	35 ppt
TOTALALKALINITY	116 mg/l as $CaCO_3$
TOTAL HARDNESS	6,500 mg/l as $CaCO_3$
SILICATE	= 3 mg/l as Si



THE SULFUR CYCLE

NITROGEN BUDGET FOR AN AQUACULTURE POND

GAINS	Kg	LOSSES	Kg
STOCK	0.12	HARVEST	2.99
FEED	11.15	POND DRAINING	0.89
N FIXATION	?	SEEPAGE	1.28
PIPE INFLOW	0.24	DENITIFICATION	
RAIN	0.52	AND DIFFUSION	
RUNOFF	0.05	OF AMMONIA	6.92
TOTAL	12.08	TOTAL	12.08

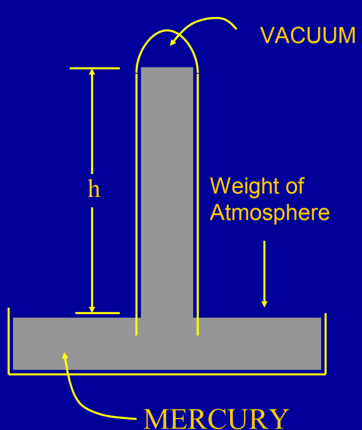
RANGES OF SECCHI DISK VISIBILITY

SECCHI DISK VISIBILITY (cm)	COMMENTS
LESS THAN 20 cm	DANGER OF DO PROBLEMS EVERY NIGHT
20 – 30 cm	PLANKTON BECOMING OVERABUNDANT
30 - 45 cm	IDEAL
45 - 60 cm	PLANKTON BECOMING TOO SCARCE
MORE THAN 60 cm	WATER IS TOO CLEAR. INADEQUATE PLANKTON PTODUCTION AND DANGER OF AQUATIC WEED PROBLEMS.

COMPOSTIION OF ATMOSPHERE

NITROGEN	78.084%
OXYGEN	20.946%
ARGON	0.934%
CARBON DIOXIDE	0.032%
OTHER	0.004%

ATMOSPHERIC PRESSURE



H = atmospheric pressure in terms of the height of a column of mercury. Standard atmospheric pressure at sea level is 760 mm Hg

EFFECT OF SALINITY AND TEMPERATURE ON DISSOLVED OXYGEN

°C	SALINITY (PPT)			
	0	10	20	30
0	14.60	13.64	12.74	11.90
5	12.76	11.94	11.18	10.47
10	11.28	10.58	9.93	9.32
15	10.07	9.47	8.91	8.38
20	9.08	8.56	8.06	7.60
25	8.24	7.79	7.36	6.95
30	7.54	7.14	6.76	6.39
35	6.94	6.58	6.24	5.92
40	6.41	6.09	5.79	5.50

PHOTOSYNTHESIS BY GREEN PLANTS

$$6CO_2 + 6H_20 \xrightarrow[\text{Nutrients}]{\text{Light}} C_6H_{12}O_6 + 6O_2$$

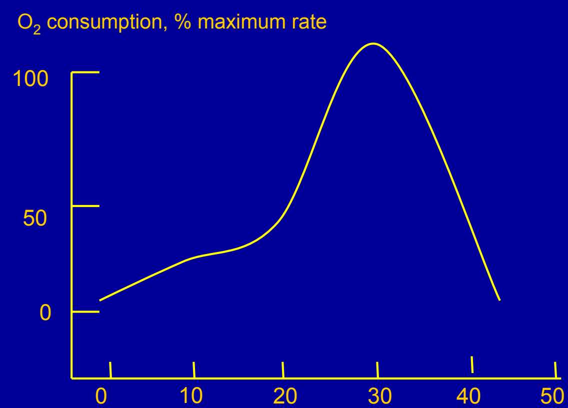
PLANTS ARE THE BASE OF THE FOOD CHAIN

Plants use sugar formed in photosynthesis to synthesize other carbohydrates, proteins, fats, etc. used to make their tissues. Animals depend upon plants as a source of food for energy and for specific organic compounds, e.g. amino acids, which they can not make themselves.

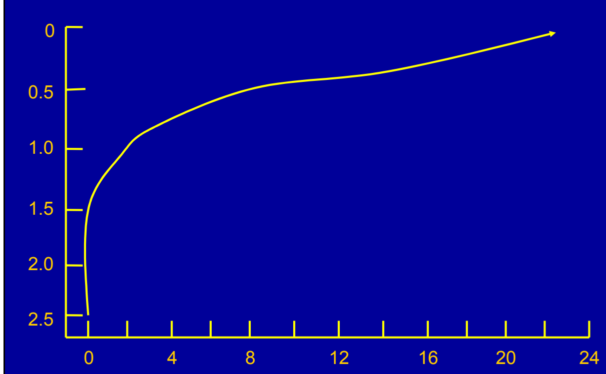
RESPIRATION

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

EFFECT OF TEMPERATURE OXYGEN CONSUMPTION BY AQUATIC ORGAINISMS



EFFECTS OF PHYTOPLANKTON ABUNDANCE ON DISSOLVED OXYGEN PROFILES IN PONDS



LIGHT - DARK BOTTLE EXAMPLE

IB = 4.00 mg/l; LB = 7.OO mg/l; DB = 2.50mg/l

Bottles incubated sunup (0600) to noon (1200)

FOR DAYLIGHT PERIOD:

NP = (LB-IB)2 = (7.00 - 4.00)2 = 6mg/l

R = (IB-DB)2 = (4.00 - 2.50)2 = 3 mg/l

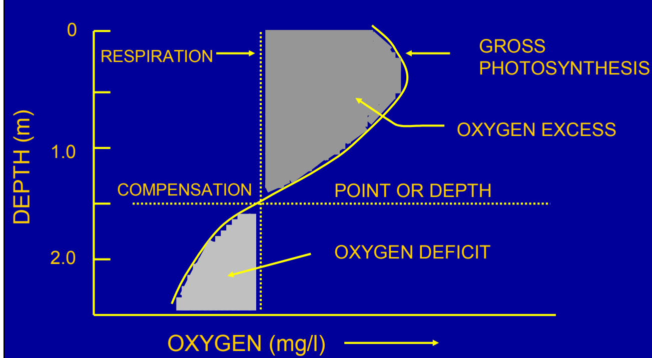
GP = NP + R = 6 + 3 = 9 mg/l

OXYGEN SURPLUS FOR 24-HR:

DAYTIME GP - R FOR 24 HR

9 mg/l - (3 mg/l)(2) = 3 mg/l

ILLUSTRATION OF COMPENSATION DEPTH



GAS SUPERSATURATION

$$\Delta P = TGP - BP$$

$$TGP = \sum P_{O_2} + P_{N_2} + P_{Ar} + P_{CO_2} + P_{H_2O}$$

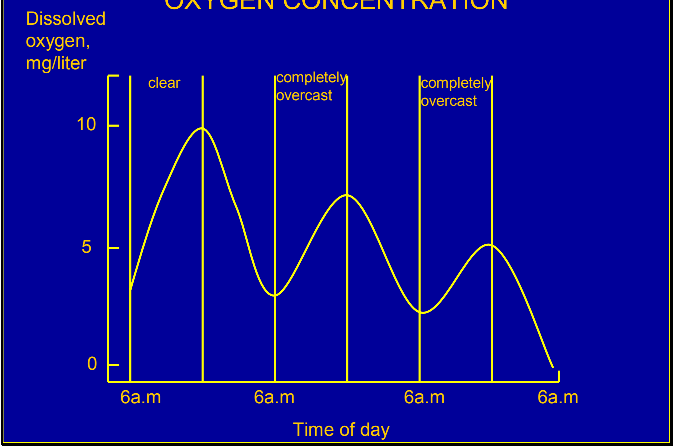
ΔP = +50 to 200

Acute gas bubble trauma

ΔP = +25 to +75

Chronic gas bubble trauma

EFFECTS OF CLOUDY WEATHER ON DISSOLVED OXYGEN CONCENTRATION



OXYGEN BUDGET FOR AQUACULTURE POND

GAINS	Kg	LOSSES	Kg
PHTOSYNTHESIS	413.1	POND DRAINING	3.2
PIPE INFLOW	6.3	RESPIRATION IN	
RAIN	2.8	WATERCOLUMN	309.3
RUNOFF	0.3	BENTHIC RESPIRATION	103.8
AERATION	9.9	RESPIRATION BY	
NET DIFFUSION	104.8	CULTURE SPECIES	120.9
TOTAL	537.2	TOTAL	537.2

ILLUSTRATION OF LC50 CALCULATION

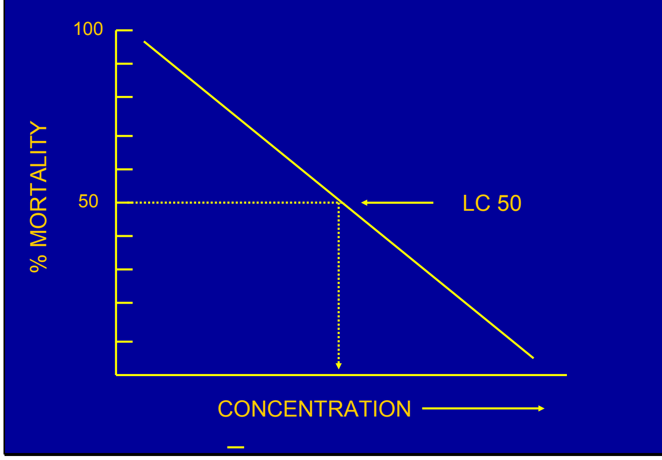
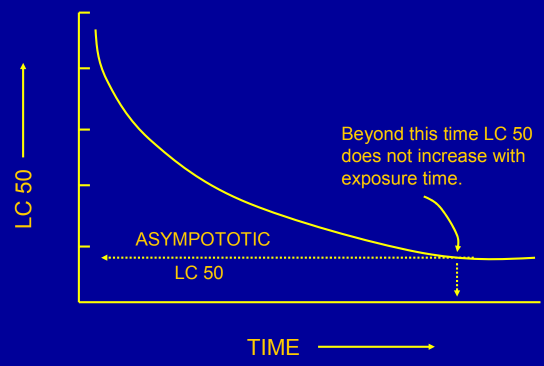


ILLUSTRATION OF ASYMPOTOTIC LC 50



TOXICITY OF METABOLITES TO SHRIMP

VARIABLE	CONCENTRATION (mg/liter) LETHAL	BEST RANGE
DISSOLVED OXYGEN	1.0 – 1.5	4-8
CARBON DIOXIDE	?	0-5
UN-IONIZED AMMONIA	1.0 – 6.0	BELOW 0.15
NITRITE	40 - 200	BELOW 0.50
HYDROGEN SULFIDE	0.5 – 1.0	0

EFFECTS OF pH ON IONIZATION OF AMMONIA

$$NH_3 + H_20 \rightleftharpoons NH_40H \rightleftharpoons NH_4^+ + OH^-$$

pH	% UN-IONIZED AMMONIA (25°)
6.5	0.02
7.0	0.59
7.5	1.75
8.0	5.32
8.5	15.10
9.0	35.98

EFFECTS OF pH ON IONIZATION OF HYDROGEN SULFIDE

$H_2S \rightleftharpoons HS^- + H^+$

pH	%UN-IONIZED HYDROGEN SULFIDE
5.0	99
6.0	89
6.6	66
7.0	44
7.6	16
8.0	7.2
8.4	3.0
9.2	0.5

TOXICITY OF SELECTED HEAVY METAL TO AQUATIC LIFE

METAL	96-HOUR LC50 (µg/liter)	SAFE LEVEL (µg/liter)
CADMIUM	80 – 420	10
CHROMIUM	2,000 – 20,000	100
COPPER	300 – 1,000	25
LEAD	1,000 – 40,000	100
MERCURY	10 – 40	0.10
ZINC	1,000 – 10,000	100

TOXICITY OF CHLORINATED HYDROCARBON INSECTICIDES TO BLUEGILLS

Trade name	96-hr LC 50	95% CI
DDT	8.6 µg/l	(6.2 – 12.0)
Endrin	0.61 µg/l	(0.5 – 0.74)
Heptachlor	13.0 µg/l	(9 – 19)
Lindane	68.0 µg/l	(69 – 101)
Toxaphene	2.4 µg/l	(2.0 – 2.8)
Aldrin	6.2 µg/l	(5.2- 7.7)

TOXICITY OF ORGANOPHOSPHATE INSECTICIDES TO BLUEGILLS

Compounds	96-hr LC 50	95% CI
Diazinon	168	(120 – 220)
Ethion	210	(141 – 313)
Malathion	103	(87 – 122)
Methyl Parathion	4,380	(3,480 – 5,510)
Ethyl Parathion	24	(15 – 38)
Guthion	1.1	(0.9 – 1.2)
TEPP	640	(537 – 762)

TOXICITY OF CARBAMATE INSECTICIDES TO BLUEGILLS

Compounds	96-hr LC 50	95% CI
Carbofuran	240 µg/l	(186 – 310)
Carbaryl (Sevin)	6,760 µg/l	(5,220 – 8,760)
Aminocarb	100 µg/l	(68 – 148)
Propoxur	4,800 µg/l	
Thiobencarb	1,700 µg/l	(1,200 – 2,300)

TOXICITY OF PYRETHUMS TO BLUEGILLS

Compounds	96-hr LC 50	95% CI
Permethrin (synthetic pyrethroid)	5.2 µg/l	(3.5 - 7.9)
Natural Pyrethrum	58.0 µg/l	(52 – 65)

TOXICITY OF FUNGICIDES TO BLUEGILLS

Compounds	96 - hr LC 50	95% CI
Fenaminosulf	85,000 µg/l	(73 – 99)
Triphenyltin hydroxide	23 µg/l	(19 – 28)
Anilazine	320 µg/l	(142 – 735)
Dithianon	130 µg/l	(120 – 140)
Sulfenimide	59 µg/l	(49 – 70)

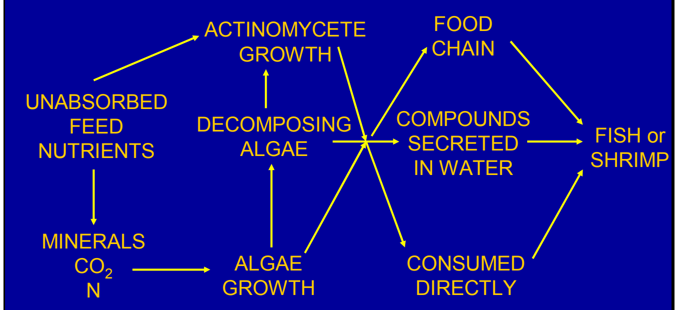
TOXICITY OF HERBICIDES TO BLUEGILLS

Compound	96 – hr LC 50
Dicambia	> 50,000 µg/l
Dichlobenil	120,000 µg/l
Diquat	245,000 µg/l
2,4–D (phenoxy herbicide)	7,500 µg/l
2,4,5-T (phenoxy herbicide)	45,000 µg/l
Paraquat	13,000 µg/l
Simazine	100,000 µg/l

TOXICITY OF INDUSTRIAL CHEMICALS TO BLUEGILLS

Compounds	96 – hr LC 50
Pentachlorophenol (wood preservative)	32 µg/l
Tri-aryl phosphate (hydraulic fluid)	> 100,000 µg/l
Purifloc (synthetic organic flocculent)	1,470 µg/l
Chlorendate (dibutyl chlorendate, plasticizer)	2,200 µg/l
Polychlorinated biphenyls (industrial chemicals)	460 µg/l
Phthalic acid esters (industrial chemicals)	>100 µg/l

PATHWAYS BY WHICH SHRIMP AND FISH BECOME OFF- FLAVOR



RELATIONSHIPS BETWEEN POND CONDITION AND OFF-FLAVOR

(1) HIGH FEEDING RATES AND DENSE PHTOPLANKTON PHYTOPLANKTON BLOOMS ARE ASSOCIATED WITH OFF-FLAVOR.

(2) CERTAIN SPECIES OF BLUE-GREEN ALGAE HAVE BEEN ASSOCIATED WITH OFF-FLAVOR.

(3) REDUCTION IN PHYTOPLANKTON ABUNDANCE TENDS TO LOWER FREQUENCY AND SEVERITY OF OFF-FLAVOR

(4) DISAPPEARANCE OF A BLUE-GREEN ALGAL SPECIES SOMETIMES IS FOLLOWED BY IMPROVEMENT IN FISH FLAVOR.

(5) HIGH CONCENTRATIONS OF ORGANIC MATTER IN WATERS AND BOTTOM SOILS ARE SOMETIMES ASSOCIATED WITH OFF-FLAVOR.

STEPS TO IMPROVE WATER QUALITY AND COMBAT OFF-FLAVOR

(1) USE OF MODERATE FEEDING RATES

(2) USE OF HIGH QUALITY FEEDS WITH FEW “FINES”

(3) AERATION TO MAINTAIN GOOD WATER QUALTIY IN PONDS

(4) PREVENTION OF DENSE ALGAL BLOOMS

CLASSIFICATION OF SOIL PARTICLES

Name of particle	Diameter limits (mm) International System	Diameter limits (mm) USDA System
Gravel	above 2.00	above 2.00
Very coarse sand		2.00 – 1.00
Coarse sand	2.00 – 0.20	1.00 – 0.50
Medium sand		0.50 – 0.25
Fine sand	0.20 – 0.02	0.25 – 0.10
Very fine sand		0.10 – 0.05
Silt	0.02 – 0.002	0.05 – 0.002
Clay....................................	Below 0.002	below 0.002

ILLUSTRATION OF CATION EXCHANGE CAPACITY OF SEDIMENT

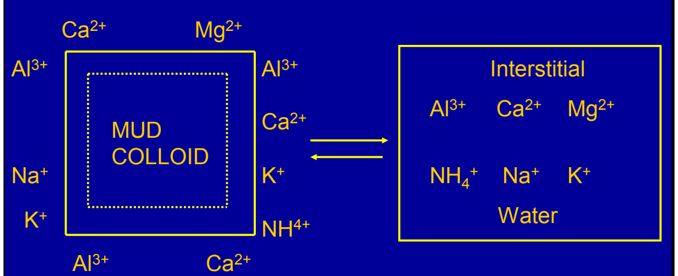
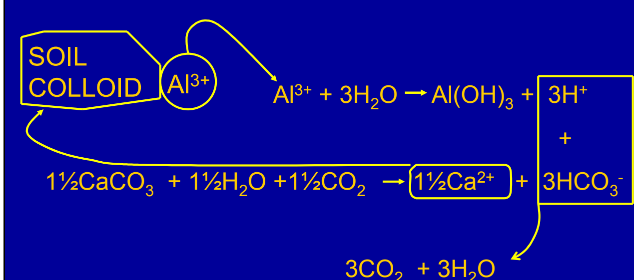


ILLUSTRATION OF REACTION OF CALCIUM CARBONATE TO NEUTRALIZE SEDIMENT ACIDITY



IRON PYRITE FORMATION IN SEDIMENT

$2CH_20 + SO_4^{2-} \longrightarrow H_2S + 2HCO_3$

$Fe(OH)_2 + H_2S \longrightarrow FeS + 2H_20$

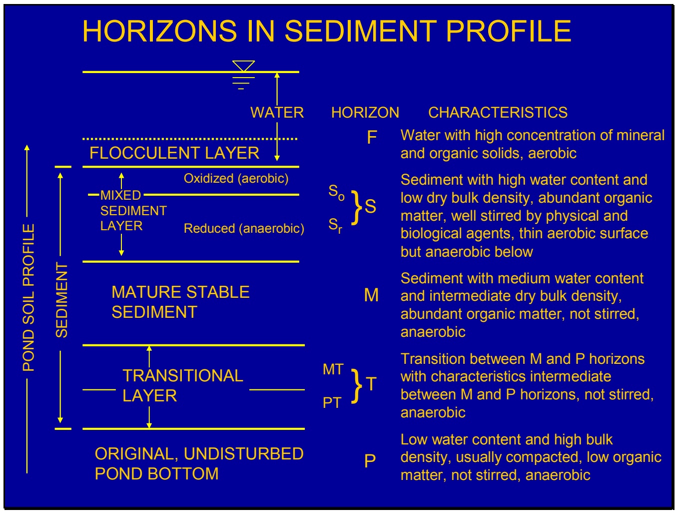
$FeS + S \longrightarrow FeS_2$

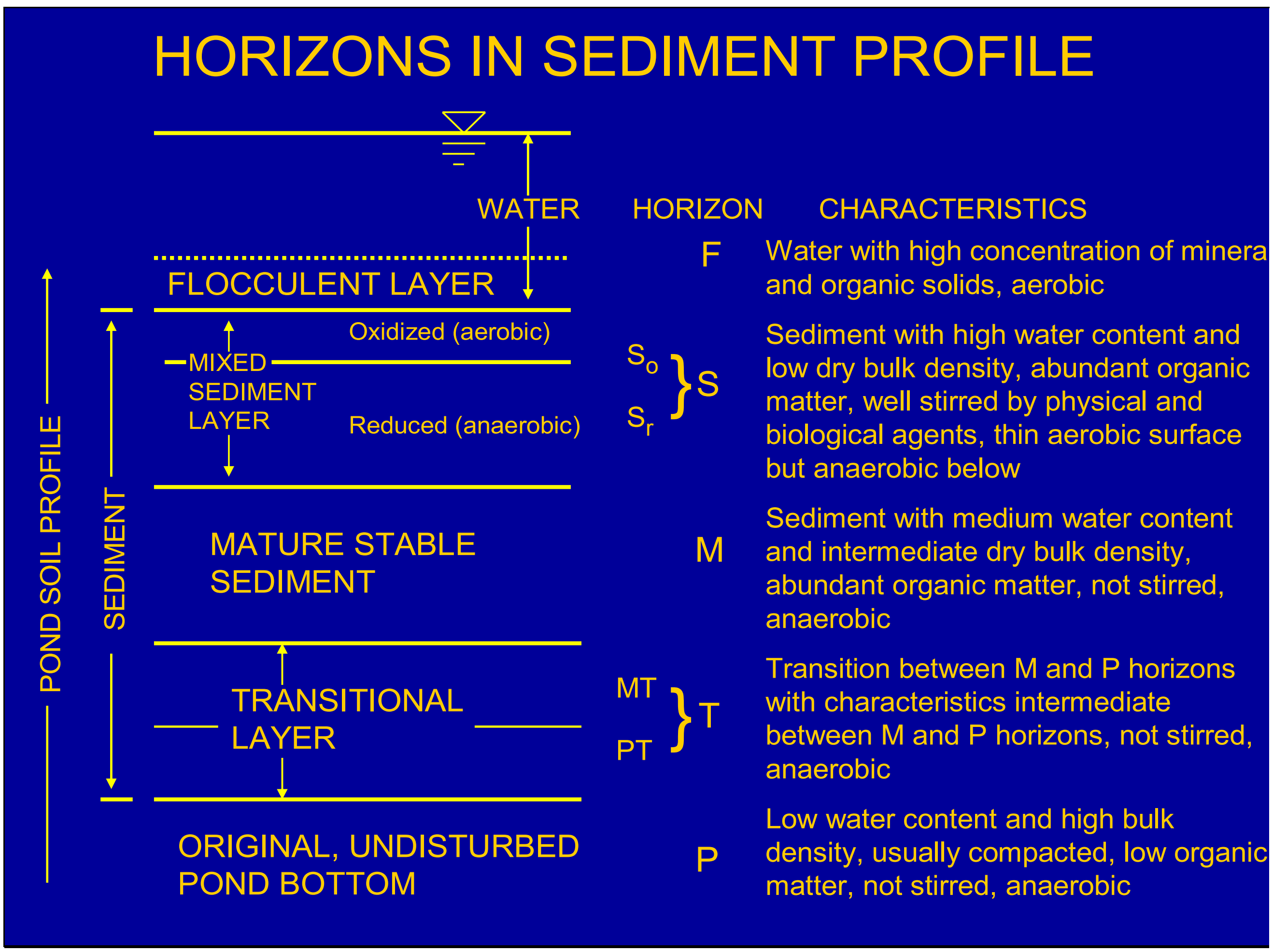
GENERAL EQUATION FOR IRON PYRITE OXIDATION

$FeS_2 + 3.75O_2 + 3.5H_20 \quad Fe(OH)_3 + 2SO_4^{2-} + 4H^+$

AN IMPORTANT POINT ABOUT SITE EVALUATION

Better to reject a site with one or more limitations than invest in a project that may be doomed to failure.


HORIZONS IN SEDIMENT PROFILE
WATER
HORIZON
CHARACTERISTICS
FLOCCULENT LAYER
F
Water with high concentration of mineral and organic solids, aerobic
Oxidized (aerobic)
MIXED SEDIMENT LAYER
Reduced (anaerobic)
S_o
S_r
S
Sediment with high water content and low dry bulk density, abundant organic matter, well stirred by physical and biological agents, thin aerobic surface but anaerobic below
MATURE STABLE SEDIMENT
M
Sediment with medium water content and intermediate dry bulk density, abundant organic matter, not stirred, anaerobic
TRANSITIONAL LAYER
MT
PT
T
Transition between M and P horizons with characteristics intermediate between M and P horizons, not stirred, anaerobic
ORIGINAL, UNDISTURBED POND BOTTOM
P
Low water content and high bulk density, usually compacted, low organic matter, not stirred, anaerobic
POND SOIL PROFILE
SEDIMENT


HORIZONS IN SEDIMENT PROFILE
WATER
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Water with high concentration of minera
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S_o
S_r
S
Sediment with high water content and low dry bulk density, abundant organic matter, well stirred by physical and biological agents, thin aerobic surface but anaerobic below
MATURE STABLE SEDIMENT
M
Sediment with medium water content and intermediate dry bulk density, abundant organic matter, not stirred, anaerobic
TRANSITIONAL LAYER
MT
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Transition between M and P horizons with characteristics intermediate between M and P horizons, not stirred, anaerobic
ORIGINAL, UNDISTURBED POND BOTTOM
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Low water content and high bulk density, usually compacted, low organic
matter, not stirred, anaerobic
POND SOIL PROFILE
SEDIMENT

ILLUSTRATION OF CARBON BALANCE IN SEDIMENT

ORGANIC INPUT → PHYSICAL AND CHEMICAL FACTORS / MICROBES / RESIDUAL OM → OUTPUT (CO_2, NH_3, etc.; SOM; POM)

SOIL ORGANIC CARBON CONCENTRATION (EVALUATION FOR MINERAL SOILS)

Concentration range (%)	Comment
0.5 and less	Less than desirable
0.5 to 2.0	Ideal
2.0 to 3.0	Becoming high
3.0 to 4.0	Higher than desirable
5.0 and above	Excessive (problematic)

PROCESSES IN DECOMPOSITION

COMMINUTION - REDUCTION IN PARTICLE SIZE PHYSICAL FACTOR

LEACHING - REMOVAL OF SOLUBLE SUBSTANCES BY WATER

CATABOLISM - ENZYMATIC DEGRADATION

AEROBIC DECOMPOSITION

SUGAR

$C_6H_{12}0_6 + 6O_2 \longrightarrow 6CO_2 + 6H_20$

ACETIC ACID

$CH_3COOH + 2O_2 \longrightarrow 2CO_2 + 2H_20$

FERMENTATION

$C_6H_{12}O_6 \longrightarrow 2CH_3CH_2OH + 2CO_2$

(GLUCOSE) (ETHANOL) (CARBON DIOXIDE)

DENITRIFICATION

$5CH_3COOH + 8NO_3 \longrightarrow 8HCO_3 + 4N_2 + 2CO_2 + 6H_20$

FERROUS IRON REDUTION

$$CH_3COOH + 2H_20 \longrightarrow 2CO_2 + 8H^+$$

$$Fe(OH)_3 + 3H^+ \longrightarrow Fe^{3+} + 3H_2O$$

SULFATE REDUCTION

$$CH_3COOH + SO_4^{2-} \longrightarrow 2CO_2 + 2H_20 + S^{2-}$$

$$S^{2-} + 2H^+ = H_2S$$

METHANE PRODUCTION

$$CH_3COOH + 2H_2O \longrightarrow 2CO_2 + 8H^+$$

$$8H^+ + CO_2 \longrightarrow CH_4 + 2H_2O$$

COMPARISON OF AEROBIC AND ANAEROBIC DECOMPOSITION

AEROBIC

$CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O$

Large amount of energy released

ΔFr_o = -206.4 kcal

ANAEROBIC

$CH_3COOH \rightarrow CO_2 + CH_4$

$CH_3COOH + SO_4^{2-} \rightarrow 2CO_2 + 2H_20 + S^{2-}$

Small amount of energy released

ΔFr_o = -9.0 kal for methane production

ΔFr_o = -10.9 kal for sulfide production

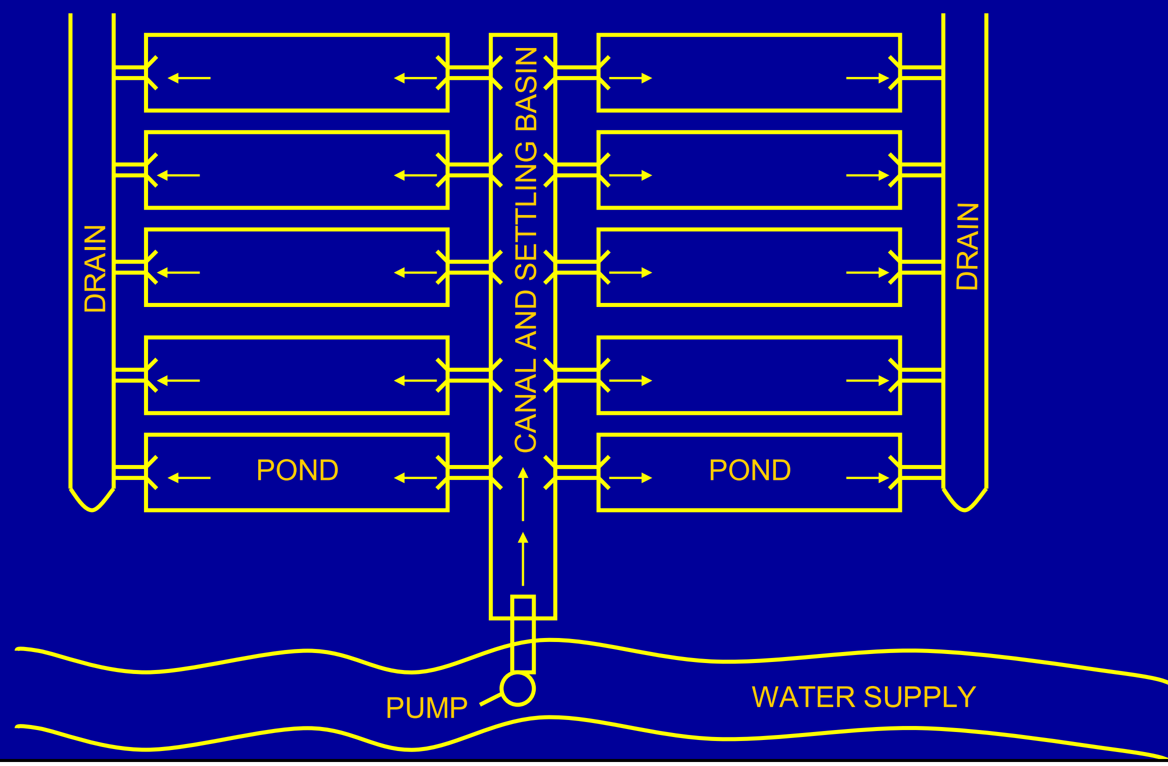
REDOX POTENTIAL AND SELECTED WATER QUALITY VARIABLES

REDOX POTENTIAL	COMMENT
0.48 volt	3 mg/liter OR MORE DO
0.34 volt	0.3 to 3 mg/liter DO NO_2^- APPEARS
0.20 volt	0 to 0.3 mg/liter DO Fe^{2+} APPEARS
0.10 volt	0 mg/liter DO H_2S APPEARS

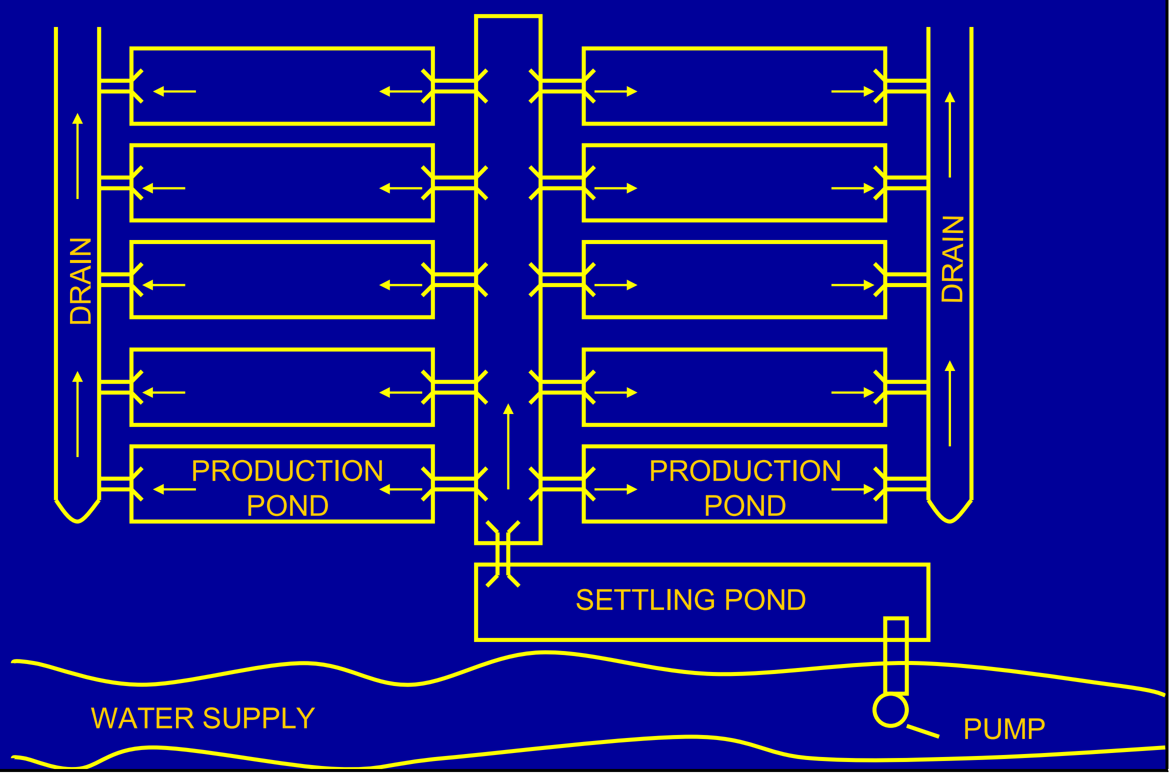
POND SEDIMENT PROPERTIES AND POTENTIAL FOR AQUACULTURE PRODUCTION

VARIABLE AND RANGE	POTENTIAL FOR AQUACULTURE PRODUCTION
pH	
<5.5………………………………..	Low
5.5 – 6.5…………………………..	Average
6.5 – 7.5…………………………..	High
7.5 – 8.5…………………………..	Average
> 8.5………………………………	Low
Available phosphorus	
< 30 ppm………………………….	Low
30 – 60 ppm………………………	Average
> 60 ppm………………………….	High
Available nitrogen	
<250 ppm…………………………	Low
250 – 750 ppm…………………....	High
Organic carbon	
< 0.5%…………………………….	Low
0.5 – 1.5%………………………..	Average
1.5 – 2.5%………………………..	High
>2.5%……………………………..	Low
C/N ratio	
< 5…………………………….	Low
5 – 10…………………………	Average
10 – 15……………………….	High

USE OF CANAL TO REMOVE SOLIDS FROM SOME WATER



USE OF SETTLING POND TO REMOVE SOLIDS FROM SOURCE WATER



CLASSIFICATION OF SHRIMP CULTURE SYSTEMS

Small ponds (<1 ha)
Large ponds (>1 ha)

Extensive (< 500 kg/ha) [No aeration]
Semi-intensive (500 – 2,000 kg/ha) [No aeration]
Intensive (> 2,000 kg/ha) [Aeration]

Small and medium farmers (< 1ha to a few ha)
Large farmers (many hectares, usually companies)

Located in tidal zone
Located above tidal zone

FERTILIZER GRADE

N - P_20_5 - K_20

ANALYSIS:	8%N, 8% P_2O_5, 8% K_20
GRADE:	8 – 8 – 8
ANALYSIS:	0% N, 46% P_2O_5, O% K_2O
GRADE:	0 – 46 – 0
ANALYSIS:	20% N, 20% P_2O_5, 5% K_2O
GRADE:	20 – 20 - 5

NUTRIENTS IN FERTILIZER

NITROGEN:
1. AMMONIUM (NH_4^+)
2. NITRATE (NO_3^-)
3. UREA (NH_2CONH_2), GIVES AMMONIUM IN WATER

PHOSPHORUS:
1. ORTHOPHOSPHATE ($H_2PO_4^-$ OR HPO_4^{2-})
2. POLYPOSPHATE (P_30_{10}, P_2O_7, ETC.), GIVES ORTHOPHOSPHATE IN WATER

POTASSIUM: POTASSIUM (K+)

APPROXIMATE GRADES OF COMMON COMMERCIAL FERTILIZERS

Fertilizer	Percentage		
	N	P_20_5	K_20
Urea	45	0	0
Calcium nitrate	15	0	0
Sodium nitrate	16	0	0
Ammonium nitrate	33 – 35	0	0
Ammonium sulfate	20 – 21	0	0
Superphosphate	0	18 - 20	0
Triple superphosphate	0	44 - 54	0
Monoammonium phosphate	11	48	0
Diammonium phosphate	18	48	0
Calcium metaphosphate	0	62 - 64	0
Potassium nitrate	13	0	44
Potassium sulfate	0	0	50

ACIDITY OF NITROGEN FERTILIZERS

$$(NH_4)_2SO_4 \longrightarrow 2NH_4^+ + SO_4^{2-}$$

$$2NH_4^+ + 3O_2 \longrightarrow 2NO_2^- + 2H_2O + 4H^+$$

$$2NO_2^- + O_2 \longrightarrow 2NO_3^{2-}$$

MATERIAL	POTENIAL ACIDITY (LBS $CaCO_3$/100LBS)
AMMONIUM SULFATE	110
MONOAMMONIUM PHOSPHATE	59
DIAMMONIUM PHOSPHATE	88
AMMONIUM NITRATE	60
UREA	83

UPTAKE OF PHOSPHORUS BY WATERS OF DIFFERENT PHYTOPLANKTON ABUNDANCE

CHLOROPHYLL a (µg/litter)	%ADDED P ABSORBED AFTER 4 HOURS
0.0	0
3.4	10.1
24.5	68.5
30.5	42.2
41.6	59.9
46.4	100.0
67.8	54.0

SUNFISH PRODUCTION WITH LIQUID AND GRANULAR FERTILIZERS

TYPE FERTILIZER	P_20_5 RATE (KG/HA/APPL)	FISH YIELD (KG/HA)
NONE	0.00	100
GRANULAR	2.25	72
LIGUID	2.25	276
GRANULAR	4.50	198
LIQUID	4.50	281
GRANULAR	9.00	287
LIQUID	9.00	373

SOME SHRIMP POND FERTILIZATION PROGRAMS USED IN EQUADOR

1. UREA AT 6 kg/hectare AND TRIPLE SUPERPHOSPHATE AT 1 kg/hectare APPLIED DAILY.
2. A 23-7-0 MIXED FERTILIZER AT 20 kg/hectare APPLIED AT 7- TO 10- DAY INTERVALS.
3. DIAMMONIUM PHOSPHATE AT 15 TO 25 kg/hectare APPLIED AT 10- TO 15-DAY INTERVALS.
4. UREA AT 20 kg/hectare AND TRIPLE SUPERPHOSPHATE AT 15 kg/hectare APPLIED WEEKLY.

	N:P2O5	N:P
FRESHWATER	1:3 or 1:4	
BRACKISHWATER	1:1 or 2:1	

NITROGEN AND PHOSPHORUS CONCENTRATIONS NEEDED FOR HIGH RATES OF PLANT GROWTH

Minimum nitrogen and phosphorus concentrations to stimulate eutrophication are 0.01 to 0.1 mg P/l and 0.08 to 0.8 mg N/l.

For agricultural plants, minimum concentrations of phosphorus and nitrogen in the soil solution for good plant growth is 0.2 to 0.3 mg P/l and 2 to 3 mg N/l.

The concentrations for crop plants appear adequate in pond aquaculture.

TYPICAL ASH AND CRUDE PROTEIN CONTENT OF THREE TYPES OF ALGAE

	%Ash	%Crude protein
Diatom	31.55	33.81
Green algae	7.40	50.00
Blue-green algae	7.17	55.69

Disadvantage of Manures

1. Low, N, ,P_2O_5 and K_20 content
2. Must apply large amounts per hectare
3. Has an oxygen demand
4. High concentration of heavy metals
5. Possibly contaminated with antibiotics
6. Composition is variable
7. Cause bottom soil deterioration

Advantages

Really, there are none

COMMON SOURCES OF NATURAL LIMING MATERIALS

LIMESTONE – MODERATELY HARD ROCK; MASSIVE STRUCTURE

CHALK – SOFT ROCK; FINE STRUCTURE

MARL – UNCONSOLIDATED DEPOSIT; OFTEN MIXED WITH CLAY

MARBLE - VERY HARD ROCK; MASSIVE STRUCTURE

SEA SHELLS – BIOLOGICAL DEPOSITS

NITROGEN AND PHOSPHORUS LOADINGS IN FERTILIZED TILAPIA PONDS

Input	Amount (kg/ha)	Output	Amount (kg/ha)	Loading (kg/ha)	Recovery of fertilizer N & P in fish (%)
5-20-5		Fish	947.0		
Fertilizer	337.5	Dry matter[A]	232.0		
N	16.9	N[B]	22.9	-6.0	100.0
P	29.5	P[C]	9.8	19.7	33.2

[A]Fish were 24.5% dry matter.
[B]Fish were 9.85% N on dry weight basis.
[C]Fish were 4.21% P on dry weight basis.

LIMESTONE

CALCITIC LIMESTONE – $CaCO_3$

DOLOMITIC LIMESTONE – $CaCO_3 \cdot MgCO_3$

LIMESTONE – usually has more $CaCO_3$ than $MgCO_3$

AGRICULTURAL LIMESTONE

MADE BY CRUSHING LIMESTONE TO A FINE PARTICLE SIZE. A LARGE PERCENTAGE SHOULD PASS A 60-MESH SCREEN (0.25 mm and smaller particles)

MATERIALS SIMILAR IN COMPOSITION TO AGRICULTURAL LIMESTONE CAN BE MADE FROM CHALK, MARL, MARBLE, AND SEA SHELLS

BURNT LIME

MADE BY BURNING LIMESTONE:

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2 \uparrow$$

REACTION OF LIMING MATERIALS WITH ACIDITY

AGRICULTURAL LIMESTONE

$$CaCO_3 + 2H^+ \longrightarrow Ca^{2+} + CO_2 + H_2O$$

BURNT LIME

$$CaO + 2H^+ \longrightarrow Ca^{2+} + H_2O$$

HYDRATED LIME

$$Ca(OH)_2 + 2H^+ \longrightarrow Ca^{2+} + 2H_20$$

HYDRATED LIME

MADE BY ADDING WATER TO BURNT LIME

$CaO + H_2O = Ca(OH)_2$

REACTIONS OF LIMING MATERIALS WITH CARBON DIOXIDE

AGRICULTURAL LIMESTONE

$CaCO_3 + CO_2 + H_20 = Ca^{2+} + 2HCO_3^-$

BURNT LIME

$CaO + 2CO_2 + H_20 = Ca^{2+} + 2HCO_3^-$

HYDRATED LIME

$Ca(OH)_2 + 2CO_2 = Ca^{2+} + 2HCO_3^-$

EFFECT OF APPLICATIONS OF AGRICULTURAL LIMESTONE ON WATERS AND SEDIMENT OF EIGHT PONDS

Initial values		After 6 months		After12 months	
Mud pH	Total Alkalinity mg/l	Mud pH	Total Alkalinity mg/l	Mud pH	Total Alkalinity mg/l
5.5	11.7	6.4	34.5	6.2	29.9
5.7	11.1	6.5	23.8	6.0	23.2
5.2	12.1	6.5	34.0	6.5	31.6
5.1	3.3	7.2	49.5	6.7	27.4
5.2	14.0	6.7	53.4	7.1	42.2
5.1	9.0	6.8	31.0	7.0	37.4
5.1	12.3	6.7	33.0	7.0	24.4
5.2	10.2	6.9	24.0	6.9	23.9

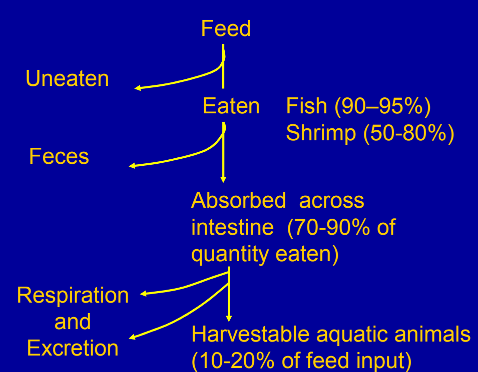
AVERAGE GROSS PRIMARY PRODUCTIVITTY IN FIVE LIMED AND FIVE UNLIMED (CONTROL) PONDS WHICH RECEIVED APPLICATIONS OF INORGANIC FERTILIZER

DATE	GROSS PRIMARY PRODUCTIVITY (G CARBON/M2/DAY)	
	CONTROL	LIME
6/26	4.12	3.70
7/12	6.28	8.65
7/25	5.71	6.22
8/8	5.58	5.85
8/21	4.28	6.48
9/4	4.47	7.90
AVERAGE	5.07	6.47

ADJUSTING AGRICULTURAL LIMESTONE APPLICATION TO SOIL pH

Soil pH (standard units)	Agricultural limestone rate (kg/ha)
7.0 or above	0
7.0 – 6.5	500
6.5 – 6.0	1,000
6.0 – 5.5	2,000
5.5 or less	3,000

FATE OF DRY MATTER IN AQUACULTURE FEEDS



CALCULATED INPUTS, OUTPUTS, AND LOADING OF CARBON, NITROGEN, AND PHOSPHORUS FOR THE PRODUCTION OF 1,000 KG LIVE PENAEUS VANNAMEI AT A FEED CONVERSION RATIO OF 2:1 (AIR DRY WEIGHT OF FEED:LIVE WEIGHT OF SHRIMP

Input	(%)	Amount (kg)	Output	(%)	Amount (kg)	Loading (kg)
Feed[A]		2,000	Live Shrimp		1,000.0	
Dry matter[B]	92.00	1,840		25.50	255.0	1,585.0
C[C]	52.10	959		43.00	110.0	849.0
N[C]	3.47	64		11.20	29.0	35.0
P[C]	0.82	15		1.25	3.2	11.8

[A]Air dry basis
[B]Oven dry basis
[C]Oven dry basis

EFFECT OF FEED CONVERSION RATION (FCR) ON PERCENTAGE OF FEED DRY MATTER, CARBON, NITROGEN, AND PHOSPHORUS RECOVERED IN CHANNEL CATFISH AT HARVEST

	RECOVERY (%)			
FCR	DM	C	N	P
1.50	16.7	20.1	24.3	27.2
1.75	14.3	17.2	20.8	23.4
2.00	12.5	15.1	18.3	20.4

EFFECT OF FEED NITROGEN CONCENTRATION ON POND LOADING OF NITROGEN FOR PRODUCTION OF 1,000 KG LIVE CHANNEL CATFISH (FCR = 2)

Feed N[A] (%)	N loading (kg)	N recovered in fish (%)
4.48[B]	70.9	20.9
5.12[C]	83.7	18.3
5.76[D]	96.5	16.2

[A]Air dry basis
[B]28% crude protein
[C]32% crude protein
[D]36% crude protein

EFFECT OF FEED PHOSPHORUS CONCENTRATION ON POND LOADING OF PHOSPHORUS FOR PRODUCTION OF 1,000 KG LIVE CHANNEL CATFISH (FCR = 2)

Feed P[A] (%)	P loading (kg)	P recovered in fish (%)
0.8	12.7	20.4
1.0	16.7	16.3
1.2	20.7	13.6

[A]Air dry basis

COMPOSITION OF DISCHARGE WATERS FROM PONDS STOCKED AT DIFFERENT DENSITIES OF PENAEUS MONODON.

	Stocking density (no./m^{2})				
Variable	30	40	50	60	70
Nitrite-nitrogen (mg/l)	0.02	0.01	0.06	0.08	0.08
Nitrate-nitrogen (mg/l)	0.07	0.06	0.15	0.15	0.15
Total ammonia nitrogen (mg/l)	0.98	0.98	6.36	7.87	6.50
Total nitrogen (mg/l)	3.55	4.04	14.9	20.9	17.1
Total phosphorus (mg/l)	0.18	0.25	0.53	0.49	0.32
Biochemical oxygen demand (mg/l)	10.0	11.4	28.9	33.9	28.8
Total suspended solids (mg/l)	92	114	461	797	498
Chlorophyll a (µg/l)	70	110	350	460	350

OXYGEN TRANSFER TERMINOLOGY USED IN MECHANICAL AERATION APPLICATION

STANDARD OXYGEN TRANSFER RATE (SOTR)
LB OXYGEN/HR

STANDARD AERATION EFFICIENCY (SAE)
LB OXYGEN/HP•HR
OR
LB OXYGEN/KW•HR

STADARD CONDITIONS:
- DISSOLVED OXYGEN = 0 MG/L
- WATER TEMEPERATURE = 20°C (68 °F)
- CLEAN WATER

BACTERIAL INOCULA

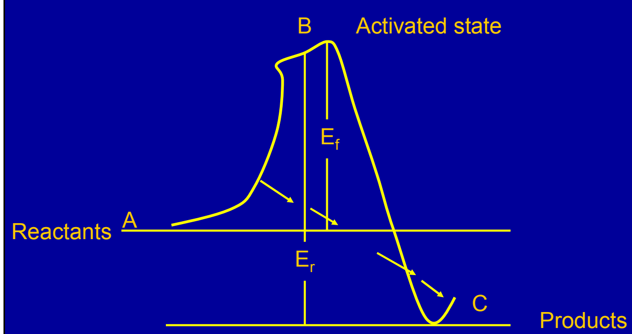
CLAIMS:

MANY. BASICALLY, IF YOU HAVE A WATER QUALITY PROBLEM THESE INOCULA WILL BE BENEFICIAL.

DATA TO SUPPORT CLAIMS:

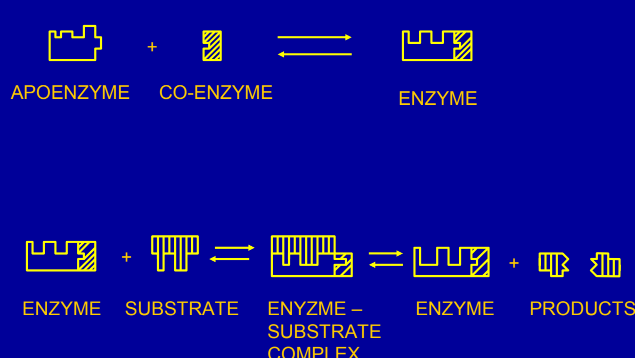
THERE ARE NO RELIABLE STUDIES TO SUPPORT THE CLAIMS, AND THERE IS NO THEORETICAL REASON WHY THEY SHOULD BE BENEFICIAL. PONDS ALREADY HAVE A VERY DIVERSE MICROBIOLOGICAL FLORA. WHICH ARE CAPABLE OF PRODUCING EXTRACELLULAR ENZYMES.

CATALYST ACTION

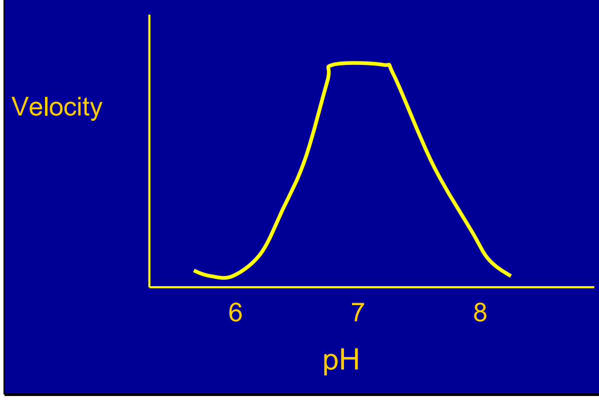


Catalysts reduce the energy of activation as indicated by the arrows

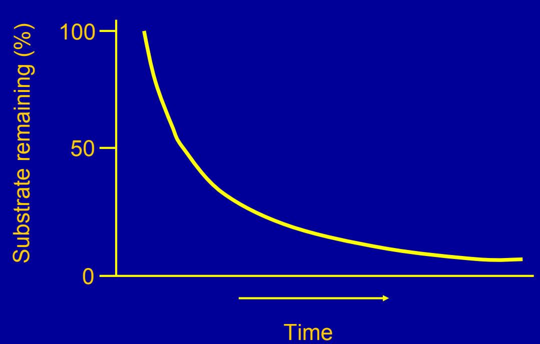
ENZYME ACTION



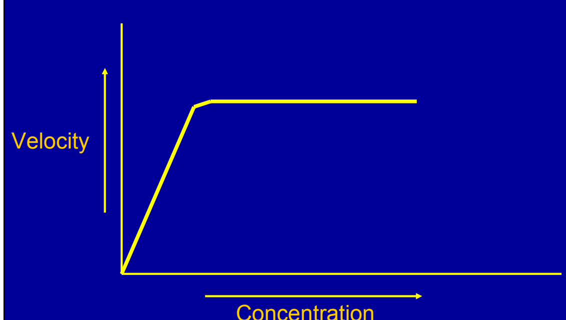
EFFECTS ON pH ON ENZYME ACTIVITY



EFFECTS OF TIME ON ENYZYME ACTIVITY



EFFECTS OF SUBSTRATE CONCENTRATION ON ENZYME ACTIVITY



EFFECTS OF TEMPERATURE ON ENZYME ACTIVITY

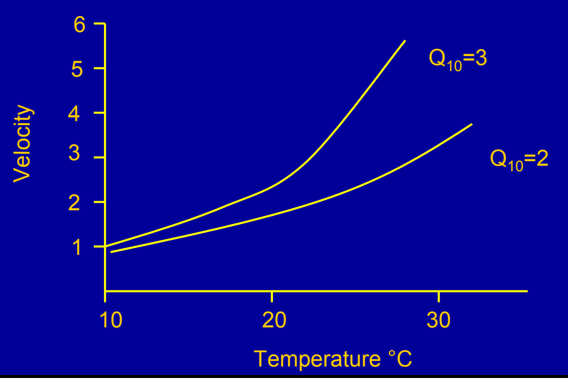
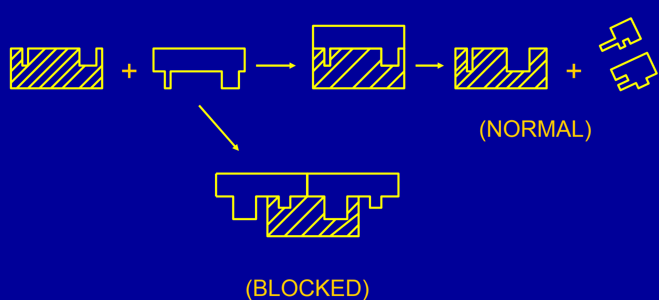


ILLUSTRATION OF ENZYME BLOCKING



COMMERCIAL SOURCES OF CHLORINE

CHLORINE - Cl_2

SODIUM HYPOCLORITE (BLEACH) – NaOCl

CALCIUM HYPOCLORITE (HTH OR HIGH TEST HYPOCHLORITE) – $Ca(OCl)_2$