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SHRIMP AQUACULTURE DIALOGUE

Effluent impact assessment:water quality monitoring vs nutrient budget

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INTRODUCTION

Shrimp aquaculture one of the fastest growing types of aquaculture worldwide.

Has raised public, governmental and non-governmental concerns of how shrimp farming affects the environment and society

Potential Impacts of Shrimp Aquaculture

- Farm construction and design
- Water use/pollution
- Feed Management
- Escapes
- Socioeconomic issues

POTENTIAL IMPACT OF SHRIMP POND EFFLUENT

- Eutrophication (nutrient enrichment) causing algal blooms
- Increase of organic matter loading resulting in greater oxygen demand
- More sedimentation
- Toxicity following discharge of hypolimnetic waters
- Contamination with pathogenic bacteria

Ultimate effect will result in an overall degradation of the ecosystem and loss of biodiversity

OBJECTIVE & GOAL

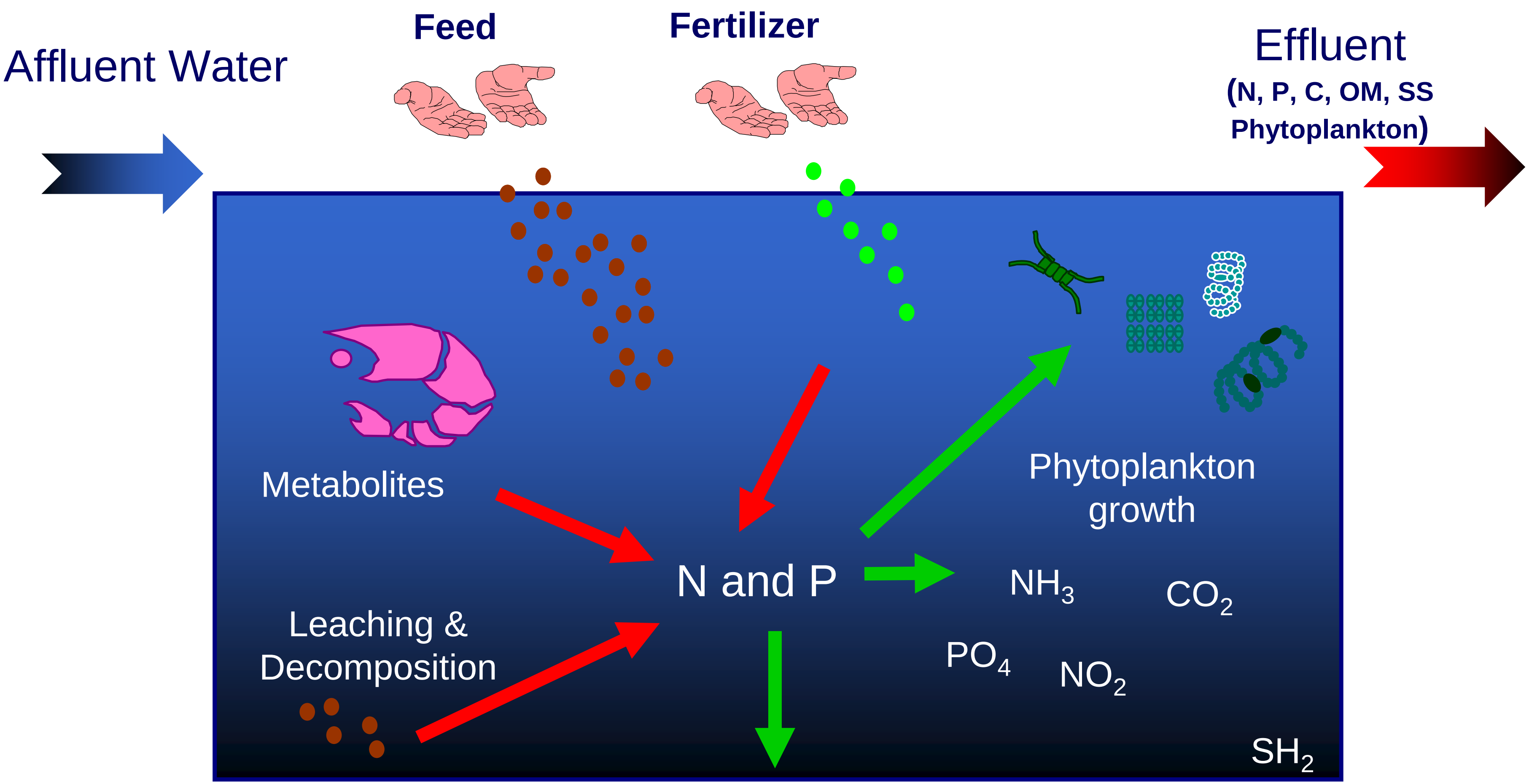
To provide information about criteria and indicators for the assessment of shrimp farm effluents and aquaculture standards by analyzing effluent composition, sources of contamination associated to management practices and water quality criteria.

Effluent standards resulting from the Shrimp Dialogue Expertise are strict enough to reduce or minimize the risk of water pollution protecting the environment, and realistic enough to be attainable by the majority of diverse shrimp farm operations worldwide.

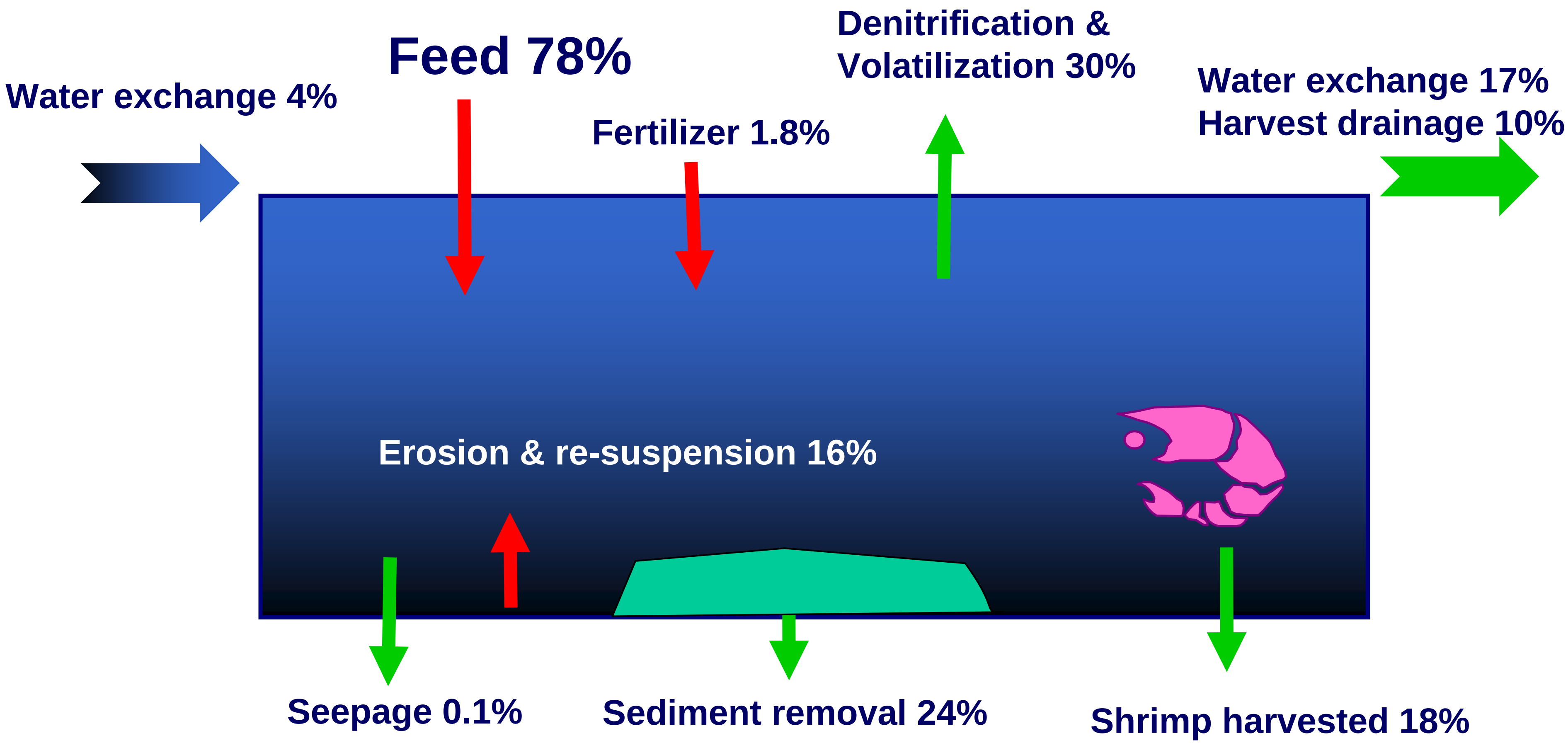
OUTLINE OF PRESENTATION

- Sources of pollutants and nutrient dynamics in shrimp ponds
- Fate of pollutants in ponds (nutrient budget case studies)
- Effluent composition (case studies)
- Potential impacts of effluents on receiving water bodies
- Considerations for formulating standards
  - Classification of water bodies
  - Water quality criteria
  - Total maximum loads
  - Toxicity
- Management practices to reduce effluent impact
- Conclusion

SOURCE OF POLLUTANTS IN SHRIMP OPERATIONS

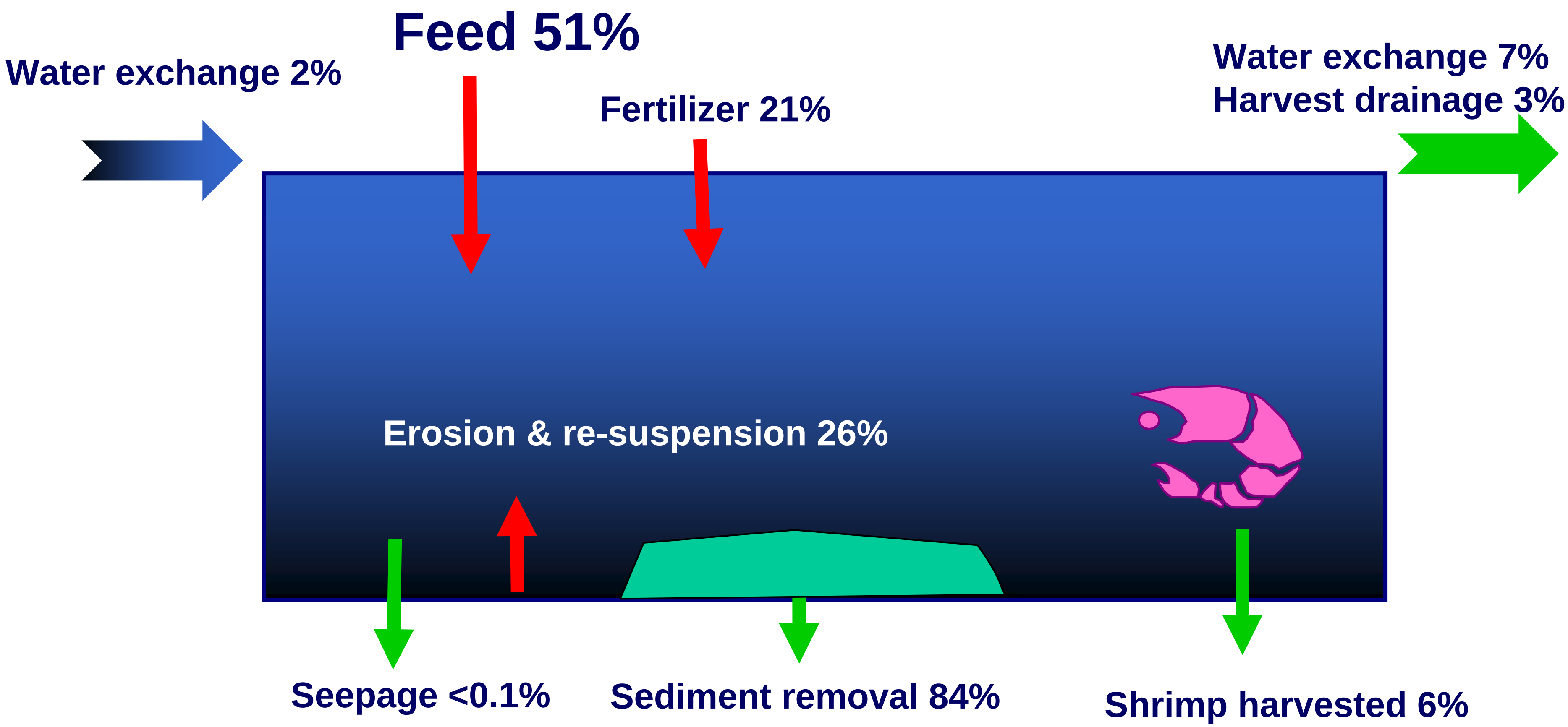


FATE OF POLLUTANTS IN PONDS (N BUDGET)



Nitrogen budget for intensive shrimp farming using water exchange
Adapted from Funge-Smith & Briggs Aquaculture 164 (1998)

FATE OF POLLUTANTS IN PONDS (P BUDGET)



Phosphorus budget for intensive shrimp farming using water exchange
Adapted from Funge-Smith & Briggs Aquaculture 164 (1998)

NITROGEN BUDGET

TABLE. Nitrogen budget for *Penaeus stylirostris* in New Caledonia

	Stocking density (shrimp/m^2)					
	1	4	7	15	22	30
Feed-N (kg/ha)	27.0	100.1	206.9	259.6	319.3	364.7
Shrimp-N (kg/ha)	9.3	30.3	54.4	76.4	63.2	62.1
Efficiency S/F (%)	34.6	30.1	26.3	29.4	19.8	17.0
Total Waste-N (kg/ha)	17.7	70.4	152.4	183.6	255.9	302.7
Inflow-N (kg/ha)	44.0	44.0	44.0	44.0	44.0	44.0
Outflow-N (kg/ha)	64.0	78.0	86.0	81.0	95.0	103.0
Waste-N Outflow (kg/ha)	20.0 (113.0)	34.0 (48.3)	42.0 (27.6)	37.0 (20.2)	51.0 (20.0)	59.0 (19.5)
Waste-N/shrimp (g/kg)	68.8	75.1	90.4	77.3	130.7	157.2

Source: Adapted from Martin et al. Aquaculture 164, 1998

NITROGEN BUDGET

TABLE. Nitrogen budget for *Penaeus vannamei* in farm operations of Ecuador & Honduras

	Stocking density (shrimp/m^2)			
	4-9 Estuarine	13-19 Estuarine	13-19 Coastal	6-8
Feed + Fertilizer N (kg/ha)	38.6	18.8	15.5	64.0
Shrimp-N (kg/ha)	5.7	7.9	11.5	29.0
Efficiency S/F (%)	14.8	42.0	74.2	45.3
Total Waste-N (kg/ha)	32.9	10.9	4.0	35.0
Inflow-N (kg/ha)	60.0	49.0	68.0	N/A
Outflow-N (kg/ha)	66.0	61.0	80.0	N/A
Waste-N Outflow (kg/ha)	6.0 (18.2)	12.0 (110.1)	12.0 (1,240)	N/A
Waste-N/shrimp (g/kg)	329	54.2	10.4	35.0

Sources:

Adapted from Saldías et al. VI Congreso Ecuatoriano de Acuacultura, 2001

C.E. Boyd & J. Queiroz. Aquaculture Asia, 1997

WASTE-N

Waste N going into the pond systems can be estimated as:

$$\text{QN "waste"/kg shrimp} = \frac{(\text{QN feed} + \text{QN fertilizer}) - (\text{QN shrimp})}{\text{Produced shrimp biomass}}$$

Where:
QN feed = Nitrogen quantity in feed (dw)
QN fertilizer = Nitrogen quantity in fertilizer (dw)
QN shrimp = Nitrogen quantity in harvested shrimp (dw)

%N shrimp (dw) = 11.2-11.5
%P shrimp (dw) = 1.1-1.2

POTENTIAL IMPACT OF SHRIMP POND EFFLUENT

Extent of impact depends on following factors:

- Type of water exchange and frequency
- Intensity of culture system (density & feeding)
- Characteristics of water bodies that will receive effluents
    - Water circulation (closed or open system)
    - Existing water quality

EFFLUENT COMPOSITION

- Has the same composition as pond water and water variables become more concentrated as stocking and feeding rates increase

Inorganic (NH_4-NH_3, NO_2, NO_3) & organic N
Inorganic (HPO_4, PO_4) & organic P
Dissolved (protein, carbohydrate, humic acids) & particulate (phytoplankton) OM
Suspended solids (inorganic & organic)
Sulfates (SH_2), carbon dioxide

WIDE-RANGING CONCENTRATIONS of EFFLUENTS

TABLE. Median, minimum and maximum concentrations of water quality variables in shrimp farm effluents from a review of 14 published papers and reports

	Median	Minimum (mg/L)	Maximum
Total nitrogen	2.04	0.02	2,600
Nitrite-nitrogen	0.05	0.00	0.91
Nitrate-nitrogen	0.30	0.001	7.00
Total ammonia nitrogen	0.38	0.01	7.87
Total phosphorus	0.26	0.01	110
Soluble reactive P	0.09	0.00	11.2
Dissolved oxygen	5.6	0.4	9.6
pH (standard units)	8.2	6.3	9.2
5-day BOD	8.9	1.3	50.7
Total suspended solids	108	10	3,671
Volatile suspended solids	43	8	713
Chlorophyll a	0.067	0.001	0.69

Source: C.E. Boyd and D. Gautier. The ADVOCATE, October 2000

EFFLUENT LOAD OF SHRIMP PONDS AT HARVEST

TABLE. Mean (±SD) content of selected water quality variables at harvest and percentage of mass content in last 25% of pond effluent at harvest (Shrimp: 4 ponds, 6-8 shrimp/m^2, 138 d & Shrimp-Tilapia: 4 ponds, 2-3 shrimp/m^2 + 7,000-120 g Tilapia/ha, 242 d).

Variable	Shrimp		Shrimp-Tilapia	
	Kg/ha	(%) last 25%	Kg/ha	(%) last 25%
Total nitrogen	**26.4±6.3**	**29**	**23.3±1.8**	**25**
Total ammonia N	**3.8±1.1**		**2.8±0.3**	
Total phosphorus	**4.4±0.9**	**28**	**16.8±2.3**	**19**
5-day BOD	**100.5±34.1**	**38**	**231.6±18.7**	**25**
Total suspended solids	**2,441±1,319**	**51**	**7,047±1,392**	**42**
Chlorophyll a	**0.7±0.2**	**13**	**3.1±0.5**	**22**

Source: S. Sonnenholzner and J. Cruz. Global Aquaculture Advocate, June 2003

CONSIDERATIONS FOR FORMULATING STANDARDS

- Classification of Water Bodies according to their maximum anticipated beneficial use

  Public drinking supplies
  Propagation of fish and wildlife
  Recreational activities
  Industrial and agricultural use
  Navigation

Most water probably was polluted and degraded below its initial pristine condition. Nevertheless, classification can prevent water quality from degrading further.

CONSIDERATIONS FOR FORMULATING STANDARDS

Water Quality Criteria

- ✓ Quantitative & qualitative values that depict the acceptable ranges of physical, chemical, biological and aesthetic characteristics of water
- ✓ Major focus is on limiting pollutants of effluents so that receiving waters comply with standards
- ✓ Overall goal is to protect environment but not unduly penalize the industry
- ✓ Simplest standards are usually based on permissible concentrations
- ✓ Standards should also consider mass-based criteria (concentration x effluent volume); e.g. kg/day
- ✓ Maximum concentration also required in mass-based criteria
- ✓ Mixing and dilution of receiving water must also be considered, recognizing that standards in mixing zone can be exceeded as long as toxic conditions are not surpassed.

CONSIDERATIONS FOR FORMULATING STANDARDS

Total Maximum Daily Loads (TMDLs)

Maximum amount of pollutant from all sources (natural & pollution) without violating standards of water body.
Maximum load allocated among different industries.

Example: TMDL of BOD = 400 kg/day. Natural sources 100 kg/day.
Thus maximum load of BOD contained in all effluents = 300 kg/day.

A safety factor can be used

CONSIDERATIONS FOR FORMULATING STANDARDS

Toxicity Limitations

- ✓ Difficult to establish toxicity limits because some substances varies greatly with water quality conditions.
- ✓ Toxicity limitations established by toxicity testing of effluents with exposure of aquatic species
- ✓ Raises the question of which water specie(s) should be considered for the test.
- ✓ What type of toxicity test (acute, chronic, early life cycle, etc)

MANAGEMENT PRACTICES TO REDUCE IMPACTS

- Use Good Management Practices (GMPs)

  - ✓ Limits on stocking and feeding rates
  - ✓ Reduction of N and P in feeds without impairing feed quality
  - ✓ Use conservative feeding practices to reduce wasted feed
  - ✓ Minimize water exchange
  - ✓ Reuse water
  - ✓ Restrict use of certain chemicals in ponds
  - ✓ Minimize erosion through good pond construction and aerator placement
  - ✓ Discharge effluents through sedimentation basins (25%)
  - ✓ Treat pond bottoms
  - ✓ Prohibit discharge of brackishwater into fresh water bodies

CONCLUSIONS

- It no longer is possible to ignore the possibility of environmental contamination by pond effluents.
- Set of standards should be based on performance in reducing a recognized water quality impact.
- Formulation of standards should be based on scientific sound criterions (mass-based, TMDL, etc).
- Clear identification of the impact on receiving water bodies (eutrophication, toxicity, salinization, sedimentation..).
- Identification of quantifiable variable(s) and methodology (nutrient budget, concentration, receiving water carrying capacity, mass balance, etc)
- Very high variation in concentrations of water quality variables in effluents (intensity of culture & water management).

CONCLUSIONS

- Pollution potential more closely related to feed input
- Only a few water quality variables have been measured carefully in shrimp effluents.
- Adopt GMPs. Only economically feasible way of improving effluent quality.
- Need to determine which parameters provide best evidence of overall pollutional strength of effluent (more data; analytical costs).
- Estuaries may already contain high levels of organic matter and inorganic nutrients which should be considered in formulation of water quality standards.

THANKS FOR YOUR ATTENTION

Picture courtesy of L. Massaut