Chapter 2

Nutrient dynamics in integrated aquaculture farming:

Closed, recirculating systems appear to be the most appropriate aquaculture systems for integration with hydroponics here after referred to as ‘integrated systems’ because nutrients can be maintained at concentrations sufficient for hydroponic plant culture.

Nutrient deficiencies in integrated system:

- The prevalence of nutritional deficiencies and yield reduction in plants caused by deficient nutrient solutions and excessive salt accumulation.
- It indicated that optimal hydroponic concentrations cannot be maintained over prolonged periods of time if commercially available diets are used.
- As a result, nutrient concentrations must be continuously monitored and nutrient supplementation and water replacement must be used to correct for nutrient deficiencies and salt accumulation, respectively.

Fish-Plant nutrition balance in integrated system:

For a given integrated system operating at steady state with no additional nutrient supplementation, nutrient concentrations will increase, decrease, or remain constant over time if nutrient production by fish is greater than, less than, or equal to nutrient assimilation by plants and nutrient losses, respectively. The rate of change in nutrient concentration can be influenced by varying the ratios of plants to fish.

Manipulating the mineral contents of diets used in integrated systems has been suggested as a means of influencing the rates of accumulation of nutrients and reducing or obviating the need to supplement nutrients artificially (Seawright, 1993). Theoretically, the nutrient content of a diet can be manipulated to make the relative proportions of nutrients excreted by fish more similar to the relative proportions of nutrients assimilated by plants. With such a diet, there would exist an optimal ratio of fish to plants and optimal nutrient concentrations could be maintained over prolonged periods without nutrient supplementation. However, the commercial promise of such a diet would require that the fish fed the diet grow at commercially acceptable rates.

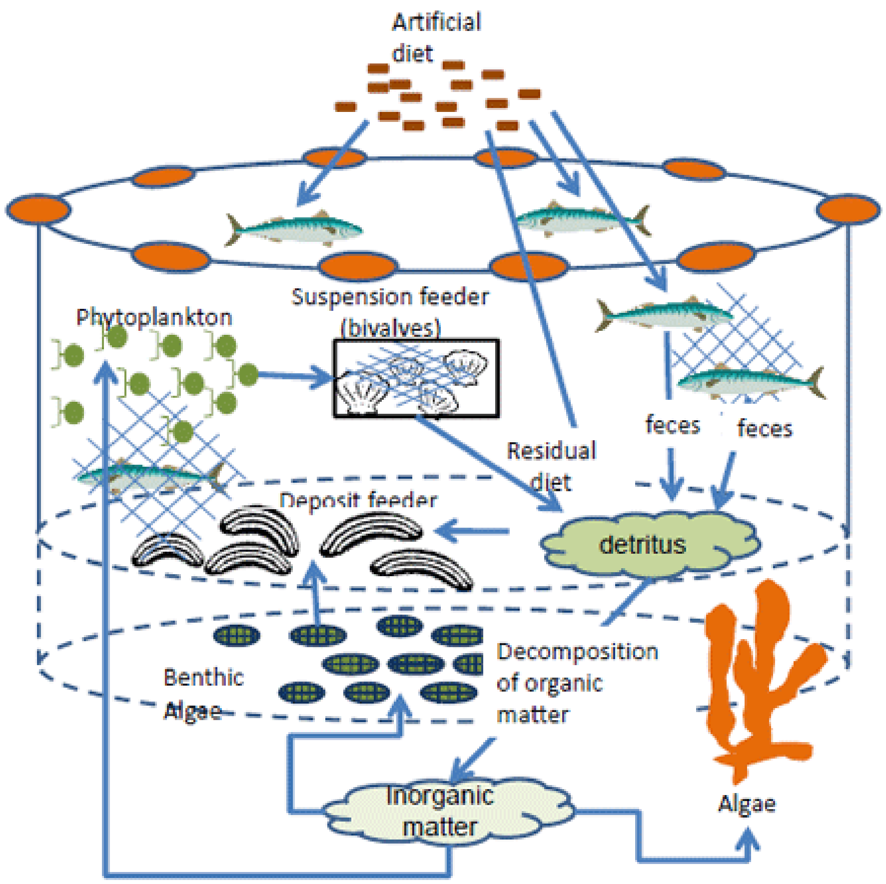

Fig: IMTA nutrient transformation system

Action of wastes on ponds:

What is waste in Aquaculture system?

- Aquaculture intensification will require the use of more inputs, especially feed per unit area of land, leading to an increase in waste generation from the production systems.
- Aquaculture is like any other production enterprise where there are inputs to generate products. There are always wastes in such systems, which are either unused inputs or byproducts. These wastes have little or no economic value and can have negative environmental impacts.
- The waste generation from aquaculture has made its sustainability a public concern. For example, the amount of waste generated from aquaculture production in an Asian country – regardless of the type of fish culture – is so high that 1 ton of fish can generate an average of 0.8 kg of nitrogen (N) and 0.1 kg of phosphorus (P), equivalent to the waste generated daily by 73 people. This highlights the need for proper methods to ensure the sustainable intensification of aquaculture.

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Waste sources and components:

1. ***Aquafeed***

Aquafeed is a critical production input in aquaculture and its level of importance depends on the type of culture technique. In an extensive system, the feed supplied to fish is mainly dependent on the environment. The fish are reared at low density over a large culture area and feed primarily on naturally occurring organisms, with some support from pond fertilization to stimulate natural productivity. In semi-intensive culture, fish are stocked at a moderate to relatively high density and rely on both food from natural production and supplemental feed from the culturists. In intensive systems, natural food production is generally not relevant and high quality manufactured aquafeeds are used targeting fast growth of fish.

Feed is a major source of waste in aquaculture systems, and this waste production depends on many factors, including its nutrient composition, method of production (extruded vs. pelleted), ratio of feed size to fish size, quantity of feed per unit time, feeding method and storage time.

2. ***Chemicals***

Current aquaculture practices generally put strict limits on the use of chemicals in fish farms; however, some chemicals are still used in the form of medications, disinfectants and antifoulants. Although these chemicals are important to fish culture, they may also have potential negative impacts on the environment. As pond water is released as effluents it flows into natural water bodies. The effect of any chemical wastes on natural water systems depends on the concentration of chemicals used, the farm size and the size of the receiving water bodies.

3. ***Pathogens***

The discharge of pathogens with aquaculture effluents and wastewater may have negative effects on natural water bodies, which have their own pathogenic loads, and receiving additional loads from fish culture systems trigger stress or mortalities. Aquaculture pond effluent is typical in open-flow, semi-intensive ponds, and the use of organic fertilizers in aquaculture in many countries can increase pathogen levels. For example, four organic fertilizers used in some areas – cattle blood waste, and manure from cattle, swine and poultry – can contribute to high levels of fecal *Streptococci*.

There are several components of waste produced from aquaculture systems, but we will focus on those major aquaculture wastes from feed, which can be classified into solid wastes and dissolved wastes.

4. ***Solid wastes***

Solid wastes are primarily derived from the uneaten feed and feces production by the cultured fish, and also from dead fish. Solid wastes can be further classified as suspended solids and settled solids. The suspended solids are fine particles suspended in the water and are the most difficult type of solids to remove from culture systems. The settled solids are larger particles that settle within a short period of time and can be easily removed from the culture column.

Solid wastes can be harmful to the fish and should be effectively removed as quickly as possible. These can clog the fish gills and lead to death, especially in the case of large settled particles. If left for a long time and allowed to decompose, these wastes lead to increases in both the total suspended and total dissolved solids. They may also increase the nitrogenous compounds and stress the cultured fish.

If solid wastes are left to remain in the aquaculture system, their aerobic bacterial activity will increase the chemical oxygen demand and biochemical oxygen demand and deplete oxygen within the culture column. In a properly managed farm – where aquafeeds are properly stored, effectively fed and the right sizes used – approximately 30 percent of the feed will become solid wastes. This can depend on the type of culture system, as it is easier to remove solid wastes from recirculating aquaculture systems than from flow through systems.

5. ***Dissolved wastes***

These are products of the food metabolism in fish or decomposed, uneaten feed, and the two major components of concern are nitrogen (N) and phosphorus (P) products. These two elements are important components of protein, the main part of fish feeds. Cultured fish typically require high dietary crude protein ranging from 25 to 50 percent – with the higher protein feeds containing high amounts of nitrogen and phosphorus – with less than half of the N and P retained in the body of the fish.

The amount of nitrogen and phosphorus retained by the fish varies, with average nitrogen retained ranging from between 25 and 30 percent to 10-49 percent and 17-40 percent for phosphorus retention. **Piedrahita** (2003) reported that fish feces contained 3.6 to 35 percent N and 15 to 70 percent P, while the amount of N and P as excretory products were 37 to 72 percent and 1 to 62 percent, respectively. The nitrogen is mainly excreted in dissolved form as ammonia, while phosphorus is excreted as particulate matter.

Management of waste in aquaculture systems

- **Proper feeding management:** The primary solution for managing the environmental impacts of aquaculture is the management of feed. Feed and feeding systems can effectively reduce wastes resulting from the fish feed through proper management of the inputs into the culture systems.
- **Management of FCR of fish**: From a study it is reported that a reduction in feed conversion ratio (FCR) by 30 percent in a fish farm will bring about 20 percent reduction in environmental impact from the fish culture system.
- **Knowledge of nutrition of fish species:** To reduce waste from aquaculture, it is important to know the nutritional requirements of the species (based on age, health and other conditions); fish biomass and size uniformity; feed quality and proper feed management and application to prevent waste.

- **Suitable Phytate in feed ingredients:** The use of grains that are low in phytate [or phytic acid, is a naturally occurring compound in plant foods like grains, beans, seeds and nuts] is also encouraged in fish feed production to reduce the amount of phosphorus released into the water through uneaten feed or fish metabolic waste. Another study reported that the majority of the phosphorus in plant protein cannot be utilized by fish, which are monogastric (an organism with a simple, single-chambered stomach) animals. Researchers have also suggested the increase of phytase in the feed formulation to increase bioavailability and utilization of the phosphorus in fish feed.
- **Use of high energy fish feed:** The development of high-energy, extruded aquafeeds has also improved nutrient utilization and has reduced FCR and waste in fish feeding. These feeds can also increase the fat content of the feed without using coating methods, thus limiting the leaching of fat into culture waters. It also allows for the production of sinking and floating feeds that are uniform and maintain physical integrity longer after immersion without nutrient leaching. The moderate size and tight compaction of these high-energy feed also limits fines (dust from pellet movement and handling) and reduces the potential waste that is associated with irregular feed sizes and fines.