

Bioremediation and its use in aquaculture

Introduction

Aquaculture production has increased steadily in recent years and is the fastest growing food production sector and has become a valuable component of national development and poverty reduction plans in many areas of the world. At a time when capture fisheries are leveling off, aquaculture production continues to increase. The increase in production is greatest in developing countries where about 93 percent of aquaculture production originates. It was once considered an environmentally sound practice because of its polyculture and integrated system of farming based on optimum utilization of farm resource, including farm wastes. Increased fish production is being achieved by the expansion of land and water under culture and the use of more intensive and modern farming technologies that involve higher usage of inputs such as water, feed, fertilizer and chemicals. As a result, aquaculture is now considered as a potential polluter of the aquatic environment and a cause of degradation of wetland areas.

What is Bioremediation?

Bioremediation consists of using living organisms (bacteria, fungi, actinomycetes, cyanobacteria and to a lesser extent, plants) to reduce or eliminate toxic pollutants. These organisms may be naturally occurring or laboratory cultivated. The physical, chemical and biological conditions of the culture environment have an influence on the shrimp to toxins like hydrogen sulphide, ammonia and carbon dioxide leads to stress and ultimately disease. Wastes produced in aquaculture farms differ in quality and quantity of components depending on the species farmed and the farming practices adopted. The wastes in aquaculture farms can be categorized as residual food and fecal matter, metabolic by-product, residues of biocides and biostats, fertilizer derived wastes and wastes produced during moulting and collapsing algal blooms. The current approach to improving water quality in aquaculture is the application of microbes/enzymes to the ponds known as 'bioremediation'. When macro and micro organisms and/or their products are used as additives to improve water quality, they are referred to as bioremediators or bioremediating agents. The newest attempt being made to improve water quality in aquaculture is the application of probiotics and enzymes to the ponds is known as bioremediation, which involves manipulation of microorganisms in ponds to enhance mineralization of organic matter and get rid of undesirable waste compounds.

Organic Detritus & Bioremediation

The dissolved and suspended organic matter contains mainly carbon chains and is abundantly available to microbes and algae. A good bioremediation must contain microbes that are capable of effectively clearing carbonaceous wastes from water. Further it would be very supportive, when these microbes multiply rapidly and have good enzymatic capability. Members of the genus *Bacillus* like *Bacillus subtilis*, *B. licheniformes*, *B. cereus*, *B. coagulans* and species *Phenibacillus polymyxa* are good examples of bacteria suitable for bioremediation of organic detritus. However, they are not normally present in the required quantities in the water column, their natural habitat being the sediment. When certain *Bacillus* strains are added to the water in sufficient quantities, they can make an impact. They compete with the bacterial flora naturally present for the available organic matter, like leached or excess feed and shrimp faeces. As a part of bio-augmentation, the *Bacillus* can be produced, mixed with sand or clay and broadcast to be deposited in the pond bottom. *Lactobacillus* is also used along with *Bacillus* to break down the organic detritus. These bacteria produce a variety of enzymes that break down proteins and starch to small molecules,

which are then taken up as energy sources by other organisms. The removal of large organic compounds reduces water turbidity.

Nitrogenous Compounds & Bioremediation

Nitrogen applications in excess of pond assimilatory capacity can lead to deterioration of water quality through the accumulation of nitrogenous compounds (ammonia and nitrite) causing toxicity to fish and shrimp. The principal sources of ammonia are excretion and sediment flux derived from the mineralization of organic matter and molecular diffusion from reduced sediment. Bacteriological nitrification is the most practical method for the removal of ammonia from closed aquaculture systems and it is commonly achieved by the setting of sand and gravel bio-filters through which water is allowed to circulate. The ammonia oxidizers are placed under five genera *Nitrosomonas*, *Nitrosovibrio*, *Nitrosococcus*, *Nitrolobus* and *Nitrospira*. Nitrification not only produces nitrate but also alters pH towards the acidic range, facilitating the availability of soluble materials. The vast majority of aquaculture ponds accumulate nitrate, as they do not contain a denitrifying filter. Denitrifying filters help to convert nitrate to nitrogen. It creates an anaerobic region where anaerobic bacteria can grow and reduce nitrate to nitrogen gas. Nitrate may follow several biochemical pathways following production by nitrification.

Phosphorous & Bioremediation

Phosphorus normally has limitations in a freshwater environment. Any deviation from the normal NO_3/PO_4 ratio is believed to be dependent on which influence the rate of nitrification or bacterial regeneration of phosphorous, is available in organisms mainly as phospholipids and nucleoproteins. Phosphorous is generated from organic compound as PO_4 by certain bacteria that produce enzymes such as phosphatases and phytases. The solubility of inorganic phosphatases is primarily a function of pH. Bacteria are capable of liberating PO_4 from these compounds through the production of organic and mineral acids.

Hydrogen Sulphide (H_2S) & Bioremediation

Sulphur is of some interest in aquaculture because of its importance in anoxic sediments. In aerobic conditions, organic sulphur decomposes to sulphide, which in turn gets oxidized to sulphate. Sulphate is highly soluble in water and so gradually disperses from sediments. Sulphide oxidation is mediated by micro organisms in the sediment, though it can occur by purely chemical processes. Organic loading can stimulate H_2S production and reduction in the diversity of benthic fauna. Hydrogen Sulphide is soluble in water and has been suggested as the cause of gill damage and other ailments in fish. Unionised H_2S is extremely toxic to fish that may occur in natural waters as well as in aquaculture farms. Bioassays of several species of fish suggest that any detectable concentration of H_2S should be considered detrimental to fish production.

Screening of Microbes for Utilization as Bioremediators

Microorganisms both gram positive and gram negative have been tested for their efficacy as bioremediators in aquaculture by various workers. *Bacillus* is the most commonly used organism followed by *Aeromonas* and *Pseudomonas*. Bioremediators commercially available in the market mainly include Nitrifiers, Sulphur bacteria, *Bacillus* sp. and *Pseudomonas* sp.

Advantages of Bioremediation

- It works on a variety of organic and inorganic compounds
- Can be done either on-site or off-site, easy to implement and maintain
- Low-cost compared to other treatment methods
- Environmentally-friendly and aesthetically pleasing
- Reduces the amount of wastes to be land filled
- Cleaner pond bottoms
- Reduced blue green algae loads (via competition for nutrients-these products are not algaecides)
- Less water exchange needed (savings in pumping costs)
- Reduced green *vibrio* counts (on TCBS, the *vibrio* associated with AHPNS produces green colonies)
- Reduced overall *vibrio* loads (the Bacillus in our products compete against the *vibrios* for nutrients)
- Reduced ammonia levels (broken down by the bacteria in our products)
- Reduced disease outbreaks (a result of a change in the microbial flora)
- Better feed efficiency (a result of a cleaner environment)
- Healthier shrimp
- Increased profits

Disadvantages of Bioremediation

- It may take several years to remediate and depends on climatic conditions
- Restricted to sites with contamination near the roots
- Harvested plants may be classified as hazardous waste
- Consumption of contaminated plants may be harmful
- There may be harmful effects on the food chain