
**ISSN Print:** 2394-7500
**ISSN Online:** 2394-5869
**Impact Factor:** 5.2
IJAR 2017; 3(7): 01-04
www.allresearchjournal.com
Received: 01-05-2017
Accepted: 02-06-2017

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# Review on seafood processing plant wastewater bioremediation – A potential tool for waste management

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**Abstract**
The use of microorganisms to degrade or reduce the concentration of hazardous wastes on a contaminated site is called bioremediation. Such a biological treatment system has various applications, such as cleanup of contaminated sites such as water, soil, sludge, and streams. Rapid industrialization, urbanization, intensive farming and other human activities have resulted in land degradation, environmental and aquatic pollution. Human activities have increased pressure on the natural resources, which in turn has resulted in myriad of pollutants. There has always been interest in developing efficient and effective techniques for the treatment of ever growing types of wastes. Bioremediation is one such process which involves detoxification, wherein the wastes detoxified and mineralized, are converted into inorganic compounds such as carbon dioxide, water and methane. There is a general interest in studying the diversity of indigenous microorganisms capable of degrading different pollutants because of their green value with regard to the environment. Seafood processing plant waste water management has been one of the serious problems faced by the seafood industry especially fish meal plants which face serious problems with public resistance for dumping of wastes into the environment. This article discusses the role of microbes in the treatment of seafood processing waste water and puts forward thoughts and scope for further research in the field.

**Keywords:** Biodegradation, waste water management, eco friendly technology, bioremediation

## 1. Introduction
The present world is seeing great industrial development whilst facing problems with a wide variety of pollutants and contaminants from these developmental activities. The concern on the quantity and quality of waste generated and discharged into natural water bodies has recently indicated the need for different strategies to address water quality challenges in the regions. India has a large network of seafood industry with a total of 465 registered seafood processing industries in all the coastal states, among these over 150 processing facilities have received European Union. The factories are located in 20 clusters along the East and West Coast of India and 42 units are located in Tamil Nadu (MPEDA, 2014) [25]. Among the 42 processing plants, 33 are located along the Tuticorin coast. These industries processes a myriad of shellfishes, comprising of shrimps, lobsters, crabs, oysters, clams and scallops; marine and inland fishes. As in any other food processing industries, seafood processing operations produce wastewater containing substantial contaminants as soluble, colloidal, and particulate forms. The degree of the contamination depends on the specific operation; it may be small (e.g., washing operations), mild (e.g., fish filleting), or heavy (e.g., blood water drained from fish storage tanks). Wastewaters from seafood processing operations have high biochemical oxygen demand (BOD), fat, oil and grease (FOG), and nitrogen content. Annually the world average effluent discharge containing soluble, colloidal and particulate forms from fish and shrimp processing plants is about 11,10,522 million liters (Carawan, 1991 and Park *et al*., 2001) [6, 29]. In addition to partially decomposed organic material and different chemical substances, pathogenic bacteria, virus and other micro flora, contribute to the heavy organic content of seafood processing wastes. Most of the wastes generated are discharged into the nearby coastal waters through discharge channels and are potentially hazardous to the receiving environments. Moreover, too many processing plants in one area will eventually overwhelm natural ecosystems, causing frequent eutrophication in coastal

waters. Bioremediation is one of the recent technology developed to degrade such environmental contaminants into less toxic forms by the application of microorganisms like bacteria, fungi, algae etc., The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere and brought to the contaminated site. To speed up the bioremediation process, seeding of contaminated wastewater with competent microflora that are capable of degrading hazardous waste, is an efficient treatment mechanism. The inoculated microorganisms either may be naturally occurring types or prepared in the laboratory to attack the target waste.

## 2. Common microbes in bioremediation

The first patent for a biological remediation agent was registered in 1974 being a strain of *Pseudomonas putida* that was able to degrade petroleum. Microbiological assays are carried out to assess the microbial growth conditions that degrade population densities and presence of enzymes capable of destroying contaminants of concern and microcosm studies to evaluate bioremediation potential under controlled conditions (Fredrickson *et al.,* 1991) [12]. During implementation of microbial bioremediation programs monitoring of pollution degrading efficiency play a key role in evaluating effective treatment mechanism. Microbial bioremediation can be cost-effective and expeditiously destroy or immobilize contaminants in a manner that protect human health and the environment (Heitzer and Sayler, 1993; Gheewala and Annachatre, 1997; Gadd, 2000) [19, 15, 14]. *Pseudomonas* sp. and *Brevibacillus* sp. are the nitrate reducing bacterial strains isolated from petroleum contaminated soil (Grishchenkov *et al*., 2000) [17]. Research is underway at a number of facilities using exogenous, specialized microbes or genetically engineered microbes to optimize bioremediation (Hassan *et al*., 2003) [18]. Studies reveal that 42 different pollutants can be biodegraded by using *Pseudomonas* species (Prescott *et al*., 2002) [31]. *Pseudomonas putida* was found to remediate PCB in the soil, another species *Pseudomonas aerogenosa* was able to detoxify chlorinated aliphatic solvents. A study by Jayashree *et al*. (2012) [22] proved that the *Pseudomonas sp.* act as fuel eating bacteria which can degrade the hydrocarbons.

*Arthrobacter sp.* was first isolated from natural environment which has the capability to reduce nitrogen by heterotrophic nitrification process (Verstrae and Alexande, 1972) [37]. In the presence of oxygen, the aerobic bacteria such as *Pseudomonas, Alcaligenes, Sphingomonas, Rhodococcus,* and *Mycobacterium* are capable of degrading pollutants. These microbes are also able to degrade pesticides and hydrocarbons, both alkanes and polyaromatic compounds. *Acinetobacter* sp. was the first bacterium used for phosphate removal (Fuhs and Chen, 1975) [13]. *Nitrosomonas* and *Nitrobacter* are chemolithotropic bacteria present in activated sludge process (Hughes and Stafford, 1976) [20]. Under oxygen restriction conditions, the dominant species are from the genera *Acinetobacter*, *Aeromonas* and *Flavobacterium* (Autheunisse and Koene, 1987) [4]. The most common genus of bacteria that carry out ammonia oxidation is *Nitrosomonas* species. The nitrite oxidation is carried out by *Nitrospira, Nitrococcus* and *Nitrocystis* (Rittmann and McCarty, 2001) [32]. Denitrification is common among the gram negative bacteria such as *Psedomonas, Alcaligenes, Paracoccus, and Thiobacillus*. Denitrification is the slow process particularly for industrial waste waters that contain high concentrations of nitrate (Foglar *et al.,* 2005) [11]. According to Narmadha and Kavitha (2012) [26], the main species involved in effective waste water treatment include lactic acid bacteria such as *Lactobacillus plantarum, L. casei and Streptococcus lacti and* photosynthetic bacteria such as *Rhodopseudomonas palustrus, Rhodobacter spaeroide*, *etc.* Pure culture of *Exiguobacterium aurantiacum* has the capability of degrading phenol and PAHs in batch culture when provided with pure compounds as a source of carbon and energy (Jeswani and Mukherji, 2012) [23].

## 3. Bioremediation of seafood processing effluents

The waste water generated during fish meal production is known to bear an extremely high organic load. The wastewater produced by the washing of surimi has also been known to have fairly high organic load. Further, wastewater may be contaminated with various microbes that may not assist in bioremediation. To suppress the growth of such heterotrophic microbes in wastewater, the inoculum must be of good quality, fast growing and of sufficient quantity to suppress the growth of contaminants (Noparatnaraporn *et al.,* 1987) [27]. High nitrogen levels are likely due to the high protein content (15–20% of wet weight) of fish and marine invertebrates (Sikorski, 1990) [35]. The characteristics of the wastewater vary greatly by the raw materials used in the processing plants. The quality of the raw materials to be processed has also been found to vary as a function of time (Omil *et al.,* 1996) [28]. N and P are normally present in the fish wastewater, their concentration is minimal in most cases (Gonzalez, 1996) [16]. Phosphorus also partly originates from the fish, but can also be introduced with processing and cleaning agents (Intrasungkha *et al*., 1999) [21]. The high-strength wastewaters such as those generated during fish meal production are often known to be diluted with cooling waters from the overall process, prior to disposal (Alfonso and Borquez, 2002) [2].

In a seafood processing plant, the effluent consists mostly of undefined mixtures of organic substances. $BOD_5$ of tuna waste generally ranged from 500–1500 mg/L, and is usually only about 40% of the COD, which ranged from 1300–3250 mg/L (Carawan *et al.,* 1979) [6]. During fish evisceration and cooking high content of COD, nutrient, oil and fat are generated in fish processing wastewater (Aguiar and Sant, 1988; Mendez *et al.,* 1992) [1, 24]. Fish meal blood water contributed to the highest COD value of 93,000 mg/L, among all other processes (Del Valle and Aguilera, 1990) [7]. The level of total soluble and suspended COD vary largely between processing industry and type of fish or raw material processing. In a fish processing industry, the effluent COD is usually higher than $BOD_5$. The ratio of process water to product is one of the major factors influencing the organic content of the fish-processing effluent. Effluent $BOD_5$: COD ratios varied widely within and among processing plants ranging from 1.1:1 to 3:1. Most of the $BOD_5$ usually comes from hold water and from the butchering process (Technical Report Series FREMP, 1994) [37]. *Rhodocyclus gelatinosus* removed 86% COD in seafood processing plant effluent in 5 days. (Prasertsan *et al*., 1993) [30]. *Rhodovulum sulfdophilum* from sardine waste water could be reduce COD up to 50% (Azad *et al*., 2001) [5]. High BOD concentrations are generally associated with high ammonia concentrations (Technical Report Series FREMP, 1994) [36]. Fish canning industries have a high concentration of organic polluting substances in the range of 10,000–50,000 mg/L (Mendez *et al*., 1995) [24]. It is difficult to generalize the extent of the problem created by this wastewater as it depends on the effluent strength, wastewater discharge rate and the absorbing capacity of the receiving water body (Gonzalez, 1996) [16]. The degree of ammonia toxicity depends primarily on the total ammonia concentration and pH. Salmon processing effluents contained 42 mg/l of ammonia concentration and 20 mg/L for fish processing. Sometimes high ammonia concentration is observed due to high blood and slime content in wastewater. As reported by a few fish processing plant the overall, ammonia concentration ranged from 0.7 mg/L to 69.7 mg/L. In the fish condensate the total ammonia content can be up to approximately 2000 mg/l. The introduction of *Bacillus sp* in fish processing waste water was found to reduce ammonical nitrogen up to ≤10 mg/l from an initial level of 500 mg/l. Some species of *Bacillus* can utilize ammonia via both heterotrophic and chemotropic pathways (Edwards, 2011) [10]. This may be the reason for enhanced removal of ammonical nitrogen from fish processing waste water only after addition of the culture of *Bacillus sp*. (Anitha *et al.,* 2012 & Sharma *et al*., 2014) [3, 35]. Maximum ammonia degradation was observed for mixed culture of *Nitrosomonas* and *Nitrobacter*. The result showed that, a maximum ammonia degradation of 135 mg/L was observed on twenty second day during the treatment of fish processing waste water (Selvi *et al.,* 2014) [34]. Biological process like anaerobic treatment followed by aerobic treatment involving bioaugmentation using the culture of *Bacillus sp* was observed to be a good and economic solution for treating the fish processing industry waste water with high ammonical nitrogen (Sarnaik *et al*., 2015) [33]. *Bacillus cereus* and *Aeromonas veronii* have been efficiently utilized to reduce BOD of fish processing unit effluent, by more than 50% in five days. These microbes performed better in a mixed consortium than individual isolates, and a consortium of 50% each of *Bacillus* and *Aeromonas* sp. efficiently reduced ammonia and improve on nitrate values indicating biodegradation (Divya *et al.,* 2015) [8, 9].

## 4. Conclusion

Bioremediation is emerging as the most ideal alternative technology for removing pollutants from the environment, restoring contaminated sites and preventing further pollution. This environment friendly technology contains a range of organisms used for bioconversion, to clean up pollution and to degrade environmental pollutants. The application of beneficial bacteria, and biodegrading microorganisms, to the waste water is a sustainable approach to minimize the environmental impacts. Every microbe have different growth requirements (temperature, pH and nutrients), hence there arises the need to isolate those forms, which can be cultured easily in the lab, with minimal requirement and can be utilized in treating variety of pollutants. Use of genetically engineered microorganisms is not necessary as in most cases there is a wide diversity of naturally occurring microbial strains. As natural resources are major assets to humans, bioremediation of contaminated sites and ecosystems will be the best ecofriendly approach to ensure efficient recycling of wastes, also preserve the scarce resources and provide a safe and pollution free environment for our future generations.

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