

PHYSICOCHEMICAL PROCESS FOR FISH PROCESSING WASTEWATER

Neena Sunny¹, Lekha Mathai P²

Assistant Professor, Department of Civil Engineering, M.A.College of Engineering, Kothamangalam, Kerala, India¹

Professor, Department of Civil Engineering, M.A.College of Engineering, Kothamangalam, Kerala, India²

Abstract: The main environmental problems of fish industries are high water consumption and high organic matter, oil and grease, ammonia and salt content in their wastewaters. The generated fish wastewater is rich in oil and grease, salt and ammonia. Biological treatments of such wastewater render them harmless. The primary causes of failure are a wide variety of inhibitory substances present in substantial concentrations in wastes. This paper consequently focuses on the inhibitors of biological treatment process for fish processing wastewater. It could be concluded from studies that system ammonia content, wastewater salinity, oil and grease play a decisive role in the efficiency of fish processing wastewater treatment. Physico-chemical was responsible for biological processes. An integrated design using physicochemical process followed by biological process would yield better treatment efficiency with less energy consumption and reduced sludge production.

Keywords: organic loading rate, fat, oil and grease, free ammonia

I. INTRODUCTION

Fisheries play a significant role in the economic and social wellbeing of nations. Fisheries and its resources constitute a wide source of food and feed a large part of the world's population besides being a huge employment sector. The fish industry consumes a large amount of water in operations such as cleaning, washing, cooling, thawing, ice removal, etc. Consequently, this sector also generates large quantities of wastewater in which the treatment is particularly difficult due to the high content of organic matter and salts and to the significant amount of oil and grease they present. These factors, together with the fact that these effluents present significant variations depending on the production process and on raw material processed makes difficult to meet the emission limit values for industrial wastewaters and to deal with this problem in a sustainable manner. A wide variety of inhibitory substances are the primary cause of anaerobic digester upset or failure since they are present in substantial concentrations in wastes. These effluents are often subjected to a pre-treatment before discharge to the sewage system for further treatment at an urban wastewater treatment plant. The common processes in fish processing plants are filleting, freezing, drying, fermenting, canning and smoking (Palenzuela-Rollon, 1999). Regarding the organic matter degradation, the wastewaters are conventionally submitted to biological treatments. It yields desired results only when carried out in optimum conditions under proper observation. This paper presents a critical review of the inhibitors that affect the wastewater treatment in fish processing industry.

II. IMPORTANCE OF PHYSICOCHEMICAL PROCESS

The inhibitors commonly present in the fish processing wastewater include wastewater salinity, fat, oil and grease, ammonia content system pH and high content of organic matter.

Hypersaline effluents are generated by various industrial activities such as seafood processing, vegetable canning, and pickling, tanning and chemical manufacturing. This wastewater, rich in both organic matter and total dissolved solids, is difficult to treat using conventional biological wastewater treatment processes (Ludzack and Noran, 1965). Saline wastewater biological treatment systems usually result in low BOD removal because of the adverse effects of salt on the microbial flora. High salt concentrations cause plasmolysis or loss of activity of cells. So an efficient treatment process for these saline wastewaters has to be considered since conventional wastewater treatment processes will not give better results with saline wastewater. Lipids (characterized as oils, grease, fats and long-chain fatty acids) are important organic components of wastewater. Carawan et al.(1979) reported the FOG values for herring, tuna, salmon and catfish processing were 60-800mg/l, 250mg/l, 20-550mg/l and 200mg/l respectively. The behavior of lipids in biological treatment systems has led to many studies, which have evaluated their removal, but still the exact behavior of lipids in these processes is not well understood. The main components of fish processing wastewater are lipids and protein (Gonzalez, 1996). The Fat, oil and grease (FOG) should be removed from wastewater because it usually floats on the water's surface and affects the oxygen transfer to water.

Ammonia is a common hydrolysis product during waste degradation and could cause inhibition when present in high concentrations. pH could be an inhibition factor alone and interacts with ammonia inhibition by changing the relative

ratio of ammonium to ammonia. Ammonia emission and proteinaceous matter decomposition is mostly pH dependent (Gonzalez, 1996). The high nitrogen levels are likely due to the high protein content (15–20% of wet weight) of fish and marine invertebrate (Sikorski, 1990). Sometimes high ammonia concentration is observed due to high blood and slime content in wastewater streams. As reported by a few fish processing plant the overall, ammonia concentration ranged from 0.7 mg/L to 69.7 mg/L (Technical Report Series FREMP, 1994). In the fish condensate the total ammonia content can be up to approximately 2000 mg N/L. High BOD concentrations are generally associated with high ammonia concentrations (Technical Report Series FREMP, 1994). The degree of ammonia toxicity depends primarily on the total ammonia concentration and pH.

Wastewater loading rate is a critical design factor for wastewater treatment systems. Organic loading rate is summarized in Table 1. In anaerobic wastewater treatment, loading rate plays an important role. In the case of non-attached biomass reactors, where the hydraulic retention time is long, overloading results in biomass washout. This, in turn, leads to process failure. Fixed film, expanded and fluidized bed reactors can withstand higher organic loading rate.

III. BIOLOGICAL TREATMENT PROCESSES

A. EFFECT OF SALINITY

Fish processing industries require a large amount of salt for fish conservation. High salinity of wastewater strongly inhibits the aerobic biological treatment of wastewater. Stewart et al. (1962) reported considerable BOD₅ reduction due to the combined effect of high salinity and high organic loading. Kincannon and Gaudy (1968) observed that due to rapid change in salinity soluble COD was increased by the release of cellular material. They found that relatively more oxygen was used by cells grown in the presence of high salt concentrations. High saline concentrations have negative effects on organic matter and nitrogen removal (Intrasungkha et al., 1999). Aloui et al., 2009 proposed an activated sludge process for the treatment of fish processing saline water. However, the pollution abatement rates decreased with increasing the COD loading rate and salt content. Inhibition process was found to be significant for salt concentrations higher than 4% NaCl.

It is well known that anaerobic treatment of wastewater is inhibited by the presence of high sodium/or chloride concentrations. Methanogenesis is strongly inhibited by a sodium concentration of more than 10 g/L (Lefebvre and Moletta, 2006). But the work of Omil et al. (1995) on fish-processing effluent using an anaerobic contact system showed that the adaptation of an active methanogenic biomass at the salinity level of the effluent was possible with a suitable strategy. Acclimation of methanogens to high concentrations of sodium over prolonged periods of time could increase the tolerance and shorten the lag phase before methane production begins (de Baere et al., 1984; Feijoo et al., 1995; Omil et al., 1995a,b, 1996b; Chen et al., 2003). The tolerance is related to the Na⁺ concentration the methanogens acclimated to and the time of exposure. Anaerobic digesters are usually more sensitive to high salinity than an activated sludge unit.

B. EFFECT OF LIPIDS

Fish lipid contains long-chain n-3 (omega-3) PUFA, particularly EPA (C₂₀:5 n-3) and DHA (C₂₂:6 n-3). In aerobic wastewater treatment systems, lipids are generally believed to be biodegradable and, therefore, considered as part of the organic load that is treated. However, lipids have detrimental effects on oxygen transfer. They reduce the rates at which oxygen is transferred, thereby depriving the microorganisms of oxygen. This effect results in reduced microbial activity. To enhance biodegradation of lipids, Keenan and Sabelnikov (2000) proposed the use of a combination of suspended and attached growth treatment systems. They found that the lipid content in the effluent wastewater could not be reduced to values below 0.3 g/l from 1.512 g/l by using a suspended growth treatment system only, whereas adding a biofilter (a solid support that could be colonized by bacteria) to the suspended growth system substantially reduced the lipid content in the wastewater effluent to 0.028 g/l. However, the treatment system reported by Keenan and Sabelnikov (2000) sporadically failed, and the content of lipids in the effluent wastewater increased to 0.386 g/l. Although the authors attributed the sporadic failures to the failure of the pH adjustment system, the complete explanation for such failures was unknown.

The treatment of lipid-rich wastewater is still a challenge. In addition to aerobic wastewater treatment systems, anaerobic systems are also widely used for treatment of lipid-rich wastewater. Most importantly, high-rate anaerobic treatment systems have been developed. Among these systems, the upflow anaerobic sludge bed (UASB) reactor is the most widely used in the treatment of domestic and industrial wastewater due to its low-cost and adequate treatment efficiency. Although UASB reactors have been well characterized, and their usefulness for treatment of municipal and industrial wastes well documented their treatment failures have also been reported when treating lipid-rich wastewater. Gujer and Zehnder (1983) demonstrated that low density of the floating aggregates slows the biodegradation of lipids.

In order to improve lipid biodegradation in such troublesome systems, Rinzema (1994) proposed rigorous mixing as a means of maintaining good contact between bacteria and lipids in the anaerobic digester. In this regard, Li et al. (2002) proposed a two-stage anaerobic digestion process consisting of a mixing unit and a high solids digestion unit for treatment of lipid-rich wastewater. However, the degradation efficiency decreased at loading rates above 20 and 33 kg COD/m³ day under mesophilic (35^oC) and thermophilic (55^oC) conditions, respectively. At higher loading rates, low degradation of lipids is expected. To solve this problem, Van Lier et al. (1994) introduced a new concept of multi-stage UASB reactor, which consists of a number of gas–solids separators. Further, Tagawa et al. (2002) investigated the ability of a multi-stage UASB reactor under thermophilic conditions (55^oC) to treat lipid-rich wastewater at retention times from 0 to 600 days. But the overall COD removal (based on the total effluent COD) was very unsatisfactory at only 60–70%. Lettinga carried out further modifications of the UASB reactor (so-called expanded granular sludge bed reactor, EGSB). Rinzema et al. (1994) took advantage of the EGSB reactors and observed no flotation of granular sludge, and achieved a high volumetric loading rate of 31.4 g COD/l day. Hence, when treating lipid-rich wastewater, it should be advantageous to run sequencing cycles of adsorption and degradation in order to enhance complete removal of lipids. This lipid considered as the highly attention source for human consumption as well as industrial use. In this sense, the financial benefits can be obtained and environmental pollution is certainly decreased.

C. EFFECT OF pH AND AMMONIA

According to Boone and Xun (1987) most methanogenic bacteria have optima for growth between pH 7 and 8, whereas VFA degrading bacteria have lower pH optima. The optimal pH for mesophilic biogas reactor is 6.7–7.4 (Clark and Speece, 1971). The study of Sandberg and Ahring (1992) demonstrated that fish condensate can be treated well in a UASB reactor from pH 7.3 to 8.2. When the pH was increased slowly to 8.0 or more, COD removal drop about 15–17%. Acetate was the only carbon source in the condensate that accumulated upon increasing the pH. It was concluded that gradual pH increment was essential in order to achieve the necessary acclimatization of the granules and to prevent disintegration of the granules and that the pH should not exceed 8.2. Aspe et al. (2001) modeled the ammonia-induced inhibition phenomenon of anaerobic digestion and concluded that methanogenesis was the most inhibited stage. The methanogenic activity was reduced by the presence of high concentrations of ammonia as a result of protein degradation during the anaerobic treatment. Ammonia inhibition was directly related to the concentration of the undissociated form (NH₃), therefore being more important at high pH levels. It was also reported that free ammonia (FA) inhibitory concentrations for mesophilic treatment have been 25–140 mg N-FA/L whereas during the thermophilic digestion of cattle manure, higher values, 390–700 mg N-FA/L, were tolerated after an initial acclimation period (Guerrero et al., 1997). Control of pH within the growth optimum of microorganisms may reduce ammonia toxicity (Bhattacharya and Parkin, 1989). The traditional method for removal of ammonia and organic pollutants from wastewater is biological treatment but ion exchange offers a number of advantages including the ability to handle shock loading and the ability to operate over a wider range of temperatures.

IV. CONCLUSIONS

Wastewater characterization is a critical factor in establishing a corresponding effective management strategy or treatment process. Based on the studies conducted by different authors regarding the wastewater treatment in fish processing industry, which includes both aerobic and anaerobic treatment processes the following conclusions could be drawn. Anaerobic treatment processes are most widely used for treating wastewaters but these processes partly degrade wastewater containing fats and nutrients. So, subsequent treatment is necessary for wastewater. The fats and nutrients could easily be removed in aerobic reactors. But a high-energy requirement by aerobic treatment methods is the primary drawback of these processes. In order to reduce energy consumption in aerobic treatment, physico-chemical treatment processes may be combined with anaerobic-aerobic combination. An integrated design using physicochemical process followed by biological process would yield better treatment efficiency with less energy consumption and reduced sludge production. Combining physicochemical adsorptive treatment with biological treatment can provide synergistic benefits to the overall removal processes. Ion exchange removal solves some of the common operational reliability limitations of biological treatment, like slow response to environmental changes and leaching. Biological activity can in turn help reduce the economic and environmental challenges of ion exchange processes, like regenerant cost and brine disposal.

Table1
Performance of aerobic and anaerobic systems for fish processing wastewater treatment

Process	Wastewater Characteristics (mg/l)	Organic loading	Removal Efficiency	Reference
Aerobic				
Activated sludge	-	0.5kgBOD/m ³ d	90–95% BOD	Carawan et al.(1979)
Aerated lagoon	-	-	90–95% BOD	Carawan et al.(1979)
Trickling filter	BOD upto 3000	0.08–0.4kg BOD/m ³ d	80–87% BOD	Park et al. (2001)
Rotating biological contactor	pH 6–7; COD6000–9000; BOD 5100; TSS 2000; TKN 750	0.018–0.037kg COD/m ³ d	85–98% COD	Najafpour et al. (2006)
Anaerobic				
Anaerobic fluidized bed reactor	COD 90000;	6.7 kg COD/m ³ d	88% COD	Balslev-Olesen et al. (1990)
Anaerobic fixed film	-	2 kg COD/m ³ d	75% COD	Veiga et al.(1991)
Anaerobic digester	COD 34,500; TS 4000;Cl ⁻ 14000	4.5 kg COD/m ³ d	80% COD	Mendez et al. (1992)
Anaerobic filter	-	0.3–0.99kg COD/m ³ d	78–84% COD	Prasertsan et al. (1994)
Upflow anaerobic sludge blanket reactor	COD 2718 ±532; lipids 232 ± 29; TKN410 ±89; pH 7.2–7.6	1–8 kg COD/m ³ d	80–95% COD	Palenzuela-Rollon et al. (2002)

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