Chapter 1
Introduction

1.1 Motivations

Currently, Thailand is the world's largest producer of farmed black tiger shrimp which earned approximately $2.187 billion US in export revenues during 2001 [Department of Export Promotion; Ministry of Commerce, 2001]. Shrimp farmers, however, confront wastewater problems. During shrimp culture, uneaten food particles and some by-products of digested food, namely amino acids and proteins, become major sources of organic compounds that accumulate at the bottom of the pond. Then aerobic bacteria convert the particulate organic compounds into dissolved organic nitrogen. This consequently causes the release of free ammonia into the water. Ammonia at a considerably low concentration (0.3 mg/L or higher) can be toxic to the health of shrimp [Malone and Reyes, 1997], and it causes the shrimp to eat less, which leads to stress in shrimp. In a long-run, ammonia causes shrimp to develop a white spot or yellow head disease [Szuster and Flaherty, 2001].

Conventional water exchange systems in shrimp farms are operated in several modes, *i.e.* opened, semi-closed and closed systems. In opened water exchange systems, seawater flows continuously through the pond. The advantages of opened systems are the ease of operation and low cost. However, this system inherits two problems: high energy requirement from pumping, and large quantity of polluted water being released into the environment. Semi-closed systems, require a much smaller volume of water makeup (only up to 10%) [Kaiser and Schmitz, 1988], but the probability of exposure to disease of shrimp in this kind of system is still high due to the carried over of the disease with the incoming seawater. Also some metabolic wastes contained in the culture seawater will still be in the discharged water.

Closed systems are usually operated with a very small makeup water volume per day [Kaiser and Schmitz, 1988] and, hence, become alternatives which holds much promise for profitable and sustainable shrimp culture. Results from earlier work showed a better control, less water demand, and improved effluent quality of closed system [Fast and Menasveta, 1998]. One common characteristics of this type of system is that the used culture seawater has to be treated and recycled back to the pond. This used culture seawater contains a large fraction of ammonia containing waste which has to be removed through a nitrification process carried out in wastewater treatment facilities. The nitrification is a two-step, aerobic, autotrophic process where ammonium ion is converted to nitrite by *Nitrosomonas* species in the first step and nitrite to nitrate by *Nitrobactor* species in the second.

A variety of nitrification treatment processes have been successfully operated. The most common techniques are trickling filter, submerged filter and rotating biological contactors. There are several advantages using these processes such as small space requirement, low operating costs, etc. However, there are also disadvantages regarding the use of these systems. For example, high maintenance costs can be foreseen due to fouling and clogging. Rotating filter usually requires high pumping cost whereas an activated sludge process necessitates a large area with an additional sludge settling tank. The main disadvantage of trickling filters is a need to regularly clean the rotating spray bar. Submerged filters suffer problems with solid collection and poor gas exchange in the submerged thin film filter.

In these regards, airlift bioreactors are more attractive than the above mentioned technologies in such a way that it is capable of creating a well-mixed aerobic compartment, leading to good mixing. In particular airlift fluidized bed bioreactor provides an excellent contact between the three phases (gas, liquid and solid). With this in mind, this work focuses on the investigation of the performance of airlift bioreactors in treating the wastewater containing ammonia. The comparison between performance of this system with other common techniques will also be carried out.

1.2 Previous work at the Biochemical Engineering Laboratory, Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University

Packed bed external loop airlift bioreactor (PBELAB) was developed at our laboratory as a complete treatment system for wastewater containing ammonia [Silapakul, 2002]. The PBELAB is designed as one aerated column (riser) interconnected with two unaerated columns (downcomer). The aerated section (riser) is a cylindrical column with a volume of 8 L and diameter of 9 cm. Each unaerated column diameter is 20 cm with a volume of 37 L. This is to ensure adequate retention time for denitrification which should be about 5-10 times larger than that for nitrification [Balderston and Sieburth, 1976; Turk, 1996]. In PBELAB, ammonia is converted to nitrate (nitrification reaction) in the aerated section and nitrate is then converted to nitrogen gas (denitrification reaction) in the non-aerated section. A few technical problems were encountered in the operation of PBELAB. The first problem is due to the difference in the nature of nitrification and denitrification reactions. Nitrification is the aerobic reaction where dissolved oxygen is the primary variable, whereas denitrification is the anaerobic. It is therefore of primary importance that the dissolved oxygen in wastewater after leaving the aerated section goes down to almost zero as rapidly as possible. Hence, the aeration rate has to be controlled by having a low superficial gas velocity (< 3 cm/s). The second problem is due to the non-equal rates of nitrification and denitrification. Currently, the nitrification rate was limiting the system and it is the aim of this work that a better system for nitrification is developed whilst controlling the superficial gas velocity under 3 cm/s. This level of superficial gas velocity is therefore the upper limit of the gas throughput used in this work.

1.3 Objectives

1. To compare the nitrification rate of various treatment techniques, *i.e.*, trickling filter, submerged filter both in conventional and airlift modes, and fluidized bed airlift bioreactor in treating ammonia containing seawater.
2. To investigate the effect of gas throughput and designed parameter, downcomer to riser cross sectional area ratio (A_d/A_r) and superficial gas velocity, on the nitrification rate of each reactor type.

1.4 Scope of this work

1. Synthesis wastewater used in this work is prepared with seawater.
2. All reactors are laboratory scale with a liquid volume of 5 L.
3. The packing employed in this work is a commercial bioball with a surface area of 32.7 cm^2 (per bioball) for packed bed airlift filter and submerged filter. For the fluidized bed airlift filter, the bioball was crushed into smaller pieces with a cubic shape (1mm x 1mm x 1mm dimension) and the surface area became 36 cm^2 for one crushed bioball.