In The Name Of ALLAH, swt

Razi University

Faculty of Chemistry

Department of Applaied Chemistry

M.Sc.Thesis

Title of the Thesis:

Simultaneous removal of carbon and nutrients from wastewater in a single draught tube bioreactor

Supervisor:

Dr. Ali Akbar Zinatizadeh

By:

Kolsoom Aftabi

February 2014

Acknowledgemnt

I am very grateful to Allah (swt) for his guidance and protection during the writing up of the thesis as well as during my life and every things that I have done.

I would like to express my deep gratitude and respect to my supervisor, Dr. Zinatizadeh, whose expertise, understanding, and patience, added considerably to my graduate experience. I appreciate his vast knowledge and skill in many areas (e.g., vision, ethics, interaction with people), and his assistance in writing reports (i.e. proposals and this thesis), which have on occasion made me "GREEN" with envy. His invaluable help of constructive comments and suggestions throughout the experimental and thesis works have contributed to the success of this research. His excellent guidance has been absolutely essential for the completion of this thesis. I would also like to thank him for being an open person to ideas, and for encouraging and helping me to shape my interest and ideas and for all I have learned from him and for his continuous help and support in all stages of this thesis. I wish him good health and success. I would also like to thank my family for the support. They provided me through my entire life and in particular. I must acknowledge my best friend, Azar Asadi, without whose love encouragement and help, I would not have finished this thesis. Cheers to AZAR for being a great reliable person to whom I could always talk about my problems and excitements. Thanks her for questioning me about my ideas, helping me think rationally and even for hearing my problems. To those who indirectly contributed in this research, your kindness means a lot to me. Thank you very much.

Abstract

Simultaneous removal of carbon and nutrients (CNP) in a single bioreactor is of high significance in terms of reactor volume and energy consumption. The bioreactor used in this study consists of two tubes. A draught tube is used as an aerobic zone and the annulus as an anoxic/anaerobic zone. The dairy wastewater was taken from a working dairy industry, Sahra Co., Kermanshah, Iran. Chemical oxygen demand (COD), total nitrogen (TN), total phosphorus (TP) concentrations in the feed used were in the range of 1800-2000 mg/l, 50-70 mg/l and 2-10 mg/l. The feed was introduced to the bottom part of the bioreactor and then flows with the sludge into a draught tube (aerobic zone) by the air-lift action. Finally, the effluent is intermittently withdrawn from the middle of the bioreactor.

Three independent variables consisting hydraulic retention time (HRT), mixed liquor suspended solid (MLSS) and air flow rate with the range of 8-16 h, 2000-6000 mg/l and 1-5 l/min, respectively, were selected to analyze the process. The circulation flow rate between the two zones, created by aeration in the draught tube, was the most important operating parameter for the process. The results indicated that sCOD removal efficiency in all experiments was more than 80% as a result of high biodegradability of the milk processing wastewater, while nutrients removal were function of the experimental conditions. The maximum nitrogen removal efficiency was 66% which achieved at MLSS, HRT, and air flow rate of 6000 mg/l, 12h and 3 l/min, respectively. Also, the maximum phosphorus removal efficiency was 68% when MLSS, HRT and air flow rate were 6000 mg/l, 8h and 5 l/min, respectively. Besides, the effluent turbidity was influenced by changing variables, so that, the minimum effluent turbidity was 3 NTU.

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Chapter 1

1-1-Wastewater

Wastewater is simply that part of the water supply to the community or to the industry which has been used for different purposes and has been mixed with solids either suspended or dissolved. Wastewater is 99.9% water and 0.1% solids. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and agriculture and can encompass a wide range of potential contaminants and concentrations. Discharge of domestic and industrial wastewater to surface or groundwater is very dangerous to the environment. Therefore, treatment of any kind of wastewater to produce effluent with good quality is necessary. Historically, the major emphasis of environmental regulation and cleanup has be focused on municipal and industrial wastes. Now, agricultural wastes are increasingly being recognized as a major source of pollution. Among the most significant pollutants in agricultural wastes are the nutrients nitrogen and phosphorous. In order to design onsite wastewater treatment systems, we must consider the nature of the wastewater because the effluent quality depends upon the influent characteristics.

Figure 1-1. Discharge of untreated industrial wastewater to a river.

1-2- Characteristics of wastewater

1-2-1- Physical characteristics

Characterization of wastewater is an important part of the initial work in the design of a treatment process. The main physical characteristics of wastewater are its solids content, colour, odour and temperature. The total solids in a wastewater consist of the insoluble or suspended solids and the soluble compounds dissolved in water. Between 40 and 65 % of the solids in an average wastewater are suspended [1].

1-2-2- Chemical characteristics

Over the years, a number of different tests have been developed to determine the organic content of wastewaters. The biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total organic carbon (TOC) tests are gross measures of organic content. Fractionation of COD in wastewater is shown in Figure 1-2.

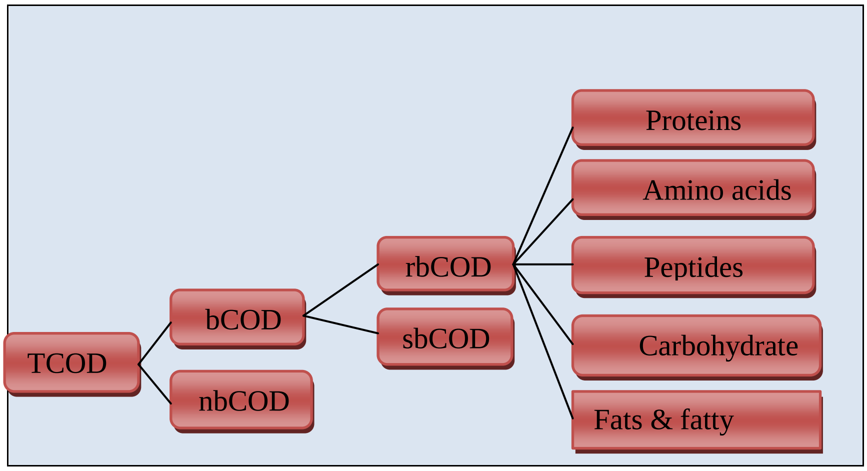

Figure 1-2. Fractionation of COD in wastewater.

The principal chemical tests include free ammonia, organic nitrogen, nitrites, nitrates, organic phosphorus and inorganic phosphorus [1]. Nitrogen and phosphorus are essential nutrient for plants and microorganism growth. Adding more of the limiting nutrient, in fact, can stimulate too much plant growth, which starts a chain of events that may eventually deplete oxygen from the water and deleterious for aquatic life. Thus, wastewater treatment systems were designed to remove organic matter as well as nutrients (N& P) [2]. Nitrogen is found in a variety of forms throughout our environment and changes forms readily. Nitrogen in raw wastewater is typically comprised of ammonia and organic nitrogen. Generally, there is little or no oxidized nitrogen present (nitrite or nitrate). The combination of ammonia, which is an inorganic form of nitrogen, and the organic nitrogen, is the Total Kejeldahl Nitrogen (TKN). The ammonia and organic nitrogen content of the TKN is generally 60 and 40 %, respectively. The fractionation of TKN in the wastewater is shown in Figure 1-3.

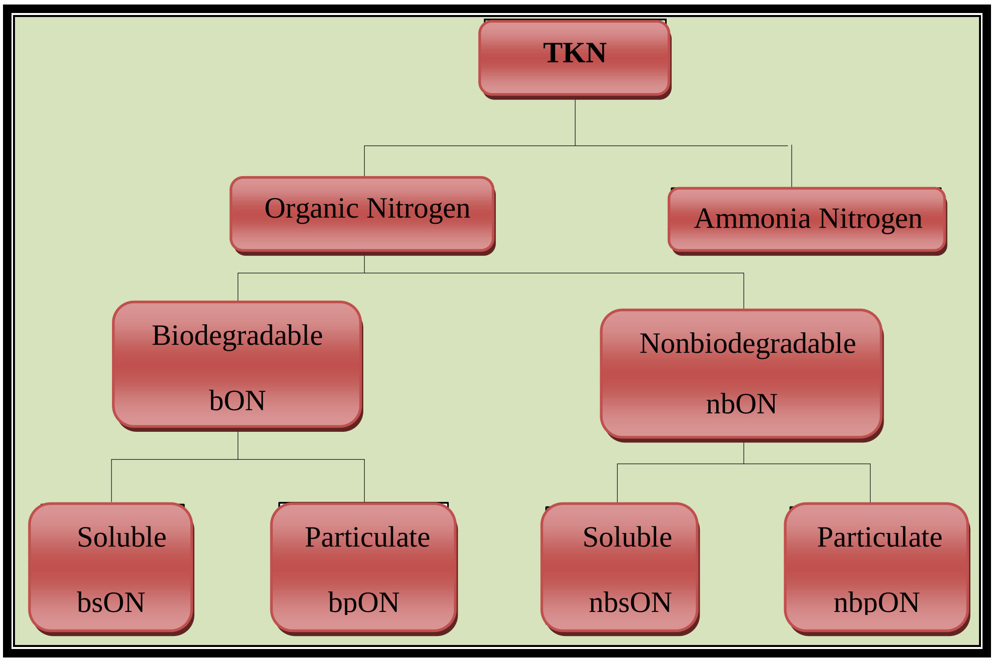

Figure 1-3. Nitrogenous constituents in wastewater.

The phosphorus compounds, predominantly found in wastewater as phosphates, can be categorized by physical means (dissolved and particulate fractions) and by chemical means as phosphate compounds. The chemical fractions consist of dissolved inorganic orthophosphate, polyphosphate or condensed phosphate, and organically bound phosphate. The orthophosphate form (PO_4^{3-}) is the simplest form of phosphorus and accounts for 70 to

90% of the TP. Organic phosphorus is also contributed by a variety of industrial and commercial sources. Other tests, such as chloride, sulphate, pH and alkalinity, are performed to assess the suitability of reusing treated wastewater and in controlling the various treatment processes. Trace elements, which include some heavy metals, are not determined routinely, but trace elements may be a factor in the biological treatment of wastewater. All living organisms require varying amounts of some trace elements, such as iron, copper, zinc and cobalt, for proper growth [1]. It should be noted that the most industries except food processing industries, the nutrients (N&P) content of the wastewater is very slight, so that addition of the nutrients are required to operate biological treatment system.

1-3- Composition of dairy wastewater

In Table 1-1, a list of wastewater characteristics for typical industries is presented. The major problem associated with the biological treatment of industrial wastewater is non and slowly biodegradable fraction of COD which inhibits the treatment performance of the bioreactors. BOD_5/COD ratio constitutes a good measure of the biodegradability of a wastewater and contaminants with a ratio of $BOD_5/COD \geq 0.4$ are generally accepted as biodegradable [3]. From a review, the BOD_5/COD ratio for industrial estate wastewaters is varied from 0.17 to 0.74 [4]. Dairy industry is considered to be largest source of food processing wastewater in many countries. The dairy industry handles large volumes of milk, and the major waste material from processing is the water. The water removed from the milk can contain considerable amounts of organic milk products and minerals. The organic components of the wastewater from dairy processing operations can be classified as proteins, lactose and fat. These will affect the environment in different ways depending on their biodegradability and their solubility. The BOD_5/COD ratio is 0.74 that demonstrated that the organic components in dairy processing wastewater are highly biodegradable. The wastewater characteristics are shown in Table 1-2.

Table 1-1 .Wastewater characteristics for typical industries (Kiely,1996) [6].

Industry	Principal pollutants	BOD_5, mg/l
Dairy, milk processing	Carbohydrates, fats, proteins	1000 –2500
Meat processing	SS, protein	200 –250
Poultry processing	SS, protein	100 –2400
Bacon processing	SS, protein	900 –1800
Sugar refining	SS, Carbohydrates	200 –1700
Breweries	Carbohydrates, protein	500 –1300
Canning fruit etc	SS, Carbohydrates	500 –1200
Tanning	SS, protein, sulphide	250 –1700
Electroplating	heavy metals	minimal
Laundry	SS, Carbohydrates, soaps, oils	800 –1200
Chemical plant	SS, acidity, alkalinity	250 - 1500

Table 1-2. Characteristcs of dairy industrial wastewater.

Parameters	Unit	Range
TCOD	mg/l	3445
SCOD	mg/l	2445
BOD	mg/l	1860
Suspended solids (SS)	mg/l	398.31
VSS	mg/l	329.25
TKN-N	mg/l	68-70
$NO3^-$ -N	mg/l	6.05-6.91
$PO4^{3-}$ -P	mg/l	12.63-13.93
Oil & Grease	mg/l	288
pH		6.5-6.7

1-4- Needs for treatment of dairy wastewaters

Continuous extraction of water has resulted in depletion of available water sources in and around the industrial areas. In addition, wastewater discharge into natural water sources has caused surface and groundwater pollution, leaving water unsafe for potable use and impairing industrial use without major and costly treatment. The current low cost end-of-pipe treatment approach will become increasingly expensive as effluent discharge standards become more stringent. Meanwhile, technological advancements now make it possible to treat wastewater for variety of industrial reuse. Most industries in even developing countries are already moving towards wastewater reuse and source separation and treatment of separated effluents is gaining more attention. Wastewater reuse potential in different industries depends on waste volume, concentration and characteristics, best available treatment technologies, operation and maintenance costs, availability of raw water, and effluent standards. Radical changes in industrial wastewater reuse have to take in to consideration rapidly depleting resources environmental degradation, public attitude and health risks to workers and consumers. Therefore, it is noted that most of the procedures that could be implemented by industrial establishments to reduce the negative environmental impacts, will also lead to reducing the effects that present a threat to the health of workers within the plants and the public living in regions affected by the various emissions from the plants. In this respect, the effectiveness of the inspection on industrial wastewater treatment plants will lead to the protection of the environment and the protection of workers and public health. Among the food industries, the dairy industry is the most polluting in volume (generating from 0.2 to 10 L of effluent per liter of processed milk) in regards to its large water consumption. Dairy food wastewater disposal represents a major environmental problem [5]. Dairy factory wastewaters contain substantial quantities of the plant nutrients (nitrogen and phosphorus). If excessive concentrations of these enter waterways then they will promote the growth of plants in the waterways. Eventually these may grow to nuisance proportions. Nitrogen is a very important component of the dairy factory wastewaters. Some protein will be lost to the waste streams. Bacteria convert the nitrogen in proteins to the inorganic forms including ammonia, and the ammonium, nitrite and nitrate ions. Each of these inorganic forms of nitrogen have different environmental effects.

1-5- Environmental regulations of effluent discharge

The highly pollution loading on the water resources from various sources (municipal, industrial and agricultural) has been led to the increasingly stringent environmental regulations. The permitting variable effluent standards are applied based on the demands of prevailing environmental circumstances. The effluent discharge standards ordinarily applicable to effluent wastewater are presented in Table 1-3.

Table 1-3. Effluent discharge standards for treated wastewater (Iran).

No.	Parameter	Discharge to surface water,(mg/l)	Discharge to well, (mg/l)	Agriculture Uses, (mg/l)
1	COD	60	60	200
2	BOD_5	30	30	100
3	TSS	40	-	100
4	TDS	10	10	-
5	NH_4	2.5	1	-
6	NO_2	10	10	-
7	NO_3	50	10	-
8	P	6	6	-
9	pH	6.5-8.5	5-9	6-8.5
10	Turbidity (NTU)	50	-	50

1-6- Problem statement

The enhanced pace of developmental activities and rapid urbanization have resulted in stress on natural resources and quality of life. There are several major effects associated with the discharge of nutrients containing streams to receiving waters. These include eutrophication, ammonia toxicity and nitrate contamination of groundwater.

The trend of increasing pollution in various environmental media is evident from the deteriorating air and water quality, higher noise levels, increasing vehicular emission etc. Realizing the urgent need for arresting the trend ,Ministry adopted policy for Abatement of Pollution which provides for several mechanisms in the form of regulations, legislation, agreements, fiscal incentives and other measures to prevent and abate pollution. Nutrients content are problems associated with industrial wastewaters which are not typically considered in conventional treatment processes design [7].

For the biological removal of nutrients (N&P) and carbonaceous matters, anaerobic, anoxic and aerobic conditions are required. Combinations of different high rate anaerobic and aerobic bioreactors have been applied with continuous regime to treat a wide range of industrial wastewater removing carbon, nitrogen and phosphorus. In recent years, the compact high-rate bioreactors have been more investigated for wastewater treatment due to small space required and less production of odor and sludge [8]. The integrated bioreactors are cost effective, efficient and have smaller foot steps as compared to the separated anaerobic–aerobic systems. One of the popular single bioreactors is sequential batch reactor (SBR) which has some advantages rather than other continuous systems like needless to clarifier and flow equalization tank [9]. Over years, SBR has been modified by adjusting the steps in the react cycle to provide An, Ax and Ox phases in sequence for biological nutrient (C, N, and P) removal from different wastewaters [10-13]. For this purpose, sequencing batch reactor (SBR) is considered as an effective choice because in the SBR, costs of services and operation running are lower than those of continuous regime systems. Furthermore, the SBR has been also effectively utilized for treatment of wastewater with high concentration of nitrogen, phosphorus and heavy metal [14-15]. SBR designers have adapted the sequence of batch systems in a mixture of ways. One category of SBR systems discriminates those that operate with continuous feed and intermittent discharge (CFID). In present study, an intermittent discharging drought tube bioreactor (IDDTBR) was applied to prepare anaerobic, anoxic and aerobic conditions in a single bioreactor by physical separation for removing carbon and nutrients from a dairy industrial wastewater. The CFID SBR reactors collect wastewater in all stages of the treatment cycle [16]. This study discusses the potential for treating dairy wastewater and treatment technologies attaining such a goal, in increasingly competitive market and stringent regulatory environment.

1-7- Research objectives

The present research has the following main objectives:

1. To design, fabricate and perform the start-up of an innovative single draught tube bioreactor in order to simultaneous carbon and nutrients (N&P) removal from a dairy industrial wastewater.
2. To study the effect of three operating independent variables (retention time, air flow rate and MLSS) on the performance of the single drought tube bioreactor (DTBR).
3. Kinetic evaluation of dairy wastewater treatment process in the DTBR.

1-8- Scope of study

Application of an innovative single draught tube bioreactor as a bioreactor derived from SBR design with CFID regime for simultaneous carbon and nutrients removal from Sahra's factory wastewater (Kermanshah, Iran) is the main focus of the present study. Three numerical variables (retention time, biomass concentration and air flow rate) were selected to analyze the process. The region of exploration for the process was taken as the area enclosed by retention time (8-16 h), biomass concentration (2000-6000 mg/l) and air flow rate (1-5 l/min) boundaries. A general factorial design was employed to design the experiments. To evaluate the process performance, variation trends of eleven significant responses sCOD removal, total nitrogen removal efficiency, effluent nitrate concentration, effluent nitrite concentration, N-organic, total phosphorus (TP) removal efficiency, effluent turbidity, sludge volume index (SVI), height of sludge, settling velocity and population of nitrifying bacteria as a function of the three independent variables were constructively investigated. The results obtained were used for kinetic study, employing a suitable kinetic model derived from mathematical concepts governing the anaerobic and aerobic processes