Journal of Hazardous Materials 178 (2010) 326–332

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Simultaneous removal of ammonia, P and COD from anaerobically digested piggery wastewater using an integrated process of chemical precipitation and air stripping

Xuejun Quan*, Changying Ye, Yanqi Xiong, Jinxin Xiang, Fuping Wang

College of Chemistry and Chemical Engineering, Chongqing University of Technology, Chongqing, 400050, PR China

ARTICLE INFO

Article history:
Received 2 September 2009
Received in revised form 15 January 2010
Accepted 15 January 2010
Available online 25 January 2010

Keywords:
Ammonia
Total phosphor and COD removal
Air stripping
Chemical precipitation
Anaerobically digested piggery wastewater

ABSTRACT

The paper presented an efficient integrated physicochemical process, which consists of chemical precipitation and air stripping, for the simultaneous removal of NH_3-N, total P and COD from anaerobically digested piggery wastewater. In the integrated process, $Ca(OH)_2$ was used as the precipitant for NH_4^+, PO_4^{3-} and organic phosphorous compounds, and as the pH adjuster for the air stripping of residual ammonia. The possibility of the suggested process and the related mechanisms were first investigated through a series of equilibrium tests. Laboratory scale tests were carried out to validate the application possibility of the integrated process using a new-patented water sparged aerocyclone reactor (WSA). The WSA could be effectively used for the simultaneous removal of NH_3-N, total P and COD. 3 g/L of $Ca(OH)_2$ is a proper dosage for the simultaneous removal. The simultaneous removal of NH_3-N, total P and COD in the WSA reactor could be easily optimized by selecting a proper air inlet velocity and a proper jet velocity of the liquid phase. In all the cases, the removal efficiencies of the NH_3-N, total P and COD were over 91%, 99.2% and 52% for NH_3-N, total P and COD, respectively. The formed precipitates in the process could be easily settled down from the suspension system. Therefore, the integrated process provided an efficient alternative for the simultaneous removal of NH_3-N, total P and COD from the wastewater.

1. Introduction

Pig farms with hundreds to several thousands of animals are in operation in many countries without adequate systems for waste treatment and disposal [1]. A large amount of piggery waste is discharged from the cages every day. This waste is a mixture of feces, urine and food wastage [2]. Piggery waste is characterized by a high content of organic matter and pathogenic microorganisms. The disposal of piggery waste without adequate treatment can cause a drastic effect on the environmental and human health [3].

According to the most common characteristics of this waste, anaerobic digestion could be considered as one of the most promising treatment alternatives, which has several advantages such as destruction of pathogenic and parasitic organisms, production of methane, low biomass production, better process stability and lower treatment cost [3,4]. It was reported that the separate anaerobic digestion of liquid and solid fractions of piggery waste is more effective than the digestion of the whole waste [5]. In practice, many large scale local pig farms in Chongqing area are now collecting the liquid and solid fractions of piggery waste separately in pig cages to minimize the amount of piggery waste. This collection mode is a water-saving process and is beneficial to later treatment. The solid fraction is directly transported to an anaerobic digester for fermentation to make organic fertilizer. The liquid fraction, a mixture of pig urine, manure leachate and washing wastewater, flows into an anaerobic digester after passing through a simple screen mesh. Practice illustrates that anaerobic digestion can greatly reduce the COD of piggery wastewater [1]. Practical operation of anaerobic digestion in many local pig farms in Chongqing area can make the COD of piggery wastewater to be reduced to the concentration lower than 500 mg/L. But the anaerobically digested liquor usually still contains more than 160 mg/L of NH_3-N and more than 30 mg/L of total P. The national discharge standard of pollutants for livestock and poultry breeding stipulates that the COD, NH_3-N and total P must be lower than 400 mg/L, 80 mg/L and 8.0 mg/L, respectively [6].

The ammonia in water is one of the major environmental pollutants, which may cause the increase of chlorine consumption and oxygen demand, toxicity to fish, eutrofication and diseases like ethaemoglobinaemia, hypertension and stomach cancer, as well as other serious environmental hazards [7]. So, the anaerobically digested liquor of piggery wastewater needs to be further treated to make its COD, especially NH_3-N and total P to be decreased to be lower than the values stipulated by the national standards.

* Corresponding author. Tel.: +86 23 68667184; fax: +86 23 68667184.
E-mail address: hengjunq@cqut.edu.cn (X. Quan).

0304-3894/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.jhazmat.2010.01.083

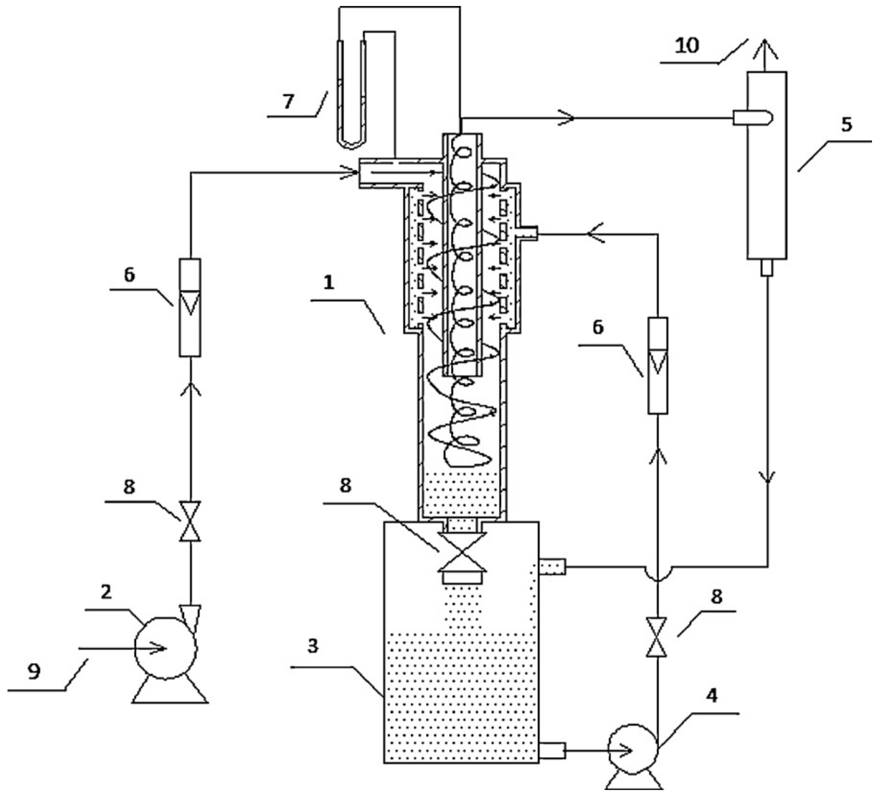

Fig. 1. The flow diagram of the experimental setup and the WSA configuration. (1) Water-sparged aerocyclone; (2) air pump; (3) water tank; (4) circulating pump; (5) gas–liquid separator; (6) rotameters; (7) U-type manometers; (8) valves; (9) air inlet; (10) air outlet.

The further removal of NH_3-N and total P from anaerobically digested liquor can be conducted using air stripping [8–12] and struvite precipitation [13–16]. Compared with the usually used biological processes [17–25], the physicochemical method cannot only remove ammonia and P, but also recover them as valuable products such as NH_3 and $MgNH_4PO_3$, which can be used as fertilizers. In addition, these processes are a time and energy-saving process.

Similar with the struvite precipitation, calcium ions can be also used as a precipitant to form $CaNH_4PO_4{\cdot}4H_2O$ [26]. The aim of this work is to present an efficient integrated physicochemical process, which consists of chemical precipitation and air stripping, for the simultaneous removal of NH_3-N, total P and COD from anaerobically digested piggery wastewater. In the process, cheap $Ca(OH)_2$ was used as the precipitant for NH_4^+ and PO_4^{3-} and meanwhile can be used as a cheaper pH adjuster for the air stripping of ammonia in comparison with the usually used NaOH. In many air stripping processes, NaOH is used as pH adjuster to avoid the serious scaling problem in stripping equipments. Compared with the usually used air stripping equipments like tanks and packed towers, the water-sparged aerocyclone reactor (WSA) is characterized by good mass transfer performance and self-clean function, and is suitable for the air stripping of wastewater system with suspended particles [27]. Therefore, the WSA was chosen as both a mixer and an air stripper to validate the large scale application possibility of the suggested simultaneous removal process. The effects of process parameters, including $Ca(OH)_2$ dosage, air inlet velocity (U_g) and jet velocity of liquid phase (U_l), on the simultaneous removal of NH_3-N, total P and COD were investigated for the optimization of operation conditions. In addition, the mechanisms for the removal of NH_3-N, total P and COD in the integrated process were tentatively elucidated through a series of equilibrium tests.

2. Material and methods

2.1. The anaerobically digested piggery wastewater

The anaerobically digested liquor of piggery wastewater used in this experiment was taken from the effluent of the largest local pig farm in Chongqing city, China. The pig farm is located in the Rongchang County, the modern animal husbandry area of China, about 100 km northwest of Chongqing city. The liquid and solid fractions of piggery waste are separately collected in the pig farm. The liquid fraction (a mixture of urine, leachate of manure and washing water) flows into an anaerobic digester after passing through a simple plastic screen. The effluent generally contains COD 150–500 mg/L, more than 160 mg/L of NH_3-N and more than 30 mg/L of total P with pH 7.3–8.0.

2.2. Equilibrium removal of N, P and COD

First the simultaneous precipitation of N, P and adsorption of COD in the digested liquor should be investigated. $Ca(OH)_2$ was chosen as the precipitant, pH adjuster and adsorbent because of its lower price. The experimental procedure is briefly outlined as follows. A prescribed dosage of $Ca(OH)_2$ powder was added into a 250 ml Erlenmeyer flask with 100 ml of the digested liquor, and then the flask was covered to prevent ammonia escape. Likewise, a series of the flasks with different dosages of $Ca(OH)_2$ powder was prepared. The flasks were then placed in a shaker and shaken at 150 rpm for 24 h at 25 °C to make the chemical precipitation reaction and adsorption reach an equilibrium. After that the solid–liquid system was filtered to get a supernatant sample, which was then used for the determination of NH_3-N, total P and COD. Each experiment was repeated to get experimental data with an error of less