Review paper

Comparison of Anaerobic and Aerobic Sequencing Batch Reactor System for Liquid Manure Treatment

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액상가축분뇨처리에서 혐기성 및 호기성 연속 회분식 반응조 시스템의 비교 연구

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Summary

Sequencing batch operation consists of fill, react, settle and decant phases in the same reactor. Operation consists of anaerobic, anoxic and oxic (aerobic) phases when nutrient removal from the wastewater is desired. Since the same reactor is used for biological oxidation (or mixing) and sedimentation in aerobic and anaerobic SBR operations, capital and operating costs are lower than conventional activated sludge process and conventional anaerobic digestion process, respectively. Therefore, Aerobic SBR and Anaerobic SBR operations may be more advantageous for treatment of small volume animal wastewater in rural areas.
(**Key words** : Biological treatment of liquid manure, Aerobic SBR, Anaerobic SBR)

INTRODUCTION

In recent years, there has been an increasing interest in the application of sequencing batch reactors (SBRs) in animal wastewater treatment. SBR is a biological treatment reactor that uses natural bacteria to degrade organic carbon and nitrogen present in the wastewater. If designed and operated properly, it may become a promising alternative for treating animal wastewater to control odors and reduce solids and nutrient contents.

The SBR is a treatment system comprising a single or multiple-stage vessel in which alternating phases of aerobic and anaerobic conditions can be provided, and it has been found to be an efficient and flexible method for treating various dilute wastewaters (Zhang et al., 1999; Fernandes, 1991; Lo and Liao 1986).

The SBR system features sequences of partial filling of the single reactor with waste liquid, followed by a react phase which is fully or partially aerated, a settle phase and then decanting the treated supernatant. Before filling, the reactor contains an active and sizeable microorganism population which will biodegrade

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the influent wastewater. At the beginning, microorganisms must be seeded in the reactor from a suitable source such as full-scale wastewater treatment facility.

The growth of paddy rice and wheat applied with digested slurry (effluent or supernatants) from the anaerobic digestion was less different from that with chemical fertilizer and the ammonia emission was suppressed by applying into soil (Miho et al., 2004).

A number of studies are reported in the literature on nutrient removal from wastewaters by SBR operation. The remaining challenge is to develop cost effective and easily adaptable anaerobic or aerobic SBR systems for farm application.

The purpose of this paper is to present a comparison of aerobic and anaerobic SBR systems based on the working principles and reviews previous and current research activities with the aerobic SBR and anaerobic SBR system for treating animal liquid waste.

AEROBIC SBR (SBR)

A SBR is used for biological removal of nitrogen from the organic wastes. Intermittent aeration is used for achieving the nitrogen removal through nitrification and denitrification. Sequencing of aeration and no-aeration periods in a treatment reactor creates alternative aerobic and anoxic environments as shown in Fig. 1 (Fernandes et al., 1991).

It is a time-oriented system and typically operates over repeated cycles of 4 phases-fill, react, settle and decant. It allows solids retention time (SRT or BRT: bacterial cells residence time in the reactor or sludge age) to be longer than the hydraulic retention time (HRT) by retaining the biomass sludge through gravity settling in the reactor during the settle phase and is more advantageous in treating dilute wastewater than conventional activated sludge reactors. The major factors that control the performance of SBRs include organic loading rate, hydraulic retention time (HRT), solid retention time (SRT), dissolved oxygen (DO), and influent characteristics, such as solids content and C/N ratio. Depending on how these parameters are controlled, the SBR can be designed to have one or more of these functions-carbon oxidation, nitrification and denitrification (Hanaki, 1990). Carbon oxidation and denitrification are carried out by heterotrophic bacteria and nitrification is by autotrophic bacteria. The SBR treatment system

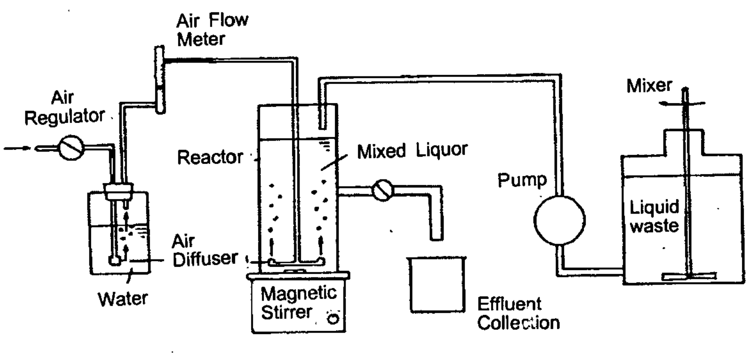

Fig. 1. Schematic diagram of the SBR experimental setup.

may be designed as a single-stage or multiple-stage system. It was found that for treating the same wastewater, the HRT of a two-stage system could be at least 1/3 shorter than that of a single-stage system (Zhang et al., 1999).

Aerobic treatment can effectively control the nature and quantity of nitrogen in the manure. Depending on the operating conditions, nitrogen can be conserved as ammoniacal nitrogen, lost via ammonia stripping during the aeration, oxidized to nitrate and conserved, or lost var. denitrification. Evans et al. (1986) found that when the aeration rate was low and DO in the liquid manure not detectable, the nitrogen remained in the forms of organic nitrogen and ammonia nitrogen for all the studied aeration treatments (0.5 to 15 day retention time) and temperatures (15 to 50°C).

Up to 50% of organic nitrogen was converted to ammoniacal nitrogen and loss of nitrogen was mainly due to ammonia stripping. At high aeration rate when DO can be detected and was at least higher than 1% of saturation, nitrification and denitrification occurs.

It has been found that the sequencing batch treatment can remove up to 90~99.5% convertible nitrogen in the manure (Fernandes et al., 1991 and Svoboda, 1995).

ANAEROBIC SBR (ASBR)

Conventional heated anaerobic reactors (or digesters) used for animal waste treatment such as continuously stirred tank (or fed and mixed) reactors (CSTR) and plug-flow digester are suited for treating concentrated wastes with high solids contents, but not economical for treating dilute wastewater. The capability of retaining biomass solids in the reactor with a reduced HRT is the key factor for improving the treatment efficiency of dilute wastewater.

Several high-rate anaerobic reactors have been developed with the concept of retaining biomass in the reactor. They include the up-flow anaerobic sludge blanket reactor (UASB), the anaerobic biofilter and the fluidized bed reactor. Compared to conventional digesters, these reactors can achieve the same or better treatment efficiencies for dilute wastewater with much shorter HRTs, which range from hours to several days. Short HRTs translate into small reactor volumes.

The ASBR is a new anaerobic process that has demonstrated excellent performance for treating animal wastes as well as other types of organic wastes as shown in Fig. 2 (Sung and Dague, 1992).

It operates on a sequencing batch mode, cycling through four distinct phases (feed, react, settle and decant) during its operation. The ASBR allows the biomass to be kept in the reactor with a long solids retention time (SRT)

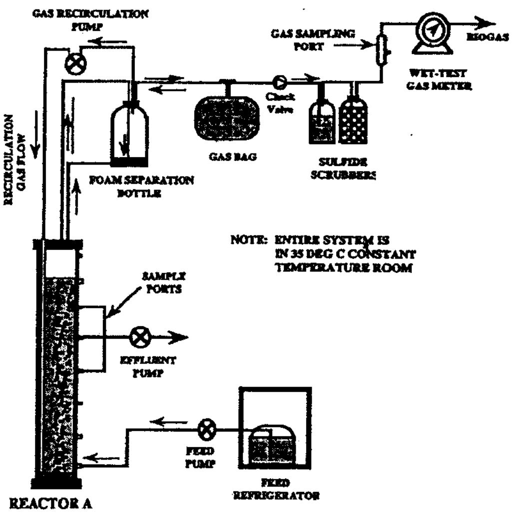

Fig. 2. Experimental set-up for ASBR laboratory studies.

while handling liquid with a short hydraulic retention time (HRT). The unique feature of the ASBR is its ability to grow and retain biomass through a natural selection process. It is simple to operate and requires low maintenance. The ASBR can be used to treat both dilute and concentrated wastes.

An ASBR moves the solids settling action as used in the anaerobic contact digester into the digester by incorporating a solids settling phase in the digester operation as a way to retain the biomass solids in the digester.

The ASBR operates in a cyclic batch mode with four distinct phases per cycle. The four phases are feed, react, settle and decant as shown in Fig. 3 (Zhang et al., 1997).

Mixing (biogas recycle) is provided intermittently during the feed and react phases. During the feed and initial react phases, the substrate concentration in the reactor is at its maximum level and biogas production rate is the highest, resulting in a high internal gas mixing for good biomass-substrate contact. During the settle and decant phases, the substrate concentration is at its minimum level and the biogas production rate is the lowest, creating optimum conditions for biomass settling in the reactor before the supernatant is removed from the top of the reactor.

The settle and decant phases are key steps in the ASBR operation. The settle phase allows biomass solids to be kept within the reactor and to continue to build up, resulting in a long SRT and improving the organic removal efficiencies. The heavier, more rapidly settleable biomass in the reactor is continuously selected through cyclic processes so that the most competitive microorganisms are maintained in the reactor and the performance of the reactor is optimized (Zhang et al., 1997).

The ASBR has been evaluated extensively in the laboratory for treatment of swine manure at mesophilic temperatures ranging from 20 to 35°C (Zhang et al., 1996).

It has demonstrated a superior performance for treating dilute swine manure with short HRTs (down to 3 days) while maintaining the SRT longer than 10 days. Because of its relatively simple design and capability of handling high concentrations of suspended

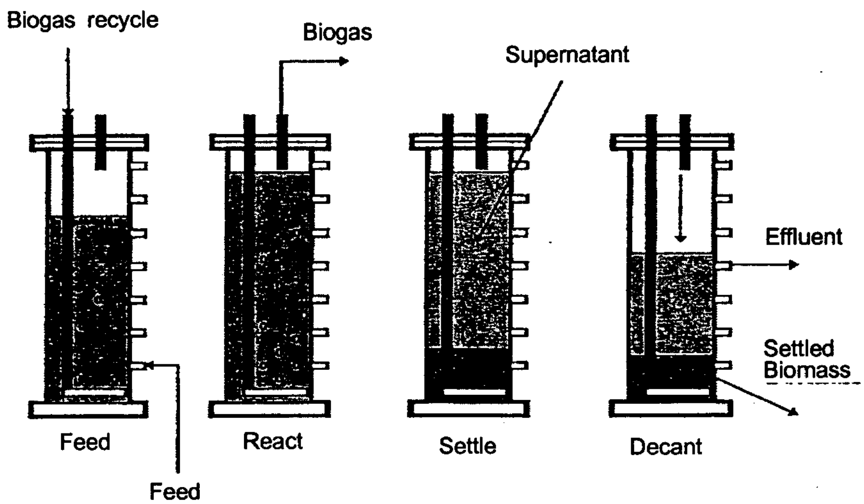

Fig. 3. Four phases of the Anaerobic Sequencing Batch Reactor.

solids in the wastewater, as compared with other high-rate digesters, the ASBR is considered to have a large potential for applications in animal waste treatment. Conceptual designs for the configurations and operational schemes of the ASBR system for working with swine confinement operations using flushing and scraping systems are presented in publication by Zhang et al. (1997).

CONCLUSIONS

Water quality issues and odor and gas emissions from animal manure treatment facilities are important issues facing producers. Public health issues related to animal manure biological treatment are emerging issues that animal producers will have to deal with in the near future.

Recently, more advanced aerobic and anaerobic biological treatment systems, such as biofilm or biofilter processes, aerobic and anaerobic sequencing batch reactors (SBR), autothermal thermophilic aerobic digestion (ATAD), biomass retaining digester such as fixed media digesters used for dilute wastewaters less than 9 percent solids, anaerobic contact digester and fluidized bed reactor have received much of the attention of researchers and technology developers for animal manure treatment.

Effluent nutrients are changed slightly during digestion. Effluent volume is unchanged from the influent volume. Therefore, effluent utilization for cultivation remains a more research need in the near future.

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