NITRIFICATION OF SWINE WASTEWATER USING BACTERIA ENCAPSULATED IN POLYMER PELLETS

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Nitrifying microorganisms encapsulated in polymer resins are used in municipal wastewater treatment plants for higher nitrification rates and smaller reactors. A prototype plant was set up in a swine operation in Duplin Co., North Carolina for nitrification treatment of lagoon wastewater. The unit consisted of a 0.34 m^3 contact aeration tank made of PVC crossflow media and used to lower influent BOD, a 0.18 m^3 sedimentation tank, and a 1.3 m^3 aerated fluidized tank used for nitrification treatment. The unit was completed with pH and DO controllers. Polyethylene glycol (PEG) pellets containing 2% activated municipal sludge were added in the nitrification tank at 10% (v/v) concentration. Pellets were successfully acclimated to swine wastewater during a 3-month period in which the ammonia loading rate was increased by decreasing the hydraulic residence time (HRT). At the initial 48 h HRT, nitrification activity of pellets increased from 0.02 to 2.0 g N/L-pellet/d in 30 d. Nitrification activity further increased to 3.2 and 4.3 g N/L-pellet/d at HRT's of 32 and 24 h, respectively. Nitrification rates were generally low during winter months (Dec.-Feb.). Nitrification efficiencies of more than 80% were obtained during spring with an ammonia load of 476 g N/m^3 tank/d (HRT=19 hr) and during summer months with ammonia loading rates of 604 g N/m^3 tank/d (HRT=12 hr).

INTRODUCTION

During recent decades, animal production methods in the U.S.A. have undergone dramatic changes. The predominant trend has seen animal production changing from small, individual operations into large, confined, commercial enterprises. Typical facilities use flush or pit-recharge systems to remove manure from the confinement houses. The flushed waste is mostly treated and stored in anaerobic lagoons and later applied to cropland. Although the anaerobic digestion process can reduce 80% or more of the organic matter from these high-strength wastewaters, these open lagoon systems are not without significant adverse environmental impact. For storage periods of 180 days typical of the Southeast, it may be anticipated that more than 50% of the nitrogen (N) entering the lagoon will escape to the atmosphere though ammonia volatilization. Its subsequent deposition across the landscape may be the largest form of nitrogen non-point source pollution in the region. It is estimated that airborne pollution now accounts for about one-third of the 2,300 Mg of N that enter the Neuse River basin of the eastern U.S.A. each year. These and other considerations, such as the potential for contaminated ground and surface waters, fish kills, and unexpected ecological shifts, provide ample reason for a greatly increased interest in finding functional and affordable alternative methods of N management for confined animal production.

NITRIFICATION ENHANCEMENT

A possible solution is to remove ammonia from animal wastewater through on-farm biological nitrification-denitrification systems. The basic problem related to nitrification of animal wastewaters is the low growth rate of the nitrifying bacteria; the generation time of these microorganisms is about 15 hours. Compared to heterotrophic microorganisms, which have generation times of 20-40 minutes, the nitrifiers compete poorly for limited oxygen and nutrients and tend to be overgrown or washed out (Wijffels *et al.*, 1993). Even when the oxygen supply is plentiful, an adaptation period is needed to reach a minimum bacteria concentration before effective nitrification. In the absence of enriched nitrifying populations, aerobic treatment of lagoons can potentially add to problems by stripping ammonia into the atmosphere, particularly if uncontrolled or excessive flow rates of air are used (Burton, 1992).

To overcome low nitrification rates in swine wastewater, we evaluated a new technology that uses nitrifying bacteria encapsulated in polymer pellets. The technology has been successfully applied to municipal wastewater treatment providing higher nitrification rates, shorter hydraulic residence times (HRT), and smaller reactors. The nitrifiers are entrapped in 3- to 5-mm pellets made of polymers that are permeable to NH_3, oxygen and carbon dioxide needed by these microorganisms, resulting in a fast and efficient removal of NH_3. Typical materials are polyethylene glycol (PEG) and polyvinyl alcohol (PVA); these pellets are functional for more than 10 years. Wastewater is treated in a nitrification tank equipped with a wedge-wire screen to retain the pellets and a whole-floor aeration system to ensure high oxygen transfer and appropriate fluidization.

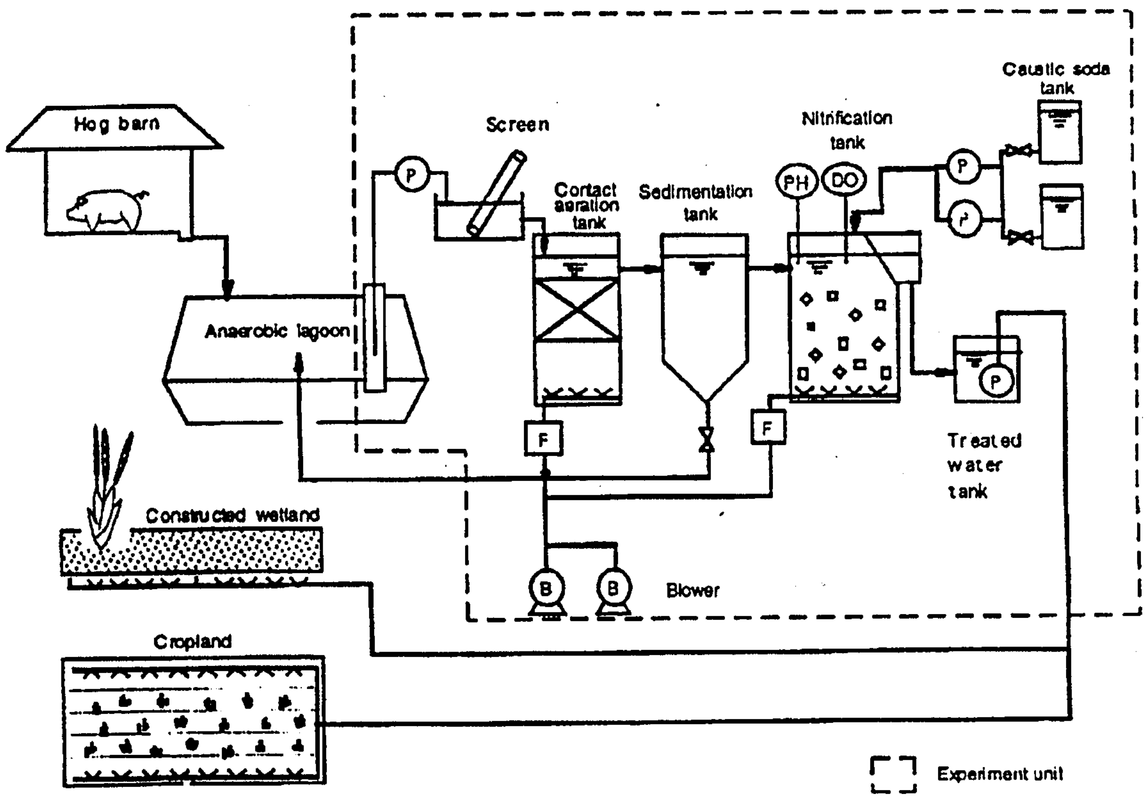
PILOT EXPERIMENT

Results of bench scale research were used to design and construct a pilot plant for biological ammonia removal from swine lagoons (Vanotti and Hunt, 1998a,b). The unit was set up in a swine operation near Kenansville in Duplin Co., North Carolina. It consisted of a 0.34 m^3 contact aeration tank made of PVC crossflow media used to lower influent BOD, followed by a 0.18 m^3 sedimentation tank, and a 1.3 m^3 aerated fluidized tank for nitrification. A 1-mm wedge-wire screen was installed at the outflow of the nitrification tank to separate the pellets and activated sludge and retain the pellets inside the nitrification tank. Polyethylene glycol (PEG) pellet cubes (3- to 4-mm size) were added in the nitrification tank at 10% of the effective tank volume. The PEG pellets were produced in Japan by the Hitachi Plant Engineering Company using a sheet polymerization technique (Aoki *et al.*, 1989), and contained 2% activated municipal sludge. The pellets were transported to the field site immediately after production for acclimation to swine wastewater. Air was provided to the bottom of both aeration tanks with a compressor and fine air diffusers (8.6% efficiency). The air flow was controlled through proportional solenoid valves in the air lines responding to dissolved oxygen (DO) concentration in the tanks. An average air flow rate of 50 L/min was applied to the contact aeration tank and 80 L/min to the nitrification tank. This ensured appropriate fluidization of the pellets and maintained DO concentration of the mixed liquor at more than 3 mg/L. The unit was completed with a pH controller and chemical tank used to keep the process pH in the nitrification tank between 7.5 and 8.0 through NaOH injections.

FIELD ACCLIMATION OF ENCAPSULATED NITRIFIERS

The PEG pellets were prepared with activated sludge from a municipal wastewater treatment plant. Therefore, we conducted an acclimation procedure to adapt the nitrifiers for swine wastewater which contains 10 to 20 times more ammonia-N. Activity of the nitrifying pellets was determined frequently through laboratory tests. Samples of the pellets were transported from the field unit to the laboratory and tested for nitrification and oxygen consumption rates. Nitrification activity was determined in 1-L aereated reactors during a 4-hour period using an inorganic salt medium (pH 8.3) containing 300 mg NH_4-N/L and 10% (v/v) pellet concentration. Nitrification rate was calculated from the slope of a regression line relating the increase in NO_3-N concentration and time. Oxygen consumption activity was determined using a DO probe in a closed glass chamber (128 mL) containing 20 mL of pellets and the inorganic salt medium. Oxygen consumption rate was calculated from the slope of a regression line describing the relationship between the decrease of DO concentration in the liquid and time.

The pellets were successfully acclimated to lagoon effluent during a 3-month period in which the ammonia loading rate was increased by decreasing the hydraulic residence time (HRT). At the initial 48 h HRT, nitrification activity of pellets increased from 21 to 200 g N/m^3 tank/d (0.02 to 2.0 g N/L-pellet/d) in about 30 d. Nitrification activity further increased to 319 and 433 g N/m^3 tank/d (3.2 to 4.3 g N/L-pellet/d) at HRT's of 32 and 24 h, respectively. Nitrification activity further increased during the subsequent 3-month period and stabilized at about 750 to 900 g N/m^3 tank/d. Oxygen consumption rate of pellets also increased with time. Typically, 1.5 to 2.0 g O_2 was needed per g of ammonia-N removed.



NITRIFICATION TREATMENT PERFORMANCE

The pilot unit was tested from December 1997 to August 1998 during cold, mild and warm water temperatures A 24-hr composite sample was collected every 3.5 d from the influent, the effluent of the contact aeration tank (data not shown) and the effluent of the nitrification tank. Samples were stored in a refrigerated sampler in the field at 4.0°C and kept cold until chemical analyses. Nitrification rates were generally low during winter months (Dec.-Feb.) when water temperatures were lower than 10°C. In addition to low temperatures, the influent wastewater during this period contained a higher proportion of organic materials and the contact aeration tank was not effective in reducing the BOD to design criteria of 100 mg/L for nitrification. Under these conditions, average nitrate production efficiency was only 28% at ammonia loading rate of 237 g N/m^3 tank/d and HRT of 33 hr. Nitrate production rates were much higher with water temperatures >10°C. Nitrification efficiencies of more than 80% were obtained during early spring with ammonia loads of 476 g

N/m³ tank/d (HRT=19 hr) and during summer months with ammonia loading rates of 604 g N/m³ tank/d (HRT=12 hr). The high nitrification rates obtained in this work indicate that this technology has potential application for treatment of high strength ammonia wastewater typical of confined animal production systems.

SUMMARY

Animal waste treatment is a significant agricultural and environmental challenge that needs additional options as a result of expanded, confined animal production. We evaluated a new technology that uses nitrifying pellets in aerated tanks for fast and efficient removal of ammonia. A state-of-the-art pilot plant was constructed in a pig operation in Duplin County, North Carolina. Pellets were successfully acclimated to swine wastewater through a stepwise procedure in which ammonia load was gradually increased by decreasing the hydraulic residence time from 48 hrs to 24 hrs. Performance of the unit was tested under a range of ammonia loading rates and temperatures during the subsequent nine months. Our results indicate that high nitrification rates of swine wastewater can be attained using enriched nitrifying populations immobilized in polymer resins. This is an attractive approach to biological ammonia removal because the capacity of the nitrification tank can be increased by increasing the nitrifiers' retention time independent from the wastewater retention time. Higher ammonia removal rates are also critical for development of nitrification units to treat animal waste because aeration cost can be a limiting factor. Current research efforts focus in the development of integrated systems sequencing solids separation, nitrification and denitrification, and phosphorus extraction unit processes.

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