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Sustainable removal of ammonia from anaerobic-lagoon swine waste effluents using an electrochemically-regenerated ion exchange process

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HIGHLIGHTS

- A new physico-chemical method for ammonia removal from swine wastes was tested.
- The method consists NH_4^+ ion exchange and electrochemical regeneration of the resin.
- Operation with swine wastes for prolonged time proved feasible and cost effective.
- Counter cations accumulation in recycled regenerant solution required short IX step.
- Overall treatment cost was $3.057 per kg ammonia oxidized (OPEX amounting to 88.4%).

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ABSTRACT

A new process, based on ion-exchange and electrochemical regeneration, was tested for removing ammonia from effluents of swine-waste anaerobic lagoons. The process, consisting of a daily sequential operation of adsorption (180 min), chemical regeneration (125 min) and electrooxidation of ammonia in the regeneration solution (8 h, applied during low-cost electricity hours), was shown feasible for reducing the ammonia concentration in the wastewater from ~1000 to ~60 mg/L with a total cost estimated at ~$3/kg N. The work focused on identifying the best operational conditions enabling continuous operation of the ion-exchange column and recycling of the regenerant solution without the need for replenishment of either. Chemical additions were restricted to in-line addition of NaOH to maintain constant pH during the electrolysis step and periodical addition of NaCl to compensate for Cl^- and Na^+ losses. It was found that removing NH_4^+ (by chabazite–zeolite) from swine wastewater characterized by NH_4^+:K^+:Ca^{2+}:Mg^{2+}:Na^+ ratio of 1:0.66:0.1:0.06:0.30 (g/g) could be carried out by the proposed treatment sequence at conditions of pseudo steady state, with an adsorption stage of 12.5 bed volumes and 14.5 min hydraulic retention time. Applying such conditions, the concentration of K^+ (the main competing cation) stabilized both in the regenerant solution and on the chabazite, enabling >90% NH_4^+ removal without need for replacing the regenerant solution. Electrooxidation efficiency constantly exceeded 90% due to the high Cl^- concentration (>17 g/L) maintained in the regeneration solution and because only a small mass of organic matter was transferred to the regenerant solution following the adsorption step.

1. Introduction

The evolution of animal agriculture to meet the needs of a rapidly growing world population is evidenced by a consistent trend toward the replacement of small animal farms by large, industrial-scale animal feeding operations (AFOs), which maximize the number of livestock confined per unit of land area. Swine production is one of the biggest sources of meat in modern agriculture; in fact, pork is the most consumed meat in the world representing about 40% of the world's total meat consumption. In 2011, the swine population in the European Union amounted to 148.6 million hogs [1]. Worldwide pork production was forecasted to amount to ~104 million metric tons in 2012, an increase of 2.7% from 2011 [2]. Swine wastes contain high concentrations of organic matter, nutrients (particularly N and P), pathogens, trace metals and salts. The effects of intense animal husbandry over relatively small areas have already been observed in many places. In Brittany (France), intensive pig-farming caused many surface and subsurface water resources to become contaminated by nitrate, with concentrations exceeding the European Community 50 mg/L drinking standard [3]. In Spain, the common practice of spreading swine wastes on agricultural soils in rural areas has impacted the quality of aquifers and surface waters to a degree that it jeopardizes the very existence of the industry. In Israel, more than 100,000 pigs

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