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Simultaneous ammonia recovery and treatment of sludge digestate using the vacuum stripping and absorption process: Scale-up design and pilot study

Wendong Tao [a,*], Mohammad A.H. Badsha [a,b], Pubudu W. Arachchilage [a], Alsayed Mostafa [a,c]

[a] Department of Environmental Resources Engineering, SUNY College of Environmental Science and Forestry, 1 Forestry Dr., Syracuse, NY 13210, USA
[b] Digester Doc, LLC, Boise, ID 83709, USA
[c] Civil and Environmental Engineering, University of Alberta, 116 Street NW, Edmonton, AB T6G 1H9, Canada

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ABSTRACT

The paradigm of wastewater treatment is shifting from costly pollutant removal in mainstream to resource recovery from sidestream. This paradigm shift, nevertheless, is retarded by the lack of scalable, cost-effective ammonia recovery technologies. The vacuum stripping and absorption (VaSA) process has unrivaled features to recover ammonia and treat digestate simultaneously. The present study introduced a multi-pool boiling mode of vacuum stripping for scale-up design and conducted pilot tests at a water resource recovery facility using a 250-L/batch 3-pool system. It stripped 80.7 % of ammonia in sludge digestate and 91.5 % in pressate in 5-h batch operation. Ammonia mass transfer coefficient reached 0.319–0.485 1/h in digestate and 0.386–0.608 1/h in pressate. The operating challenge was to properly maintain vacuum and configure the demister where vapor–liquid equilibrium changed as it was scaled up. In contrast to the optimum vacuum pressure of 25–27 kPa and feed boiling temperature of 65 °C in the single-pool boiling stripper, the vacuum pressure in the 3-pool boiling stripper was increased to 46.3–46.9 kPa by the higher demister temperature (74 °C). The recovered crystals contained 98.4–103.7 % of $(NH_4)_2SO_4$. Vacuum-assisted alkali/thermal treatment of digestate under the VaSA conditions increased the dissolved fraction of volatile solids from 7.5 % to 32.8–34.1 % and decreased fecal coliform to mostly undetected. Solids solubilization also resulted in generation of volatile organic compounds, primarily allyl chloride, methylene chloride, 2,5-octadecadiynoic acid methyl ester, and (E)-1,2-dichloroethylene. The low concentrations and small vapor pressures of these compounds were unfavorable for co-stripping. The co-stripped compounds were largely retained in condensate and absent in vacuum exhaust. This study validated the scalability of multi-pool boiling design of VaSA for efficient ammonia recovery and elucidated the effects on digestate treatment.

1. Introduction

Nitrogen (N) limits are increasingly added to wastewater discharge permits and become more stringent over time. Currently, biological nitrogen removal in the mainstream of water resource recovery facilities is costly. When primary and activated sludge is treated in anaerobic digesters, organic nitrogen is converted to ammonia and ammonia-N concentration increases from 14 to 41 mg/L in the mainstream [1] to 0.8–2.5 g/L in the typical effluent of full-scale sludge digesters and even up to 6 g/L in high-solids sludge digesters [1..4]. Therefore, recovering ammonia in sludge sidestream presents a cost-effective alternative to mainstream removal because the sidestream from sludge digesters accounts for only approximately 0.5–1.5 % of the mainstream flowrate [1] and 29..92 % of total ammonia loading based on the typical ammonia concentrations in sludge digestate. Nevertheless, ammonia recovery from wastewater still lacks scalable, cost-effective technologies to accelerate the paradigm shift from nitrogen removal in the mainstream to ammonia recovery in the sludge sidestream.

Most of the ammonia recovery technologies are in the proof-of-concept stage at lab scale [5..7]. The gas stripping technologies that are commercially applied to recover ammonia from sludge digestate require costly solid..liquid separation to avoid clogging of stripping beds, incur high costs for supplying air or steam, and often take days of hydraulic residence to reduce ammonia concentration by more than 80

* Corresponding author.
E-mail addresses: wtao@esf.edu (W. Tao), abu@digesterdoc.com (M.A.H. Badsha), alsayed2@ualberta.ca (A. Mostafa).

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