A membrane contactor for ammonia stripping, pilot scale experience and modeling

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1. Introduction

Ammonia is even in low concentrations problematic to life in water environments due to the effect as a fertiliser promoting eutrophication and is normally removed by denitrification in waste water treatment plants. Likewise ammonia in animal manures poses a threat to the environment in various ways without careful administration of the manure as a fertiliser. This often results in inadequate use of the animal manures and in the case of denitrification of MSW ammonia is sacrificed at the expense of considerable energy consumption. A better solution is to strip the ammonia from these sources for subsequent optimal uses.

There are many conventional ways to remove ammonia from water but most methods are dependent on relatively large amount of energy for the operation. Membrane contactors offer a superior solution for stripping ammonia because they provide a large surface area that facilitates fast separation of the ammonia from the wastewater even at low energy input per mole ammonia removed. Experiments have been reported using porous, hydrophobic hollow fibre and tubular membrane contactors for ammonia stripping from various wastewater treatment effluents following anaerobic digestion [1–3] but so far this technology has only been reported in larger scale operation in a few cases [4]. In this investigation both laboratory and fairly large scale pilot plant operation has been in operation in order to optimise the use of the technology.

2. Theory and experimental

The membranes commonly employed for CM are hydrophobic polypropylene (PP) or PTFE. These polymers have the ability to allow a vapour or gas to permeate the membrane, totally rejecting the aqueous phase. Volatile components are transported across the membrane and either stripped by a carrier gas or directly absorbed in a suitable liquid (acid) flowing along the membrane interface. The driving force for liquid–liquid ammonia removal by CM is the difference in ammonia partial pressure between the feed and the absorbing liquid. For efficient removal the ammonia has to be in its volatile form. Increasing the pH or
temperature to a point where all ammonium-nitrogen \((\text{NH}_4 - \text{N})\) is in its volatile ammonia form ensures this. In a simple theoretical treatment of the problem the temperature and pH of the bulk feed, the volume and the membrane area is uncoupled from the mass transfer coefficient \(k_m\), so that it essentially contains information about mass transfer resistances due to the membrane physical properties and ammonia partial pressure. All data was fitted using the integrated form of central differential equations shown in Eq. (1).

\[
\ln \left( \frac{[\text{NH}_3] - N_s}{[\text{NH}_3] - N_{\infty}} \right) = k_m \cdot \frac{A}{V_o} \cdot \text{FA} \cdot t
\]  

(1)

A laboratory and a similar pilot scale set-up were used to predict the overall mass transfer coefficient, \(k_m\). The membrane module consists of a bundle of polypropylene (PP) capillaries encased in a PP pressure vessel (Microdyn-Nadir Gmbh). The feed was on the inside of the capillaries and the strip solution on the shell-side. The strip solutions used was solutions of \(\text{H}_2\text{SO}_4\) (1% w/w). For both setups, acid was dosed with a dosing pump and pH controller which controlled the pH within ±0.2 pH units. CM feed consisted of UF-permeate from a full-scale ADUF plant in one series of experiments and of reject water from a decanter centrifuge concentrating secondary sludge from a MSW plant. Decarbonisation was done by chemically precipitating calcium carbonate \((\text{CaCO}_3)\) with lime \((\text{Ca(OH)}_2)\), which in all instances also precipitated the bulk soluble \(\text{PO}_4^{3-}\) as hydroxyapatite as reported by Graham et al., [5].

3. Results and discussion

A range of experiments was performed to assess the influence of pH (Fig. 1a) and temperature (Fig. 1b) on ammonia mass transfer. It was found that a higher pH and subsequently a free ammonia (FA) fraction close to unity, yielded the best results in terms of ammonia mass transfer. The relative effect of temperature on ammonia mass transfer rates was also noticeably higher at pH values exceeding 10. In Fig. 1a the predictions of ammonia concentration during the stripping operation calculated from a simple theory is shown as solid lines. In the trials shown sulphuric acid was used as absorber for ammonia. Other acids are also viable and an interesting experiment could be performed with carbonic acid as absorber producing ammonium bicarbonate, which has a beneficial potential use as a hydrogen storage medium.
4. Conclusions

Ammonia removal by CM seems viable, especially for small streams with high ammonia concentrations. The process can essentially function efficiently at ambient temperatures. The resulting ammonia salt solution could have a high market value, if sufficiently concentrated. The use of steam could be completely avoided by implementing CM.

References


