IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

Highly efficient neutralization of VOCs in wastewater from CO_2 capture systems

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Abstract

Solvent degradation during aqueous amine point-source carbon capture can lead to potentially adverse economic, environmental, and human-health impacts. During operation the amine, CO_2 and system temperatures leads to the increased volatility and emissions of organic degradation compounds. Volatile organic compounds (VOCs) are particularly important as they are potentially dangerous when emitted to the environment and are generally regulated. To ensure environmental regulations are met as carbon capture technologies move towards widescale deployment, the concentrations of emitted VOCs must be kept at a minimum using a proactive, targeted approaches for their neutralization within the CO_2 capture systems. Locations in which the VOC compounds can be targeted prior to emission include the waterwash systems, acidwash systems, bulk solvent and liquid condensate recovered from the overhead condenser after the stripper (as depicted in **Fig. 1**). These locations provide a concentrated process stream, potentially better suited for targeted treatment.

To enable the targeted neutralization of VOCs like N-nitrosamines and Aldehydes, a flow-through electrochemical cell technology was developed. The flow-through electrochemical cell utilizes permeable electrodes to facilitate the destruction of these regulated species without the production of secondary waste streams or the need for additional treatment steps, lowering the environmental impacts. To improve the effectiveness and cost of this electrochemical system for large scale application, low cost carbon-based electrode materials were screened and tested. In this work, the neutralization of four N-nitrosamines (N-nitrosopyrrolidine (NPY), N-nitrosodiethylamine (NDEA), and N-nitrosomorpholine (NMOR) N-nitrosopiperazine (NPZ)) in a waterwash matrix using the flow-through electrochemical cell with four different carbon-based electrode materials was investigated. Evaluation in waterwash matrices represent those found in capture systems using primary amines (MEA), secondary amines (piperazine) or advanced solvents like CESAR1 (3 M 1-amino-2-methyl-1-propanol and 1.5 M piperazine). Results showed the decomposition of N-nitrosamines up to 99% while also exhibiting long-term electrode stability with consistent decomposition for over five hundred hours of continuous operation. The electrochemical flow-cell also showed the concurrent neutralization of formaldehyde, acetaldehyde and propionaldehyde in the same waterwash matrix at rates up to 92% without impacting N-nitrosamine decomposition.

Following up on the results in a waterwash solution, the flow-through electrochemical cell was adapted to target and neutralize these VOCs in an acidwash solution, bulk solvent and condensate streams. Treatment of an acidwash solution (pH ~2) exhibited efficient VOC decomposition up to 98%. The targeted neutralization of N-nitrosamines directly from MEA and CESAR1 showed decomposition rates up to 78%, indicating effective neutralization from the solvent itself and provides an alternative method to the

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induced thermal degradation of N-nitrosamines to help mitigate their emissions. Furthermore, operation of the electrochemical cell using condensate effectively neutralized VOCs similar to rates observed in waterwash matrices.

Overall, operation of the flow-through electrochemical cell results indicate that N-nitrosamines, formaldehyde, acetaldehyde and propionaldehyde can be efficiently decomposed in a waterwash from various solvents at rates up to 99%. It was also demonstrated that VOCs can be targeted and neutralized in condensate, acidwash solutions, and directly in the amine solvent. The effective destruction of these hazardous compounds in a variety of process streams and solvents highlights the robust nature of this flow-through electrochemical cell leading to operations that can be tailored to the needs of each individual capture systems. This type of flexible emissions mitigations systems is essential in minimizing the secondary emissions of potentially harmful compounds and diminishing the environmental impacts of CO_2 capture facilities.

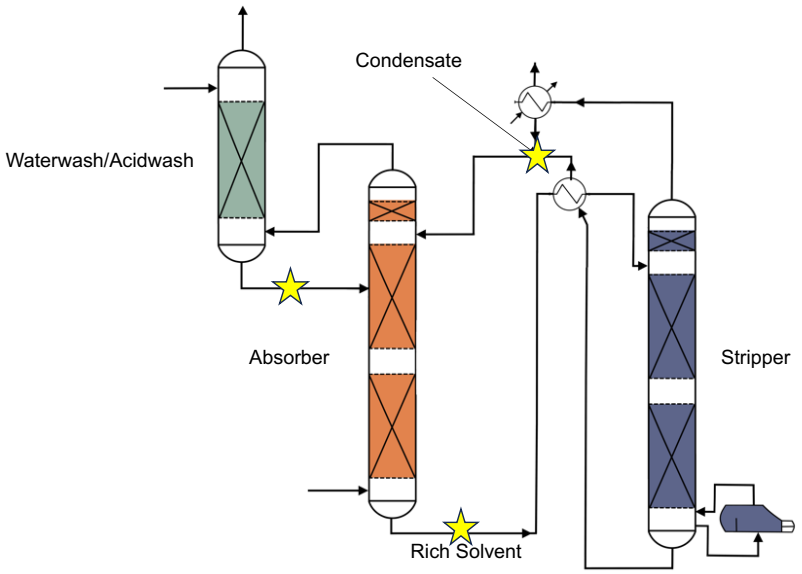

Fig. 1. Primary process streams in a conventional CO_2 capture plant identified for the targeted neutralization of VOCs

Keywords: Amine degradation; Volatile Organic Compounds; N-nitrosamines; Aldehydes; Emissions mitigation