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The impact of solvent degradation products on operation and environment

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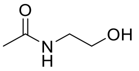
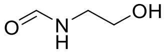
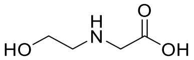
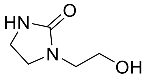
Abstract

Solvent degradation during the CO_2 capture process is known to reduce capture capacity, increase corrosivity, emissions and solvent toxicity, and complicate operation of the plant. The wide variety in degradation compounds include charged species, typically referred to as heat stable salt (HSS), amides, acids, nitrosamines, small volatile organic compounds, ammonia, and more. To prolong the time in operation of an amine solution, solvent management strategies are implemented in the large-scale process, where thermal reclamation is among them. Thermal reclamation is typically performed by first adding sodium hydroxide (NaOH) to the degraded amine solution, prior to distillation of the solvent.[1–3] This is meant to hydrolyse the amides and recover non-degraded amine and an organic acid, hence reduce the loss of amine in the reclaiming process. Other degradation compounds, such as some nitrosamines are known to decompose to their corresponding amines at the elevated temperatures, either of the reclamation process itself, or even at stripper conditions.[4]

In this work we are performing alkaline hydrolysis and thermal stability testing of individual, known degradation compounds of ethanolamine (MEA). This is done inspired by the procedures described by Closmann et al. 2009[5] and, Freeman and Rochelle 2012 [6], by mixing 1 part 5 M NaOH (*aq.*) to solutions with 1 part of a solution with MEA degradation compounds, such as the species shown in *Table 1*. The mixtures are then left at room temperature for 24 hours, and then heated to 140°C for 24 hours, and the composition of each solution is measured by LCMS before and after each treatment. The experiments will also be performed with fresh MEA and MEA that has been used and degraded in the SINTEF cyclic solvent degradation rig (SDR)[7,8], where more amides than those for which pure, individual standards were purchased. It is assumed that reactions analogous to that given in *Scheme 1* will take place during the experiments, meaning that we should see both an increase in MEA, and possibly organic acid, as well as a decrease in amide concentrations. The experimental work will be extended to the CESAR1 solvent and its components once its degradation chemistry is better understood and analytical methods for its degradation products are in place.

Table 1: MEA degradation compounds tested under alkaline hydrolysis conditions.

CAS-number	Abbreviation	Name	Structure
142-26-7	HEA	*N*-(2-hydroxyethyl)-acetamide	
693-06-1	HEF	*N*-(2-hydroxyethyl)-formamide	
5835-28-9	HEGly	*N*-(2-hydroxyethyl)-glycine	
3699-54-5	HEIA	1-(2-hydroxyethyl)-2-imidazolidinone	

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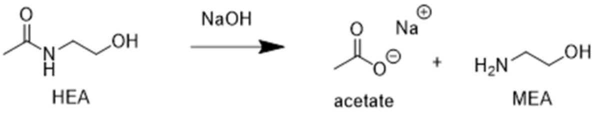
Scheme 1: Hypothesised alkaline hydrolysis reaction of the MEA degradation product HEA, upon addition of NaOH.



With the results from these experiments, as well as a review of the available literature on degradation, toxicity, and volatility of amine degradation products, we are categorising degradation products according to their impact on the operation of the process, as well as on safety, and environmental impact. The results of this study will contribute to a deeper understanding of the chemistry of the reclamation process, as well as giving an insight into what one should focus on in the process, which compounds to keep an eye out for, and which are less threatening to the operation and safety of the CO_2 capture process. This in turn brings us closer to designing more targeted solvent management strategies, that aim to combat the actual problematic compounds in the process and reduce unnecessary solvent management based more on general assumptions on solvent behaviour rather than a deep understanding of the process chemistry.

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2) The AURORA project, which has received funding from the European Union’s Horizon Europe research and innovation programme under grant agreement No. 101096521. https://aurora-heu.eu/

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