IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

SO_2 Influence on MEA Degradation in CO_2 Capture Absorption-Regeneration Process: Corrosion Impact on Oxidative Degradation

Loris Baggio[a]*, Grégoire Léonard[a]

[a] *Université de Liège, 4000 Liège, Belgium*

Abstract

Carbon capture technologies have become essential in our climate mitigation strategy as atmospheric CO_2 concentrations continue to rise. The IPCC has identified carbon capture and storage (CCS) as indispensable for achieving the Paris Agreement's temperature stabilization targets, particularly considering the EU's 2050 carbon neutrality commitment.

Among carbon capture technologies, the absorption-regeneration one using amine-solvent is a widespread technology known for almost a century [1], even if the interest for this technology in the climate change context is above 30 years [2]. However, this technology still requires improvements, especially regarding solvent management related to the various degradation mechanisms that occur with the amine component of the solvent used. Among these solvents, one of the most well-known is monoethanolamine (MEA), typically dosed at 30% by mass in water. Numerous degradation products, as well as their mechanisms, have already been identified regarding aspects related to both thermal degradation and oxidative degradation of MEA [3], [4], [5]. In addition to this type of degradation, other pollutants present in most of the flue gases could have serious impacts on the solvent, which is the case for SOx and NOx. Indeed, NOx, reacting with amine (and especially DEA present as an impurity in MEA) will form nitrosamines and nitramines which are known carcinogens, even at very low concentrations. On the other way, SO_2 is known to form Heat Stable Salt (HSS) via reaction between protonated MEA and the dissolved sulfate anion SO_4^{2-} [6]. Moreover, another specificity of SOx and NOx is their corrosion impact on steel equipment. Following the work of Lamprou et al. [7], NOx and SOx contaminants have particular effects on corrosion behaviors of stainless-steel in MEA solutions. This corrosion will lead to the release of metal cations in the solvent which can cause an acceleration of oxidative degradation kinetics due to the catalytic effect caused by these cations [8].

In this work, we evaluate both impacts of SO_2, knowing the reaction with MEA but also its corrosion effect, to develop a kinetic model. Using the Degradation Test Rig (DTR) developed by Léonard et al. [9], different gas conditions are used. Indeed, based on a 72h test with accelerated degradation conditions, it is possible to find similar degradation

---

* Corresponding author. Tel.: +32-475-232981
E-mail address: loris.baggio@uliege.be

products obtained after several months on pilot-scale structures. Accelerated conditions include temperature (120 °C), pressure (4 barg) and agitation speed (700 rpm) in a semi-batch reactor containing around 300 mL of MEA solvent. A diagram of the DTR is shown in Figure 1, where the 4 gas lines can be seen, as well as the main pieces of equipment, while pictures of the DTR are shown in Figure 2.

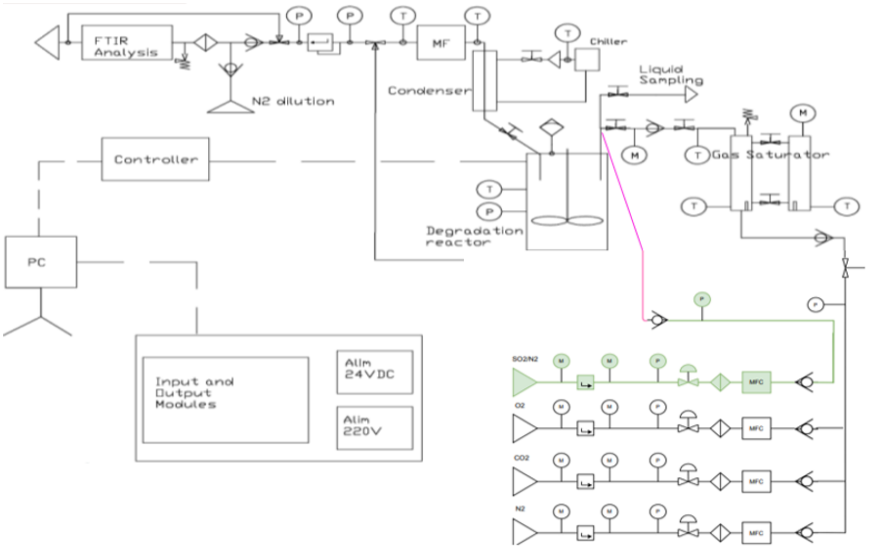

Figure 1:Diagram of the Degradation Test Rig

After 3 days of experiments, samples are analyzed through different analytical devices including HPLC-RID, GC-FID, and ICP-OES. HPLC enables the measurement of MEA concentration in different samples taken throughout the experiment, while GC enables to have the different degradation products present in the liquid sample. The ICP is used for analyzing the metal concentration of Fe, Cr, Cu, and Mn ions in the solvent, whatever their complexation state. The main identified oxidative degradation products are NH_3 (gaseous emission), HEI, HEIA, HEPO and OZD (in the solvent). The impact of SO_2 on those will be studied as a priority.

Figure 2: Degradation Test Rig

Based on those conditions, an initial CO_2-loaded MEA solvent went from 30 %-mass. to 24 %-mass. showing the degradation of 20 % of its initial MEA content, when it is submitted to a gas mixture of 5 %-vol. O_2, 15 %-vol. CO_2, and 80 %-vol. N_2. This concentration was measured 3 times by using HPLC and performing at the same time a calibration with precise MEA-H_2O mixture with a concentration range from 0 to 30 %-mass. This degradation experiment was set as the base case for experimental planning describe below. Currently, GC-FID calibration is made for the main degradation products described above to compare with previous studies [3], [4] in order to have relevant data for studying the SO_2 impact. An example of GC-FID spectra completed during the PhD thesis of Léonard [4] is shown below for a base case at 400 rpm during two weeks of experimentation with the above-mentioned gas mixture.

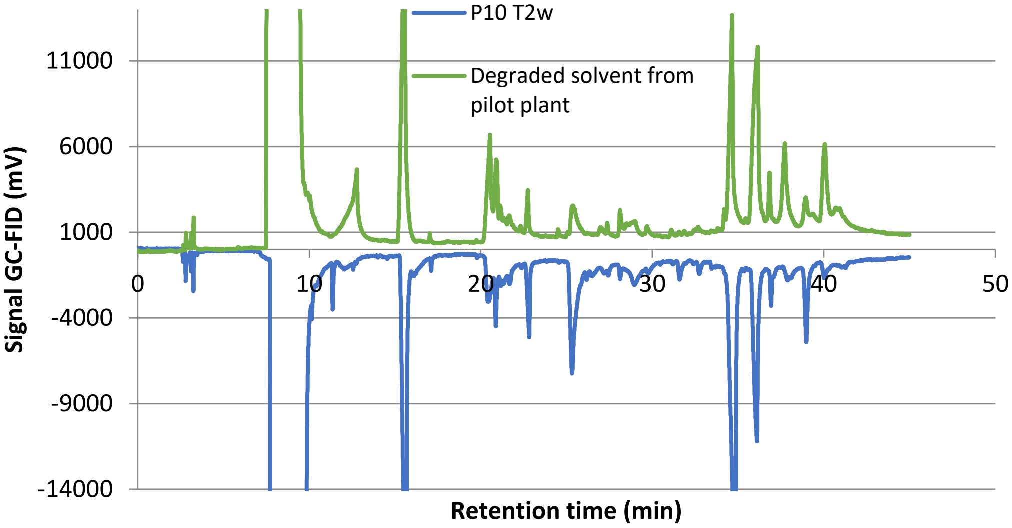

Figure 3: GC spectra from MEA degradation [4]

To analyze the corrosion effect, three similar experiments are performed first in a stainless-steel reactor (316L) and then in the same reactor with Teflon coating to lower the contact with metal. The SO_2 concentration is varied between 0 and 150 ppm, while the CO_2 and O_2 concentrations in the feed gas are maintained at 15% and 5% respectively, with N_2 used as a balance gas to reach 100%, knowing that each experiment follows the same procedure as described above.

Future work will expand these experiments across different temperatures and O_2 concentration to develop kinetic models that can predict MEA degradation due to SO_2 into simulation model for industrial CO_2 capture plants using amine-based absorption-regeneration processes.

This abstract is supported by the Walloon Region as part of the HECO2 – Saturn project financed by European Union.

References:

[1] R. R. Bottoms, ‘Process for separating acidic gases’, US1783901A, 1947
[2] ‘Norway’s Sleipner: Where CO2 has been buried in the rock since 1996’, Vattenfall. Accessed: Mar. 17, 2025. [Online]. Available: https://group.vattenfall.com/press-and-media/newsroom/2024/norways-sleipner-where-co2-has-been-buried-in-the-rock-since-1996
[3] H. Lepaumier, ‘Etude des mécanismes de dégradation des amines utilisées pour le captage du CO2 dans les fumées’, PhD Thesis, 2008. [Online]. Available: http://www.theses.fr/2008CHAMS038
[4] G. Léonard, ‘Optimal design of a CO2 capture unit with assessment of solvent degradation’, PhD Thesis, Université de Liège, Liège, 2013. Accessed: Sep. 12, 2023. [Online]. Available: https://orbi.uliege.be/handle/2268/152320
[5] L. Braakhuis, ‘Development of Solvent Degradation Models for Amine- Based CO2 Capture’, PhD Thesis,

Norwegian University of Science and Technology, Trondheim, 2024. [Online]. Available: https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/3118629

[6] G. Puxty *et al.*, ‘A Novel Process Concept for the Capture of CO2 and SO2 Using a Single Solvent and Column’, *Energy Procedia*, vol. 63, pp. 703–714, 2014, doi: 10.1016/j.egypro.2014.11.078.

[7] E. Lamprou *et al.*, ‘Effect of NOX and SOX Contaminants on Corrosion Behaviors of 304L and 316L Stainless Steels in Monoethanolamine Aqueous Amine Solutions’, *Coatings*, vol. 14, no. 7, p. 842, Jul. 2024, doi: 10.3390/coatings14070842.

[8] C. Sun, S. Wang, S. Zhou, and C. Chen, ‘SO2 effect on monoethanolamine oxidative degradation in CO2 capture process’, *International Journal of Greenhouse Gas Control*, vol. 23, pp. 98–104, Apr. 2014, doi: 10.1016/j.ijggc.2014.02.010.

[9] G. Léonard, D. Toye, and G. Heyen, ‘Relevance of accelerated conditions for the study of monoethanolamine degradation in post-combustion CO_2 capture’, *Can J Chem Eng*, vol. 93, no. 2, pp. 348–355, Feb. 2015, doi: 10.1002/cjce.22094.

Keywords: MEA, oxidative degradation, SO_2, corrosion