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Aerosol and volatile emissions control in an amine-based CO_2 capture plant

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Abstract

Post-combustion CO_2 capture (PCC) is critical for reduction of greenhouse gas emissions, particularly in hard-to-decarbonize industrial sectors, such as Waste-to-Energy (WtE). Amine-based technology has been implemented for capturing CO_2 from several types of flue gas sources. CO_2 capture, using aqueous 30wt% monoethanolamine (MEA) is considered as the benchmark technology [1], and is also being used at pilot scale at Twence, a WtE plant located in the east of The Netherlands. Twence has formulated a multi year development roadmap based on three pillars: (1) Renewable energy generation, (2) Circular economy by closing energy and material loops and (3) Biobased economy by production of materials from biogenic waste streams. PCC can act as a bridging technology since it improves CO_2 footprint of CHP and can act as a building block molecule for production cycles. Thus, Twence has been a first mover in accelerating WtE PCC. This year, it has secured funds to build a CO_2 capture plant with capacity to produce 100 kilotonne of CO_2 per year.

The CO_2 capture pilot used in this study was commissioned in 2014 [2], and has been operational since then. The pilot treats ca. 1.5 vol% of the flue gas from Twence's waste incinerator line (ca. 3300 Nm^3/h), and produces up to 500 kg/h of CO_2. Part of the CO_2 is used to produce sodium bicarbonate, which is in turn used in the flue gas de-sulfurization process. The remainder of the CO_2 is purified, liquified, and sold for external use (e.g., as food-grade CO_2 in the horticulture sector), see Figure 1. Since 2018, it operates with 30 wt% monoethanolamine (MEA).

There are economic and environmental challenges associated with the wide spread implementation of PCC. Emission of aqueous amine solvents, not only increases the environmental impact of PCC, but also leads to higher operating costs. The volatile nature of amines contributes to emissions and observed MEA emissions in the treated flue gas at pilot plant operations are typically either below 10 mg/Nm^3 or in the range of 100–1500 mg/Nm^3 [3]. The high emission range is caused by aerosol-based emissions, and is significantly higher than the emission limit of 15 mg/Nm^3 proposed at the TCM plant [4]. Traditionally, water wash and demisters are used as emission management techniques. But these counter measures are not sufficient for mitigating aerosol-based amine emissions, which are caused by the presence of aerosol particles in the gas, with diameter below 5 µm [3]. The most mature technology (TRL7) for controlling aerosol-based amine emissions is the Brownian Demister Unit (BDU), a filter capable or removing small particles from the flue gas [3]. While the BDU was used at different campaigns at the TCM pilot plant, the publications on those campaign focus on reporting the efficiency in particle removal, but fail to report on the impact on amine emissions reduction [4], [5].

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The Twence pilot plant is equipped with a water wash column. In 2021, it was also equipped with a BDU. Amine emission measurements performed with a Fourier Transform Infrared Spectrometer (FTIR) shortly after the installation of the BDU confirmed the technology's efficacy: the MEA emissions dropped from around 750 mg/Nm^3 (average over 1 hour) to 2.7 mg/Nm^3 (average over 2 hours), when the BDU is used to filter the gas inlet to the absorber. The number concentration of aerosol particles, measured with an Electrical Low Pressure Impactor (ELPI), dropped from where in the order of magnitude of 10^6 cm^{-3} at the BDU inlet, and was reduced to 10^3 cm^{-3} at the BDU outlet. These results were already presented in our previous publication [6].

Figure 1. Schematics of Twence's CO_2 capture pilot plant

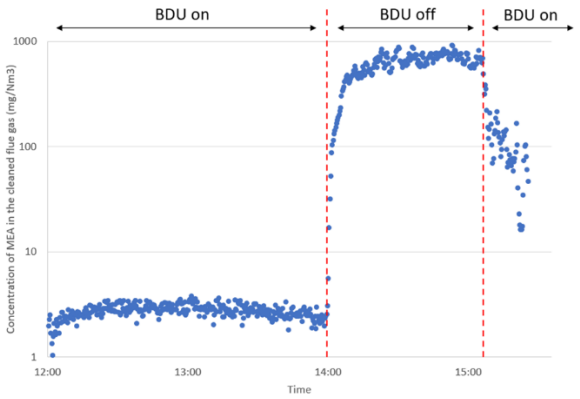

Figure 9 – MEA emissions at the pilot with and without the BDU, March 2021

The transnational project SCOPE (Sustainable OPEration of post-combustion Capture plants, ACT 3 Project No 327341) aims to remove barriers to CCUS deployment and accelerate large CO_2 capture projects by giving plant operators, regulators and decision makers access to the tools and data that are essential for improving our understanding of emissions of amine-based CO_2 capture plants (and their fate). Within this context, TNO will perform additional tests at the Twence pilot plant facility, to generate more data on volatile and aerosol-based emissions, as well as on the long-term performance of the BDU. The new data and insights will be presented at GHGT-16.

Keywords: emissions; amine; CO2 capture; brownian demister unit

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