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Carbon capture demonstration at Irving Oil Whitegate Refinery

Eirini Skylogianni[a,*], Roberta Veronezi Fugueiredo[a], Juliana Monteiro[a], Solrun Johanne Vevelstad[b], Andreas Grimstvedt[b], Kai Vernstad[b], Niamh Callanan[c]

[a]TNO, Leeghwaterstraat 44, 2628CA Delft, the Netherlands
[b]SINTEF Industry, P.O.Box 4760 Torgarden, NO-7465 Trondheim, Norway
[c]Irving Oil Whitegate Refinery, P25 HD93 Cork, Ireland

Abstract

The refining industry is a highly energy-intensive sector with direct CO_2 emissions varying from 100 to 200 kg CO_2/tonne oil. Primary challenge related to CCUS lies in having several relatively small sources with various levels of CO_2 concentration, from which CO_2 must be captured. To address this challenge, the REALISE project[1] was initiated with the goal to demonstrate a Refinery-Adapted Cluster-Integrated Strategy to Enable Full-Chain CCUS Implementation, through the integration of a multi-absorber concept for capturing CO_2 from different stacks[2]. Within REALISE, CO_2 capture technology will be demonstrated at Irving Oil Whitegate Refinery using TNO's mobile pilot plant and the novel HS-3 solvent.

TNO's mobile plant has been developed in order to demonstrate CO_2 capture solutions, allowing for the testing of different types of solvents, solvent management technologies as well as emission mitigation strategies. The mobile plant is fully automated allowing for continuous operation and it has been operated using both synthetic flue gas in the lab and real flue gases at various industrial sites. It has a capture capacity of 25 kg CO_2/day and is equipped with a quench for flue gas conditioning and removal of impurities (i.e. SOx) as well as water washes in both absorber and stripper top for water balance and amine losses control. Along with that, the operation in a refinery environment must fulfil the requirements for use in potentially explosive atmospheres (ATEX directive). Therefore, the pilot plant has been modified to become ATEX-compliant by being placed inside an ATEX-certified container. During the operation, the pilot plant will be operated continuously and it will be controlled remotely by TNO.

Irving Oil Whitegate Refinery is located in Cork, Ireland. There are 15 emission points in the refinery, 6 of which were selected in the project to capture CO_2 from. The main selection criteria were three: their distance between the stack and pilot plant's location inside the refinery, the number of impurities and, most importantly, their CO_2 content. The combined emissions of the selected stacks comprise 84% of the total CO_2 emissions of the refinery. Regarding impurities, the flue gas from the selected stacks includes various concentrations of particles, SOx, NOx and CO_2 in order to stress-test the performance and chemical stability of HS-3 solvent.

HS-3 solvent is a novel solvent developed in HiperCap project[3,4] and optimized within REALISE in order to be used in the demonstration activities. It is an aqueous mixture of 40wt% of 1-(2-Hydroxyethyl)pyrrolidine (CAS: 2955-88-6) and 15wt% of 3-amino-1-propanol (CAS: 156-87-6). The solvent has been tested and brought to TRL 5 in a short-campaign with the pilot plant at TNO's premises in the Netherlands in order to determine the operation parameters (L/G ratio, stripping pressure, temperature profile etc.) for the different flue gases met at the refinery, and, overall, de-risk the operations during the demonstration.

* Corresponding author. Tel.: +31-06-2531-2940, *E-mail address:* eirini.skylogianni@tno.nl

The demonstration is planned to start in January 2022 with an 8-month duration. It will consist of six campaigns, five short ones of 4 weeks' duration each, and, in the end, one longer campaign of 12 weeks' duration. In the latter, the stack with the highest CO_2 concentration will be used in order to maximize the impact of the CO_2 capture activities. Prior to the campaigns, TNO will measure the amount of particles using an ELPI (Electrical Low Pressure Impactor) and the flue gas composition using an FTIR (Fourier-Transform Infrared Spectroscopy), in order to get updated information on the flue gas characteristics. In the course of the demonstration activity, samples will be taken twice a week. The amine concentration and CO_2 loading in the solvent samples will be followed via a mini-ATR (Attenuated Total Reflection), while emission levels will be constantly monitored by an FT-IR located downstream the absorber water wash. On a weekly basis, the samples will be transported to the advanced mass-spectrometry lab at SINTEF (MS lab), Norway, where further analysis will be performed in terms of degradation products using LC-MS (Liquid Chromatography–Mass Spectrometry), as well as metal content using ICP-MS (Inductively Coupled Plasma-Mass Spectrometry). In this way the stability of the solvent and potential corrosion in the pilot plant will be monitored and evaluated along the campaigns by SINTEF and TNO, in order to decide if and when a solvent management technology should be added in the process. The two solvent management technologies that will be assessed are a) DORA (Dissolved Oxygen Removal Apparatus) [5], and IRIS (Iron Removal In-Situ), both aiming at reducing solvent degradation.

This work will present the results of the demonstration campaigns at Irving Oil Whitegate Refinery and provide data on solvent performance and solvent management at the industrial setting of a refinery.

Keywords: post-combustion carbon capture; demonstration; pilot campaign; refinery; HS-3 solvent

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