PILOT-SCALE TESTING OF AL-MOF FOR POST-COMBUSTION CO_2 CAPTURE AT TECHNOLOGY CENTRE MONGSTAD (TCM)

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Carbon capture and storage (CCS) or Use (CCU) has emerged as a leading approach for CO_2 mitigation, particularly in carbon-intensive for achieving net zero emissions by 2050. However, the current amine-based absorption process has limitations such as high energy demands and solvent degradation. CO_2 separation by adsorption is a promising alternative due to potential lower energy consumption and reduced environmental impact. Although extensive lab-scale studies highlight the potential of MOFs for CO_2 capture, industrial-scale application remains limited, and the effects of real operational conditions on factors like productivity, purity, and energy consumption are not yet fully understood.

Addressing the issue, a consortium of 14 partners from 8 different countries has collaborated to establish the MOF4AIR project. The initiative aims to develop and demonstrate the performance of promising MOF materials in post-combustion CO_2 capture contexts. Technology Centre Mongstad (TCM) is one of the three selected demonstration sites to test the MOF-based CO_2 capture technology at industrial scale as part of the MOF4AIR project.

The Vacuum Pressure Swing Adsorption (VPSA) demonstration pilot setup at TCM is designed to treat 50 to 100 Nm^3/h of flue gas coming from a residual fluid catalytic cracking unit (RFCC) or from a steam boiler (Mongstad heat plant (MHP)). The VPSA pilot includes (i) a scrubber, (ii) a dryer unit, (iii) a contaminants removal unit, and (iv) the MOF section, which comprises three 41 L columns filled with 55 kg of pelletized MOF MIL-160(Al) $Al(OH)(O_2CC_4H_2OCO_2)$) [1-2] provided by MOFTech. The VPSA pilot operates a 6-step cycle composed of an adsorption step, heavy reflux, co-current evacuation, counter-current evacuation, light reflux and light product pressurization [3].

This VPSA demonstration unit was firstly optimized with a simulation model developed with the results obtained with the laboratory scale VPSA pilot using an aliquot of the sample [4]. Optimization of the VPSA unit using a genetic algorithm (NSGA-II) was performed to maximize purity and recovery while minimizing energy consumption [5].

Performance tests were carried out based on an experimental plan derived from VPSA simulations. Various VPSA adaptations were tested to improve CO_2 recovery and purity. During the test campaign, parameters such as co-current evacuation time, co-current flow rate, and counter-current flow rate were found to significantly influence the adsorption process. However, achieving the target levels for CO_2 capture and purity has been challenging, with fine-tuning hindered by the process's inherent complexity.

The VPSA unit was extensively modified to enhance performance. After more than one year of tests and improvements, current results indicate solid overall performance of both the VPSA system and the plant's operational flow. The maximum CO_2 purity achieved was 95.6 ± 3.6 % with a recovery of 91.1 ± 0.3 % and with an energy consumption of 743 ± 12.2 kWh/ton. The data was calculated based on a 2-hour operating period representing 35 consecutive cycles.

The results from the TCM site demonstration reach the project objectives with a recovery higher than 90% and a purity higher than 95% and demonstrates the feasibility of using MOFs in a post-combustion CO_2 capture process.

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