**Phase-Change Solvents For CO2 Capture: Sustainability Aspects.**

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**Highlights**

* Sustainability assessment should be considered already during solvent selection
* Assumptions will significantly influence the results of the assessment
* Extra equipment might be required to guarantee safety of the workers

**1. Introduction**

2°C warming scenario requires widespread adoption of efficient carbon capture and storage technologies. Post-combustion CO2 capture by chemical absorption is the most mature of existing ones. However, high energy requirement and associated costs of the capture process hinder the technology’s diffusion and large-scale employment. Phase-change solvents is a novel solution to an energy penalty problem of post-combustion CO2 capture. At certain temperatures the solvents generate two phases and one of them is recycled back to the absorber reducing the input to the energy-intensive stripping process.

While the improved performance processes using phase-change solvents are proven by various studies [1], [2] there is limited research done on the environmental and health aspects of such processes. Many of the phase-change solvents are new molecules with no or very limited occupational safety and health information that makes it challenging to perform a sustainability assessment. Potential hazards linked to the process use of the harmful molecules affect the cost and design of the process and need to be considered already during the selection of solvent.

**2. Methods**

The analysis was done with the help of literature study and a holistic method combining life cycle (LCA) and environmental, health and safety assessments (EHS). During the literature study problems associated with process use of CO2 capture solvents were gathered and evaluated in terms of applicability to phase-change solvents. Additional challenges were also thought through. Since there is no data on industrial use of phase-change solvents, different scenarios and assumptions were generated to anticipate the different behavior of the system in terms of solvents loss and process specific hazards such as products of solvent degradation and volatile emissions.

**3. Results and discussion**

Two phase-change solvents were used for the study: MCA (N-methylcyclohexanamine), and a novel solvent S1N. The molecules are structurally similar chemicals, however MCA is a more volatile and S1N- more soluble in water. LCA impact of solvent manufacturing is lower for S1N solvent. EHS values for the chemicals are close, but MCA has worse S (safety) and H(health) values due to higher mobility of the chemical, whereas S1N performs worse in E (Environment) category. Losses of the solvent during the capture process due to degradation, aerosol formation and vaporization and energy consumption of the process are the main contributors to the LCA impact in such categories as global warming potential, cumulative energy demand and ReCiPe endpoint indicator at the process level. The overall impact is highly influenced by the assumptions discussed below.

Due to low vapor pressure and high solubility in water S1N is expected to have the lowest loss of the solvent during the process operation [2]. It is more difficult to estimate loss of the solvent due to aerosol formation. It has been reported that aerosol formation can increase the emissions by 1-2 orders of magnitude if left uncontrolled [3]. Study performed by [4] states that substantial amine loss via aerosols can occur even for low volatility solvents, thus to recover and remove the significant part of the MCA and S1N solvents from the gas leaving to the atmosphere and control the escape of solvent degradation products a wash section was added to the process sheet.

Another complex phenomenon difficult to estimate is solvent degradation. MCA is a secondary amine, therefore expected to degrade significantly in presence of oxygen. MCA reported to degrade 1.5-3 times more than MEA [2]. To estimate the oxidative degradation potential of S1N, degradation data on structurally similar compounds was used for calculation. Thus, it was assumed that the degradation rate is 3-10 times of MEA. It is reported that a product of oxidative degradation for MCA is ammonia [2], S1N might also produce a different degradation compound, allylamine. Scenarios considered cases of 85% and 65% of degradation products being volatile and the rest - heat stable salts (HSS) for MCA and vice versa for S1N, since it is believed that the majority if the S1N degradation products will stay in the liquid phase. Phase-change solvents can be recovered at lower temperatures; therefore the thermal degradation is expected to be generally lower than for systems using MEA.

During the capture with phase-change solvents part of the process stream is recycled back to the absorber and some part of the degradation products formed in the absorber including dangerous to health substances like nitrosamines, can follow the stream back to the absorber avoiding their removal in the reclaimer and also the thermal process of stripping responsible for partial destruction of the hazardous substances [5]. Additional safety measures and an extra reclaiming point might be required.

**4. Conclusions**

There are several aspects of the CO2 capture of the process using phase-change solvents that can significantly influence the result of sustainability assessment. Extra equipment might be required to guarantee safety of the process. This will lead to added costs and should be considered already during the solvent selection and early design phase of the carbon capture process.

**References**

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