IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

Biological contamination in direct air capture systems

Keemia Abad[a,b], Jenna Roseman[a,c], Xin Gao[a], Kunlei Liu[a,d], Jesse G. Thompson [a,b]*

[a]University of Kentucky, Institute for Decarbonization and Energy Advancement, Lexington, KY 40507
[b]University of Kentucky, Department of Chemistry, Lexington, KY 40506
[c]University of Kentucky, Martin-Gatton College of Agriculture, Food and Environment, Lexington, KY 40508
[d]University of Kentucky, Department of Mehanical and Aerospace Engineering, Lexington, KY 40506

Abstract

Direct air capture (DAC) is a proven method for removing CO_2 directly from the atmosphere, which in combination with other carbon capture technologies can help achieve decarbonization goals. There are various methods to capture CO_2 using DAC including sorbent-based, membrane-based, and solvent-based systems. While each method has its own advantages and disadvantages, all DAC systems rely on the intake of ambient air remove carbon from the atmosphere, whose contents are highly variable across time and space. While high energy input, regeneration costs, and economic viability are important considerations that need to be made when implementing DAC systems, little information is available on the risks of contamination within these systems. As a result, careful consideration for the potential of biologic contaminants that could infiltrate and contaminate DAC systems needs to be made. Biological contamination can lead to the interruption of operations for maintenance and fouling of equipment on both the capture and regeneration sides, thereby raising costs and lowering efficacy.

The University of Kentucky (UK) Institute for Decarbonization and Energy Advancements (IDEA) DAC system operates with a hybrid absorber using sprayed aqueous potassium hydroxide featuring a multifunctional demister for absorption coupled with an electrochemical regenerator for solvent regeneration, while also producing hydrogen (H_2) to offset the DAC cost. The UK IDEA developed DAC technology will tie in directly with intermittent renewable power sources, including solar, wind, and hydro, to facilitate negative emissions and demonstrate load-response capability. During capture, the solvent is introduced as a spray onto a multifunctional catalyzed demister absorption surface. By using a catalyzed surface, bicarbonate formation and rich solvent loading are augmented leading to enhanced capture performance and reduced energy costs. After capture the CO_2 loaded solution is pumped to a flow-through type electrochemical regenerator using catalytic electrodes and a cation exchange membrane to regenerate the solvent, release CO_2 and produce H_2. While the stability of the system components has been studied, little research exists regarding the impacts of potential biological contaminants from the atmospheric air.

Biological contaminants in the air include, but are not limited to bacteria, fungal spores, pollen, plant matter, insects, and dust, the presence of which depends on the location. Any accumulation or growth of these contaminants in the solvent and system can lead to lower capture efficiency, clogging of solvent spray, and fouling of the electrochemical regenerator. Therefore, understanding the composition and impacts of these biological contaminants presents a more concrete understanding of the DAC system operation while providing insight on the importance of placement and filtration considerations when constructing and maintaining these systems and maintaining these systems.

---

* Corresponding author. Tel.: 1-859-257-0355; *E-mail address:* jesse.thompson@uky.edu

In this work, the collection and evaluation of biological contaminants were evaluated over 1500 hours of operation in a small-scale DAC system. During operation, a variety of biological contaminants were identified and collected including plant matter, insects, bacterial and fungal spores. The initial results showed that there is a strong potential for contamination in DAC systems by common airborne particulates and small invertebrates during continuous operation if proper filtration is not implemented. It was also noted that the majority of contamination, by weight, was smaller than 0.45 um which is important in understanding the limitations/efficacy of potential filters. These observations will help guide the construction and operation of DAC system to ensure solvent and equipment longevity as well as preventing the fouling of the electrochemical regenerator. This guidance can help minimize operational downtime to ensure maximum capture potential. The evaluation of these biological contaminants will not only ensure efficient operation of the UK IDEA's DAC but also helps provide a framework for considerations to be made in the construction of more efficient DAC systems in general and more accurate cost analysis.

Keywords: Direct Air Capture; Biological contamination; Solvent fouling