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Adsorption of CO_2 using biochar - Review of the impact of gas mixtures and water on adsorption

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ABSTRACT

Biochar produced from sources such as forestry, agricultural, and marine wastes has demonstrated an ability to adsorb CO_2. The adsorption capacity is a function of biochar surface properties, which subsequently depend on biochar feedstock and production conditions. This is a comprehensive review on the use of biochar as a carbon capture adsorbent with a particular focus on the impact of the properties of biochar and feed gas composition CO_2 adsorption. Applying biochar in carbon capture at the industrial scale requires detailed knowledge of the impact of co-adsorption effects of other gases. This is particularly true of water, biogas, syngas, and other gas streams. The study of these impacts is diffuse across the literature, where only one other gas is typically studied. This review brings these studies together to give a comprehensive picture of the impact of gas mixtures as a function of biochar properties on carbon capture. This review highlights the limited study in this area, where the bulk of research work is focused on gas mixtures, demonstrating more work is required on this topic. Examining biochar affinity toward various gases can also indicate if biochar has potential applications in gas separations to recover gases such as H_2. Articles focused on H_2 purification from gas mixtures using carbon-based adsorbents are also studied. This review indicates the potential for biochar to separate H_2 from syngas, particularly using biochar produced during gasification to then purify syngas, making it a closed-loop system.

1. Introduction

Mitigation of carbon dioxide (CO_2) emissions involves both minimization and capture/sequestration [1,2]. The overall goal of carbon capture, sequestration or storage is carbon neutrality or carbon negativity [2]. However, in the development of any CO_2 capture process, the nature of the gas mixture must be considered as CO_2 is rarely produced as a single component gas but rather as a gas mixture. In addition, combustion, syngas, and other CO_2-rich exhaust gases are typically rich in water vapor, which could change the properties of the biochar surface and/or the adsorption behavior of CO_2.

Post-combustion gas streams from fossil fuel/biomass combustion consist of CO_2 and N_2, with varying amounts of volatile organic compounds (VOCs), H_2O, O_2, CO, sulfur oxides (SOx), and nitric oxides (NOx) [3,4] depending on the fuel source and combustion conditions [3]. In addition to the combustion of fossil fuels and biomass, gasification is becoming increasingly used in fuels [5]. Gasification product gases are dominated by H_2, CO, CO_2, CH_4, and lower weight hydrocarbons where the composition depends on the biomass feedstock and gasification conditions [6,7]. For instance, if the air is the gasifying agent, a large amount of N_2 is present in the syngas resulting in lower concentrations of other components [7]. A summary of some syngas compositions from different gasification processes is presented in Table 1 as an example of how CO_2 is always emitted with other gases. Since gasification is becoming increasingly used in fuels, the heating value is also an important characteristic of the produced syngas. The syngas heating value is determined by the oxidizer used for the gasification step. Air, which is the least costly option, produces the lowest heating value syngas (4–7 MJ/Nm^3), whereas oxygen as the oxidizer produces the highest heating value syngas (12–28 MJ/Nm^3) [8]. Therefore, the heating values of the syngases have been reported in Table 1 as well. Another source of CO_2 release is biogas from anaerobic digestion of the organic waste. Biogas can be used as fuel and is typically a mixture of around 50–75% of CH_4, 25–50% of CO_2, 2–8% N_2, and smaller amounts of gases such as H_2S, NH_3, H_2, and other volatile organic compounds [9]. This review focuses on the impact of the gases

Abbreviations: BET, Brunauer–Emmett–Teller; FTIR, Fourier transform infrared.

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