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Carbon dioxide removal through physical adsorption using carbonaceous and non-carbonaceous adsorbents: A review

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ABSTRACT

Recently, the catastrophe of global warming by virtue of carbon dioxide emissions has turned into paramount anxiety. To overcome this issue, various carbon dioxide capture and separation processes have been presented so far. Absorption and adsorption are promising methods for carbon dioxide removal, however, the energy penalty drawback of the absorption technology makes the adsorption using solid adsorbents is the prevailing technology nowadays. Adsorption technologies using solid adsorbents eligible for CO_2 removal from a gas mixture shown various potential features in comparison with other classic carbon dioxide removal using amine solvents. Thus, numerous groups of researchers have been involved in the modification of new solid adsorbents for carbon dioxide removal with high adsorption capacity and desired economics. Many promising physical adsorbents such as carbonaceous materials (activated carbons, carbon molecular sieve, carbon nanotubes, and graphene) and non-carbonaceous materials (Zeolite-based, silica-based, metal-organic framework materials) for capturing of carbon dioxide have been reviewed. The performance features of the solid adsorbents are evaluated in terms of some desired criteria such as CO_2 uptake, CO_2 selectivity, adsorbent regeneration, adsorption/regeneration kinetics, and durability. A comprehensive evaluation and analysis study of the literature on the physical solid adsorbents have been executed to update the new progress in this area. A brief comparison of some adsorbents at different stages is located. Finally, some recommendations have been presented for future research to advance the carbon dioxide capturing using physical solid materials.

1. Introduction

1.1. Climate change

Emissions of greenhouse gasses particularly CO_2 is the main contributor to climate change. This undesired impact considers serious challenging and urgent environmental problems facing the world. Increasing the population around the world results in rising the demand for energy which tuns in continuous emissions of carbon dioxide. The main reason behind the carbon dioxide emissions is human activities such as post/pre-combustion of fuels, agriculture practices, transportation, and industrial operations [1]. Many possible consequences can be presented such as ecosystems, floods, and droughts that will negatively impact future generations. The highest recorded amount of the released carbon dioxide to the environment was during the years of 2000–2010 0f 49 Gt; 78 % of this amount is from industry and the combustion of fossil fuels [2]. While, in 2014, the amount of carbon dioxide released was around 16 Gt only from coal uses [3]. Liu et al. [4] stated that the 500 Mw power plant using coal will release 3 million tons of CO_2 per year. The Scripps Institute of Oceanography reported that the CO_2 amount in the atmosphere elevated from 315 ppm from 1958 to 391 ppm in 2011 and almost 398 ppm in 2014. Later, it has been recorded that the carbon dioxide concentration was 400 ppm in 2016, 414.7 ppm in May of 2019, and it is expected to reach 500 ppm by 2050. Many studies have stated that carbon dioxide concentration in the environment should be alleviated in a range of 350 ppm–450 ppm [5]. Researchers presented many different technologies to capture CO_2 from other gases mixtures such as absorption, membranes, cryogenic carbon dioxide, and adsorption. The traditional absorption technology deploys single amines like MDEA, DEA, MEA, and TEA and mixed amines like PZ/MDEA, MEA/MDEA, SULFOLANE/MDEA, etc. to absorber carbon dioxide from other gases (See Fig. 1) [6–8]. The main

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