Chapter 9
Sustainable Cooling Research Using Activated Carbon Adsorbents and Their Environmental Impact

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ABSTRACT

Conventional vapour compression system is one of the most utilized cycles in refrigeration and air conditioning systems, due to its compact size, the relatively low running cost, the high coefficient of performance and the wide range of the operating temperatures. Nevertheless, the system suffers from the high initial cost and the high-energy consumption. Unlike the vapour compression cycle, adsorption heat pumps have the advantage of utilizing waste heat reducing the energy consumption and the carbon emissions. Activated carbon is a porous adsorbent material that can be efficiently used in low temperature adsorption refrigeration systems. This chapter reviews the recent developments in the compact adsorption cooling systems using activated carbon regarding the enhancement of the material properties, the design of the sustainable adsorption systems and their environmental and cost perspectives.

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INTRODUCTION

Air-conditioning systems in commercial buildings and households consume 15% of electricity produced. Such significant energy consumption leads to the depletion of fossil fuel resources and increasing the emissions of carbon dioxide and thus increasing the greenhouse effect. Adsorption refrigeration systems utilise waste heat from automobile exhaust gas, solar energy and process waste heat and can help in producing cooling effect without environmental harmful effects. So they are concerned to low global warming potential and zero ozone depletion potential. Although absorption cooling systems between liquid and vapour have become commercially available technology in the last few decades, they suffer from corrosion, toxicity and the potential crystallisation of the working fluids. In contrast, adsorption cooling between solid and vapour systems offers a number of advantages including the lower energy consumption without circulating pump, low temperature heat sources, and increased operation reliability due to reduced number of moving parts.

Activated carbon materials have been used with various refrigerants in adsorption systems. The activated carbon is mainly obtained by gasifying the char using an oxidizing agent and the raw material for wood and coconut shell. After gasifying, it exhibits high porosity and a high BET surface area of 500-3000 m^2/g and, therefore, is commonly used for low temperature (< 0 °C) cooling systems because of the properties of its high uptake, large surface area and pore volumes (Tamainot -Telto, & Critoph, 1996; Meunier, 1985; El-Sharkawy, Kuwahara, Saha, Koyama, & N*g,* 2006). Compared to activated carbon granular or powder, its fiber (ACF) has a larger surface area and more uniform pore structure but suffers from the high thermal contact resistance between the fibres and the heat exchanger surface (Yeo, Tan, & Abdullah, 2012). Modified activated carbon adsorbents have also been produced with composites (Wang, Wu, Wang, & Wang, 2006) or acid-treatment (Yeo, Tan, & Abdullah, 2012), enhancing uptake capacity as compared to their original form (Yang, 2003). The composites are formed through impregnating salts on the porous material for an enhanced performance (Aristov, 2007).

This chapter provides a comprehensive review of different classes of activated carbon used for refrigerants and their material characterisation, sustainable adsorption cycles, environmental impact of adsorption cooling and the cost performance are presented as compared to those of other systems in addition with their fundamentals of adsorption cooling systems. Also, the classification of activated carbon materials and their recent researches are reviewed in the point of view of sustainable adsorption cooling for the configurations and environmental concerns.

1. The first section introduces the fundamentals of adsorption cooling systems, the thermodynamic cycle analysis as well as the parameters used to assess their performance as Coefficient of Performance (COP) and Specific Cooling Power (SCP).
2. The second section describes the different techniques used to measure the properties of activated carbons for various refrigerants. In terms of adsorption kinetics, adsorption isotherms, the techniques used for their measurements and the models developed for the adsorption kinetics are explained.
3. The third section is concerned with sustainable cycle configurations used with activated carbons for low temperature cooling for enhancing heat recovery, mass recovery and cascading. Lastly adsorption systems were evaluated from environmental and economic perspectives.