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Highly effective asphaltene-derived adsorbents for gas phase removal of volatile organic compounds

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ABSTRACT

A novel nitrated asphaltene-derived adsorbent (Asf-Nitro) was prepared using facile isolation and modification procedures. The successful modification was confirmed by Fourier-transform infrared spectroscopy (FTIR). The nitrated adsorbent was evaluated in terms of dispersive and specific interactions, Lewis acid-base properties and adsorption isotherms by means of inverse gas chromatography (IGC). Nitration was found to be extremely effective in enhancing adsorption properties of asphaltenes towards variety of chemical compounds. Asf-Nitro adsorbent exhibits superior dispersive interactions ($197.50 \pm 1.12\,mJ\,m^{-2}$ at 423 K), as compared to unmodified asphaltenes, which are comparable with activated carbons, zeolites or alumina. Examination of the specific interactions revealed a shift from basic to acidic character of the surface, what will be beneficial for adsorption of alkaline gases. Additionally, adsorption isotherms revealed that developed surface properties of the Asf-Nitro results in more than doubled monolayer adsorption capacity. Obtained results demonstrates the applicability of the asphaltene-derived materials in adsorption processes as highly effective and low cost adsorbents. This studies revealed a highly effective adsorption of environmentally important VOCs, e.g. *n*-butanol (odorous compound), trichloromethane (chlorinated hydrocarbon) and benzene (carcinogenic).

1. Introduction

Volatile organic compounds (VOCs) are a large group of organic chemical compounds having vapor pressure of at least 0.01 kPa at standard conditions [1]. They are present as gaseous airborne chemicals and as chemicals adsorbed on solids (indoor surfaces, airborne particular matter) [2,3]. The effects of some groups of VOCs on human health as well as ecosystems [4] relate to number of acute or chronic hazards e.g.: cancer, allergies, respiratory and immune effects, central nervous systems dysfunctions, formation of tropospheric ozone and photochemical smog [5–7].

Apart from increased health risk and ecosystems deterioration, VOCs can be problematic even if their toxicity is not confirmed. Odorous compounds emitted from industries and landfills can decrease the quality of life and pose a problem for a company's image, since odors are commonly perceived as an indicator of harmful and toxic activity [8,9]. This issue is gaining particular importance due to development of both industrial and residential areas [10,11].

The issue of VOCs emission from anthropogenic sources is acknowledged and demand for VOCs emission control is increasing an enforcement of environmental legislations, e.g. European Union obliged member states to cut the emission of VOCs by 40% till 2030 [12]. Development of separation techniques is a part of remedial measures to reduce emission of VOCs.

Among the available technologies for removal of VOCs, adsorption-based processes proved their usefulness and effectiveness in purification and separation of gaseous streams [13,14]. Since the key parameter in adsorption processes is a type of adsorbent, the main developments in this field are focused on new adsorbents [15]. To replace commonly used activated carbon, zeolites, silica or polymers, new adsorbent must exhibit unique adsorption properties or/and its application must be economically feasible. Three main trends in the research on new adsorbents can be observed:

(1) synthesis of new types of adsorbents e.g. carbon nanotubes, graphene [16], molecular organic frameworks [17],
(2) development of low-cost activated carbon prepared from waste materials [18–20]
(3) direct application of natural materials as bio-adsorbents [21,22]

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