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Review

Development of sludge-based adsorbents: Preparation, characterization, utilization and its feasibility assessment

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ABSTRACT

The increasing generation of sludge and its subsequent treatment are very sensitive environmental problems. For a more stable and sustainable treatment of sludge, there have been many studies, including the conversion of sludge into sludge-based adsorbents (SBAs) for pollutants removal. In this review, current SBAs preparation conditions and use as adsorbent for contaminant removal in water treatment are summarized and discussed. Carbonization, physical activation and chemical activation are three common preparation methods. The controlling key parameters include pyrolysis temperature, dwell time, heating rate, activator and feedstock type. The efficacy of SBAs in contaminant adsorption depends on their surface area, pore size distribution, surface functional groups and ion-exchange capacity. It has been demonstrated that SBAs can attain high uptakes of dyes and metal ions due to their high cation exchange capacity; whereas the strong antibiotics adsorption performance of SBAs derives from high degree of mesoporosity. In addition, thermal treatment significantly stabilizes heavy metals contained in sludge. The paper also discusses the economic feasibility and environmental safety of preparation and application of SBAs. Further research will include investigations on the migration and transformation of element in sludge by thermal treatment, more economical and efficient chemical activation reagents, obtaining SBAs for designated application, combination of coagulation and SBAs adsorption, regeneration of SBAs and full-scale tests.

1. Introduction

Sludge is a byproduct of water and wastewater treatment processes and contains amounts of heavy metals, organic pollutants and pathogenic microorganisms. Three main kinds of sludge are sewage sludge, industrial sludge and waterworks sludge. Sewage sludge is a mixture of exhausted biomass generated from the aerobic and anaerobic digestion of the organic constituents in municipal/urban sewage and inorganic materials, such as sand and metal oxides. Industrial sludge includes wastes from industry sites whose composition varies widely from industry to industry (e.g. paper mill sludge contains plenty of lignocellulose, while the fertilizer industry sludge is rich in carbonaceous slurry). Waterworks sludge is mainly from the sedimentation tank or clarifier sludge water and filter backwash water, and amounts to about 4–7% of the total amount of water (Hossain et al., 2011).

Common options of sludge management include landfilling (Diamantis et al., 2013), application to farmland and forestry and thermal treatment, e.g. incineration. Agricultural use of sewage sludge has been the traditional approach for sludge treatment; however, sludge is rich of metals, pathogens and low concentration antibiotics, which are of primary concern in limiting its potential use as a fertilizer and may cause secondary pollution problems in the environment.

Sludge is carbonaceous in nature, and its conversion to adsorbents might be a promising way, not merely to ecofriendly solve the problem of secondary pollution, but also to allow its reuse in water treatment applications. In previous studies, many researchers (Bandosz and Block, 2006; Hwang et al., 2008; Qian et al., 2009) have used sewage and industrial sludge to prepare sludge-based adsorbents (SBAs) which are low-cost alternatives of activated carbon (Pollard et al., 1992) and have wide and efficient applications in adsorbing different dyes, organic compounds, heavy metals and even in removing gaseous contaminants.

Aim of this paper is to review the preparation methods of SBAs, with an emphasis on the techniques of carbonization and

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activation of both industrial and sewage sludge. Some studies used dewatered sewage sludge (Dhaouadi and Henni, 2009; Kayranli, 2011), powered waste sludge (Pamukoglu and Kargi, 2007a,b, 2009) and sludge ash (Wajima and Munakata, 2011) as adsorbents. As this method does not include thermal treatment process, it is not mentioned in this review. Four aspects are considered in this study: (1) influence of thermal treatment parameters, such as pyrolysis temperature, heating rate, dwell time, activator selection, activator concentration, etc.; (2) environmental safety; (3) application of SBAs in water treatment; (4) economic feasibility. A schematic diagram of aspects considered in this review is shown in Fig. 1.

2. Effects of preparation conditions on SBAs' structure and chemistry surface characteristics

The efficacy of SBAs in contaminant removal is determined by its structure and surface chemistry characteristics. The widely used method of evaluating structure of an adsorbent is the Brunauer–Emmett–Teller (BET) surface area (Brunauer et al., 1938). Micropore volume (V_m) was obtained by t-plot method, while macropore and mesopore volumes, and pore size distribution were calculated by the Barrette Joynere Halenda (BJH) method. This section discusses the effects of pyrolysis conditions on the SBAs' structure.

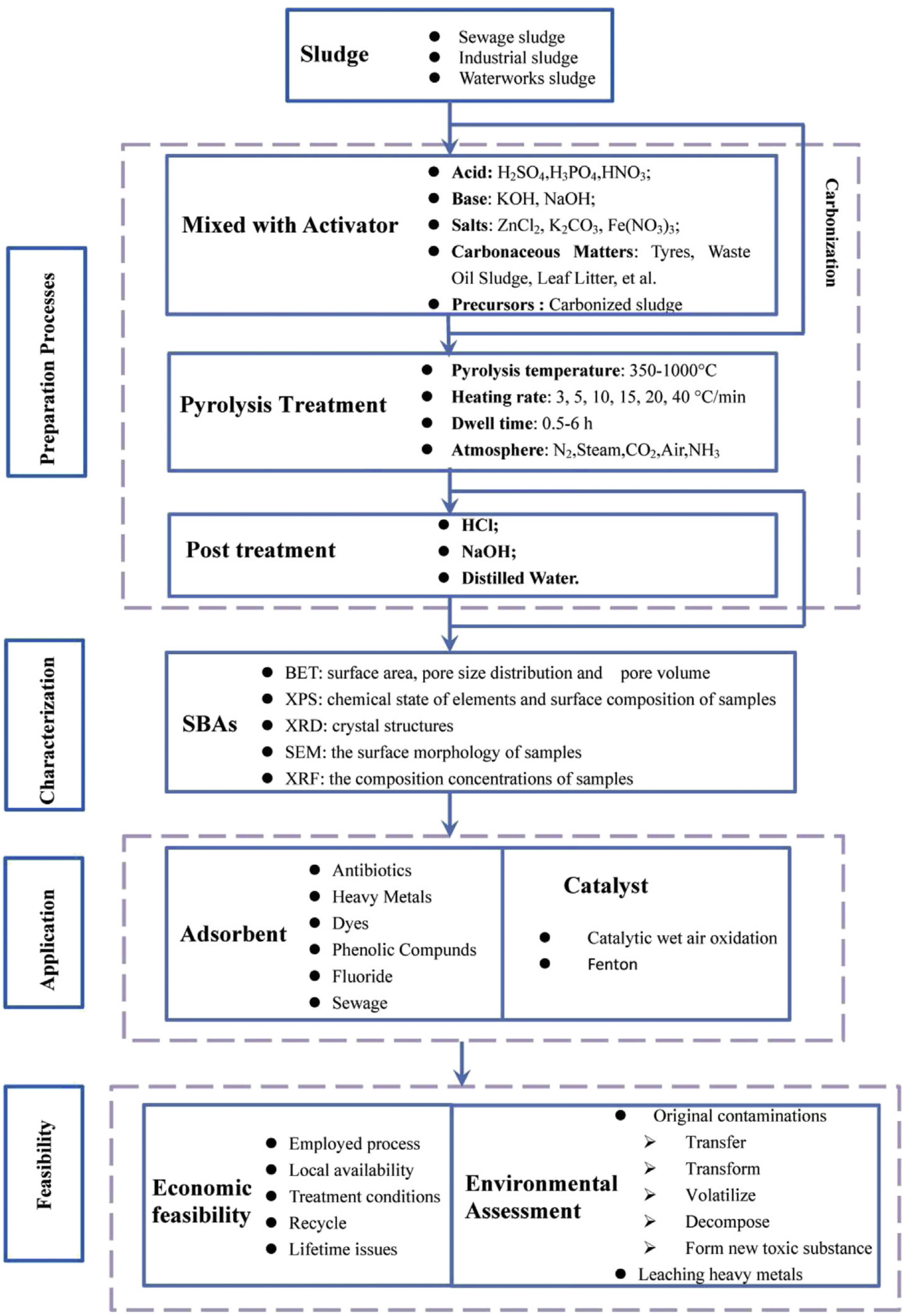

Fig. 1. Schematic research pathway of sludge-based adsorbent including preparation, characterization, utilization and feasibility assessment.