Journal of Hazardous Materials B127 (2005) 196–203

Journal of Hazardous Materials

www.elsevier.com/locate/jhazmat

Advanced tertiary treatment of municipal wastewater using raw and modified diatomite

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Received 4 April 2005; received in revised form 7 July 2005; accepted 8 July 2005
Available online 24 August 2005

Abstract

Advanced technology for more efficient and effective wastewater treatment is always timely needed. The feasibility of using raw and modified diatomite for advanced treatment of secondary sewage effluents (SSE) was investigated in this study. Raw diatomite at a dosing rate of 300 mg/l showed a similar potential as activated carbon for removing most organic pollutants and toxic metals from SSE. Its performance was found poor in removal of arsenic and crop nutrient constituents (e.g. ammoniacal nitrogen and phosphate) and remained unsatisfactory even when the dosing rate increased up to 500 mg/l. Where modified diatomite was in lieu of raw diatomite, the removal efficiency for all target constituents was improved by 20–50%. At the dosing rate of 150 mg/l, modified diatomite enabled the post-treated effluents to satisfy the discharge consents, with the levels of all target constituents below the regulatory limits. Modified diatomite has advantages over raw diatomite in improving removal efficiency and reducing the dosing rate required for satisfactory treatment of SSE. It is concluded that modified diatomite is much more effective and efficient than raw diatomite, as an alternative to activated carbon, for economic treatment of SSE.

Keywords: Diatomite; Removal efficiency; Secondary sewage effluent

1. Introduction

Disposal of improper treated wastewater often pose risk to the environment and ecology. Using advanced technology to mitigate risk by refined wastewater treatment is a key issue in meeting legislative guidelines, e.g. EU Water Framework Directive. Municipal wastewater treatment typically comprises preliminary treatment, primary treatment and secondary treatment. Preliminary treatment includes a series of screens and grit removal to prepare wastewater for subsequent treatment. Primary treatment involves the separation of readily-removable suspended solids through gravity sedimentation. Following these two basic processes, wastewater is then subjected to secondary treatment in which biological and/or chemical processes are involved to remove dissolved constituents. The secondary treatment was previously considered as a complete process, with its effluent being discharged into the receiving environment after disinfection with chlorine gas [1]. However, as environmental regulations are getting stringent and introduction of EU Water Framework Directive in 2000 [2], secondary sewage effluent (SSE) was no longer a guarantee for discharge [3]. Advanced tertiary treatment is therefore, required for further decreasing the residual constituents in SSE.

A variety of technologies have been developed and applied for the treatment of SSE. The commonly used techniques include membrane filtration with the aid of coagulants, chemical oxidation and precipitation, activated carbon adsorption and constructed wetland [4]. Activated carbon adsorption has been held to be a particularly competitive and effective process in removing organic and inorganic constituents from the waste effluents [5–7]. However, activated carbon is less economically viable as an adsorbent due to the costly activation and regeneration of the spent carbon and disposal

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0304-3894/$ – see front matter
doi:10.1016/j.jhazmat.2005.07.016

of regenerant wastes. As a result, over recent years there has been growing interest in using low-cost natural minerals for treating wastewater. Among these minerals is diatomite.

Diatomite, also referred to as diatomaceous earth, is durable, extremely lightweight and highly porous; it has a large surface area of 50–200 m^2/g [8]. It consists primarily of the fossilized skeletons of diatoms, which were once marine planktons and algae. There were isolated and H-bonded hydroxyl groups detected on the surface of diatomite [9]. As a result of its unique physical and chemical properties, diatomite has been put in industrial application as filtration media for various beverages [10]. A number of laboratory-scale studies were also performed to investigate the potential of diatomite as an absorbent for removing waterborne radionuclides, e.g. uranium [11], heavy metal ions, e.g. Pb^{2+}, Cu^{2+} and Cd^{2+} [12,13] and basic textile dyes [14,15] from wastewater. While these studies have demonstrated promising outlook of diatomite for wastewater treatment, most of them were focused on individual constituent or a limited number of toxic metals in synthetic wastewater. It is poorly understood whether diatomite can be applied for treating the real waste effluent that contains a wide range of organic and inorganic constituents.

The objectives of this study were to (i) identify the feasibility of using raw diatomite as an alternative to activated carbon for tertiary treatment of municipal wastewater and (ii) investigate whether the removing efficiency of the target constituents from SSE could be improved by using chemically-modified diatomite. To achieve these objectives, two treatment systems were involved: a laboratory-scale system, i.e. batch reactor system (BRS); a pilot-scale system, i.e. continuous flow system (CFS). The comparison in treatment efficiency between these two systems was established.

2. Methods and materials

Materials used in this study involved raw diatomite, modified diatomite, powdered activated carbon and wastewater samples. Raw diatomite powder was provided by Yunnan Qingzhong Environmental Co. Ltd., China. According to manufacturer's information [16], diatomite was produced by milling diatomaceous sedimentary rock, and then refined and purified using a low-cost physical method instead of conventional expensive technique (i.e. acid washing). The refined diatomite contains 98% diatoms, which have honeycomb structure (Plate 1) and particle size ranging from 40 to 200 μm. Chemical analyses of diatomite composition showed 84.2% SiO_2 (of which non-crystalline SiO_2 97.5% and crystalline SiO_2 2.5%), Al_2O_3 6.51%, Fe_2O_3 5.23% and CaO 1.32%.

The chemically-modified diatomite was prepared by placing raw diatomite powder with solid aluminum sulfate and lime at the ratio of 6:1:3 in a mixing bowl, stirring for 20 min at 100% moisture of distilled water. This was followed by treating the mixed samples in an ultrasonic bath for 15 min and then oven drying at 60 °C. The oven dried samples were ground through a 100-mesh sieve, and charred in Muffle furnace at temperature of 450 °C for 2 h.

Powdered activated carbon (PAC) was obtained by grinding through a 100-mesh sieve the commercial granule activated carbon manufactured by Xinsen Chemical Industry

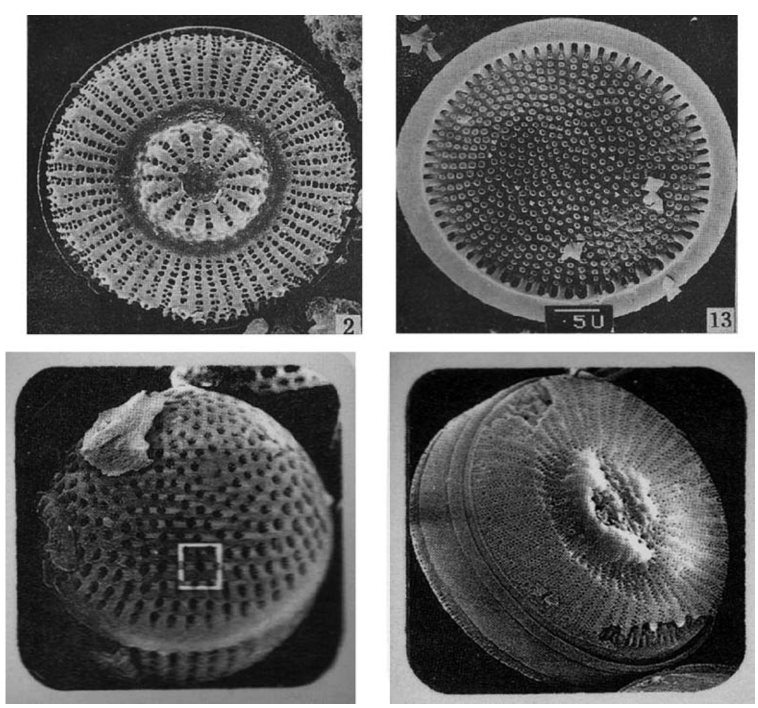

Plate 1. Honeycomb structure of diatom skeletons in different shapes.