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Preparation of Adsorbent with Lead Removal Ability from Paper sludge using Sulfur-impregnation

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Abstract

During the manufacture of recycled paper, paper sludge is discharged as an industrial waste. The amount of sludge discharged from manufacturing plants increases annually. In this study, the organic constituents, such as cellulose, in the sludge were converted into carbonaceous heavy metal absorbents using sulfur treatment, and its removal ability of lead from aqueous solution was examined. The sludge was treated with 5 M HCl to remove inorganic content, and then immersed in 1 M K_2S solution to prepare sulfur-immersed sludge. The immersed-sludge was heated at 100-1000 ^oC for 1 hour in nitrogen gas to produce the sulfur-impregnated adsorbent by pyrolysis. The product obtained at 400 ^oC (Product-400) has a high removal ability for lead ion, which has high specific surface areas and high sulfur content. The product-400 shows the highest adsorption of lead from aqueous solution, and high selective removal for lead ions in low pH solution.

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Keywords: Lead removal; Paper sludge; Pyrolysis; Sulfur-impregnation

1. Introduction

Millions of dry metric tons of sludge are generated as a waste byproduct from the paper manufacturing industry. Methods currently used for the disposal of this sludge include recycling as fertilizer, burial in landfills, dumping at sea, and incineration. During the last few decades, disposal of paper sludge has become

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an increasingly severe problem. In densely populated industrial countries, regulations have been made to protect the environment and the potential risk to groundwater quality. This has led to a significant reduction in the amount of available landfill space and a rise in the cost of land disposal. Most of the paper industries and municipal authorities are facing increasing regulatory and cost-related pressures regarding the handling, treatment and disposal of waste sludge and solid wastes. Political, as well as social, authorities also encourage recycling of waste products.

The presence of heavy metals in the aquatic environment is of significant concern to scientists and engineers because metals cause increased discharge, are toxic in nature, and cause other adverse effects on the receiving waters. Metals that include chromium, lead, copper, zinc, cadmium, nickel, and manganese are non-biodegradable toxic pollutants that affect public health. Lead is used by many industries, such as storage battery manufacturing, printing, pigments, fuels, photographic materials, and explosives manufacturing [1]. Lead poisoning in humans causes severe damage to the kidney, nervous system, reproductive system, liver, and brain, causing sickness or death [2]. As a result of their extensive use, lead can pollute water and soils, producing a serious environmental problem. The removal of lead (II) from water and wastewater is highly essential. According to the World Health Organization (WHO), the permissible level of lead in drinking water is 0.01 mg/L in the United States, Canada, and Japan [3].

Several methods have been developed to remove the metal ions that are present in industrial wastewaters and soils, such as chemical precipitations, conventional co-agulation, reverse osmosis, ion exchange, and adsorption [5]. Among these methods, adsorption appears to be the most widely used for the removal of heavy metals [6-8]. Over the past two decades, research on heavy metal adsorption has focused on the use of low-cost and effective sorbents. Activated carbon is widely used in wastewater treatments to produce drinking water, control atmospheric pollution, separate poisonous gases, and recover solvents [9, 10]. Any inexpensive carbonaceous material with a high carbon content can be used as raw material for the production of activated carbons. Activated carbon effectively removes organic chemicals from wastewater, but is not effective in removing metals and inorganic pollutants from aqueous solutions [11]. This is mainly due to the relatively non-polar character of activated carbon, which inhibits the attraction between charged metal species and the surface of the activated carbon (even though some functional groups may be present on the surface). In previous studies, sulfur-impregnated adsorbents with high removal abilities for heavy metals were prepared from coal or palm shell using H_2S gas or K_2S powder [12-15]. According to the Pearson theory, the sulfur, as a soft base, should interact with heavy metals such as Zn^{2+}, Pb^{2+} and Cd^{2+} (soft acids) rather than with oxygen (a hard base) in the activated carbon [16, 17]. It is possible to produce a low cost heavy metal adsorbent from coal and organic wastes. However, little information is available on the heavy metal removal ability of sulfur-impregnated adsorbents.

In this study, we convert industrial waste, paper sludge, into carbonaceous heavy metal adsorbents using sulfur treatment with K_2S solution. Properties such as specific surface area, sulfur content and heavy metal removal, especially for lead ion, were examined.

2. Materials and Methods

2.1. Raw Material

Paper sludge (PS) exhausted from one of the paper companies in Japan was used as the starting material. The PS was dried at 80 °C overnight in a drying chamber, crushed with a mortar and sieved to less than 500 μm for experimental use. The PS consisted of 5% water, 45% organic components such as cellulose and 55% inorganic components, which were estimated from differential thermal analysis / thermogravimetry (TG-DTA) curves.