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Cyanide removal study by raw and iron-modified synthetic zeolites in batch adsorption experiments

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A R T I C L E I N F O

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A B S T R A C T

The environmental concerns for treating cyanide-containing wastewater via adsorption technology has been advancing which resulting in the need for a robust yet simple method. Synthetic zeolite was used as a suitable adsorbent for cyanide removal due to its excellent surface properties. In this study, the modification of zeolite was made by iron doping to trigger a better adsorption performance. Then, the comparison between the effectiveness of each zeolite follows subsequently. SEM, XRD, and BET analyses were employed to study the adsorbents characteristics. Cyanide uptake experiments were conducted by a batch technique for certain contact times at room temperature, while adsorbent dose and agitation speed were set constant. The results showed that before the equilibrium, iron-doped zeolite removed 20% more cyanide by following the pseudo-second-order kinetic model than raw zeolite which fits the pseudo-first-order model. Langmuir model was better in describing the adsorption behavior of cyanide onto iron-modified synthetic zeolite. The maximum uptake capacity of cyanide onto iron-zeolite was known as 33.978 $mg\ g^{-1}$.

1. Introduction

Cyanide is a chemical compound that has been commonly used in several industrial processes as well as gold and silver extraction [1]. Gold cyanidation, which was established as MacArthur-Forrest process in 1887, has been applied as the main and the most economical technique for gold extraction. It is popular due to the high effectiveness of cyanide as the leaching agent in alkaline condition [2]. However, the prospect of using cyanidation technique for extracting gold from the ores is in doubt owing to the tremendous potential risk of cyanide toxicity to the environment [3].

Some options for removing cyanide from effluents in gold mining have been proposed based on chemical, physical, biological, and even, adsorption techniques [4]. In recent years, adsorption process has received more interests for cyanide removal from wastewater because this simple method does not require hazardous chemicals in operation [5]. This technique is quite promising since there are abundant candidate materials that could be potentially developed as the adsorbents for eliminating cyanide [6]. Researchers have investigated and reported some materials, including plain and iron impregnated activated carbon [7,8], natural zeolite [9], ion-exchange resin [10], and also bio adsorbent materials [11,12].

It is known that cyanide adsorption by activated carbon has been largely practiced in mining industries [13]. However, the method still has some shortcomings, especially on the recovery of cyanide and the low degree of carbon regeneration during the process, which lead to high operating costs [14]. On the other hand, ion-exchange material, such as synthetic zeolite, has been proved to overcome the cyanide recovery problem [15]. The reason is that synthetic zeolite has high volumes of empty spaces with its unique property, such as uniform micropore-sized and its possibility to be regenerated [16,17]. It also possesses the excellent flexibility to be modified with metal, especially iron which has high affinity with cyanide [18]. Iron-zeolite is likely to have more potential to be implemented for removal of cyanide from the waste effluents [19]. Therefore, this work aims to investigate and evaluate the performances of raw and iron-modified synthetic zeolites for cyanide adsorption process and to analyze the effectiveness of those zeolites regarding kinetics and isotherm behaviors.

2. Materials and methods

2.1. Preparation of iron-modified synthetic zeolite

An MFI-type of synthetic zeolite (purchased from Zeolyst International) with a SiO_2/Al_2O_3 ratio of 23 was used as raw material. Iron-doped zeolite was prepared by modifying raw zeolite with 300 mL of aqueous solution containing 5 mmol $FeCl_2{\cdot}4H_2O$ (supplied by Wako Chemicals) in a 500 mL Erlenmeyer flask and agitated for 24 h at 313 K.

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Table 1
Method for cyanide removal study using raw and iron-synthetic zeolites.

Adsorbents used	Experimental Parameters	Models used for Kinetic Studies	Isotherm Analysis
Raw and iron-modified synthetic zeolites	Initial CN^-: 50, 100, 200, 300 mg L^{-1}; 50–600 mg L^{-1} (for isotherm analysis); Temperature: ambient; Adsorbent dose: 10 g L^{-1}; Stirring speed: 200 rpm.	Pseudo-first order model [23]	Langmuir model [25]
		Pseudo-second order model [24]	Freundlich model [26]

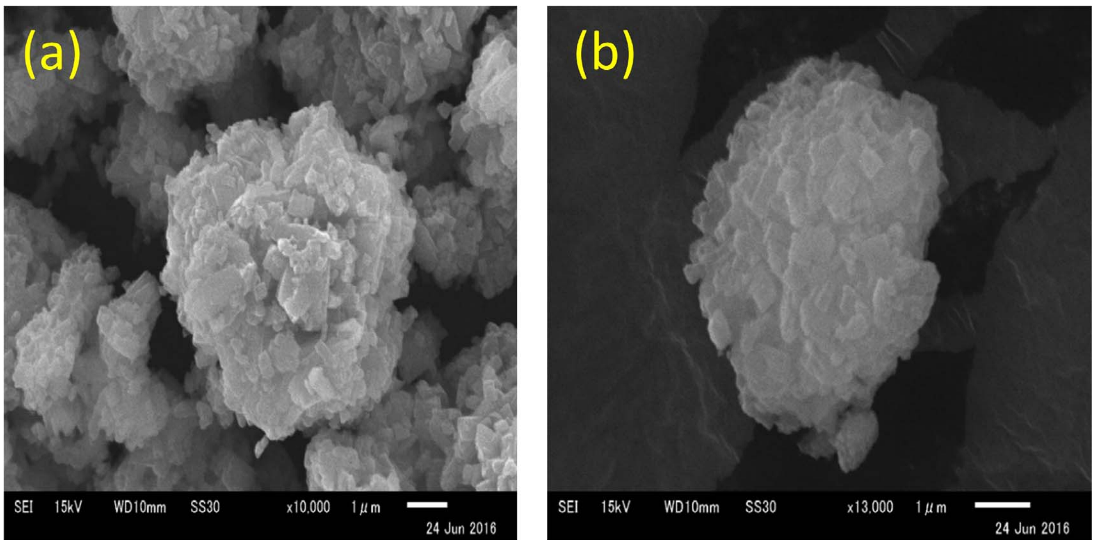

Fig. 1. SEM images of raw (a) and iron-doped zeolites (b).

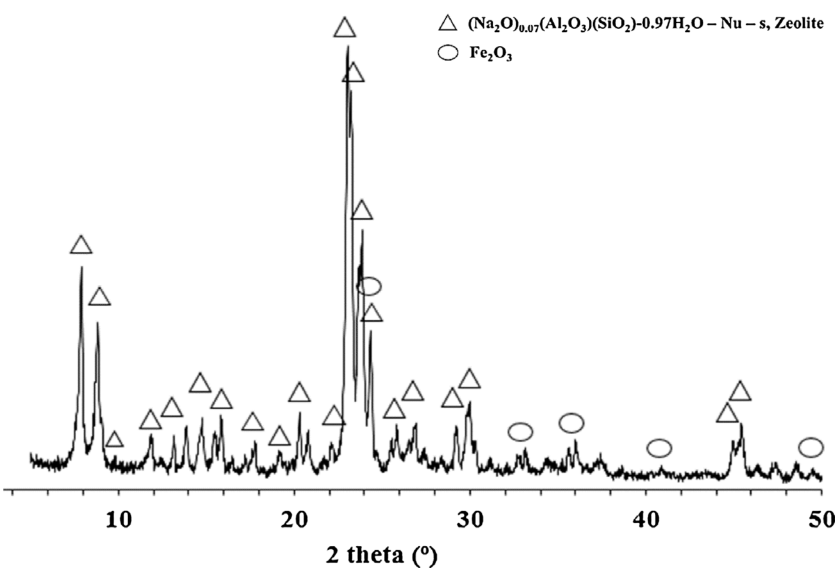

Fig. 2. XRD pattern of iron-doped zeolite material after calcined at 773 K for 6 h.

Table 2
BET surface area, pore volume, and average pore size of raw and iron zeolite.

Surface characteristic	Raw Zeolite	Fe – Zeolite
S_{BET} ($m^2 g^{-1}$)	290.956	278.208
Pore Volume ($cm^3 g^{-1}$)	0.187	0.191
Average Pore Size (nm)	1.290	1.370

Then, the suspension was filtered, and the solid part was calcined in a muffle oven at 773 K for 6 h in the presence of air.

2.2. Adsorbents characterization

SEM observation was conducted using Analytical Scanning Electron Microscope (JEOL JSM-6610LA) to study the surface and structure of the raw and iron-doped zeolites. XRD analysis was then tested to confirm the result of the iron-doping process. For specific surface area measurement, zeolite samples were degassed at 523 K for 3 h under vacuum. The BET surface area was measured by BET analyzer (QUADRASORB SI Automated Surface Area & Pore Size Analyzer) using