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Synthesis of Zeolites from Coal Fly Ash and Their Environmental Application

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Abstract: This study aims to make adsorption-capable zeolite from coal fly ash, a waste product from coal-fired power plants (CFA). When it comes to commercializing sorbent, the total cost and efficiency of the adsorbent material are critical. This work used tap water instead of distilled water (DW) to synthesis zeolite from fly ashes at 90°C crystallization temperatures. The discovery lays the door for a cost-effective but easy technique of synthesizing viable zeolitic materials for adsorption applications using waste products like coal fly ash. According to the comprehensive characterization, the support for the use of TP to make zeolites is based on its larger particle size, and lower carbon impurities. The generated zeolite was homogenous and A-type, and applied as an adsorbent to remove traces of heavy metals contaminants. During a 25-minute agitation period, the zeolites produced with TP had a greater adsorption capacity. In principle, the proposed approach permits the synthesis of low-cost, high-efficiency zeolite-based adsorbent materials for environmental remediation without the use of harmful or expensive chemicals.

Keywords: Synthesis zeolite, adsorption, coal fly ash, tap water.

Introduction

Water is one of the critical items for human survival on the blue planet. More quantities of the water on this planet are stored in glaciers and oceans, and it is hard to be recovered for our various needs. The rainwater meets our requirements or demand, by surface and groundwater resources. The amount of useable water is very limited on earth, but world communities significantly rely on rainwater and groundwater for daily activities, including irrigation practices (Goel 2006, Galadima, 2011). Although water resources are continuously filtered by precipitation and evaporation, but human activities have contaminated the water. In the recent period, water pollution has developed a major ecological problem (Kumar, 2019).There may be many reasons for this situation, but the serious water pollution mainly comes from industries, urbanization, and agriculture observed in the past decades (Verma and Dwivedi, 2013). Due to its chemical and physical properties, water is a renewable resource and universal solvent.

Water pollutants are divided into three factors, which are physical, chemical, and biological, that adversely affect aquatic organisms and water (Owa, 2013). Most contaminants are chemical forms that are easily soluble in water. The details of the primary water pollution sources are population growth, domestic sewage, pesticides and fertilizers, industrialization, urbanization, plastic and polythene bags, and weak management systems. Nowadays, industrialization growth is increasing, especially in mainland China, which is caused some nasty conditions, including serious pollution of the water sources. Waste material from various industries like textile, chemical, sugar, dyes, pharmaceuticals, electroplating, pesticides, mash, and paper contaminate the water (Zhang, 2010). It is reported that the main cause of water pollution is industrial waste and additional waste making water no longer suitable for drinking, agriculture, and aquatic organisms. Different industries untreated sewage discharged into water resources is the leading cause of water pollution. Hazardous material dumped into the earth and released into water resources from the industries. Pollutants depend on the nature of the Industry (Dojlido and Best, 1993, Eckenfelder, 2000). The industries produce almost 25% contamination of the world. In polluted water, an enormous amount of bacteria are discovered, unsafe for human health (Namasivayam and Senthilkumar, 1998, Haseena, 2017). More than a billion people still drink contaminated water. As a result, diarrhoea and other illnesses claim the lives of hundreds of youngsters every day. Therefore, a large number of children continue to infect from diarrhea and hygiene-related diseases. About 80% of the total residents are facing water security threats. It is suggested that the worldwide community control water pollution and treat industrial waste for environmental purpose (Wu, Maurer, 1999, Schwarzenbach, 2010).

As part of sustainable development and waste management policies, one should aim to reduce waste and transform it into usable items through recycling or reusing methods. This can help cut down and maintenance costs, the amount of raw materials needed, the amounts of waste materials generated, and environmental consequences (Crini, 2006).Wastewater has been commonly used to treat solid waste from coal combustion. Fly ash, on the other hand, has a lower adsorption potential than conventional adsorbents. Fly ash can be transformed into zeolites using a cost-effective and reliable activation process. Since zeolites perform better in certain adsorbents in terms of adsorption, the production of high-performance zeolite adsorbents using fly ash has only recently been explored (He, 2016, Visa, 2016).

At present, filtration of wastewater using an adsorption mechanism is a quick, low-cost, and efficient method of eliminating dissolved drugs and dye waste from wastewater. According to Babel and Kurniawan (2003). This technology success primarily depends on the configurations of high-efficiency adsorbents. For these applications, a range of materials and methods have been used. The use of synthetic zeolites and their modified versions offers the benefit of low cost and widespread availability in many parts of the world. As a consequence, zeolites are widely used as adsorbents for ion absorption in wastewater treatment (Inglezakis, 2007, Misaelides 2011, Pandey, 2016).The main purpose of this study convert coal fly ash in zeolites and used resultant products for environmental application.

Materials and Methods

Samples of fly ash represented as CFA were collected from the Huaneng thermal power plant, Beijing (880 MW) and the Beilun Power Plant, Zhejiang (5000 MW), respectively. Which are also utilized for making zeolite precursors. Beijing Chemical Reagent Co., Ltd provided ceftazidime, NaOH, tap water, and hydrochloride. These reagents were of analytical grade and did not require further purification.

Synthesis of Zeolites

Coal fly ash (i.e. CFA) is converted to zeolite using a simple hydrothermal method. Tap water was used as the hydrothermal solvent for each CFA in the tests. In a typical experiment, 10.0 g of CFA was crushed with solid NaOH at a 1:1.2 ratio after passing through a 325 mesh screen. To complete the fusion process, thermally fuse the fine powder mixture at 550°C. The powdered CFA was then separately dispersed in Tap water in a ratio of 1:5. These samples were then placed in an ultrasonic bath for 2h before hydrothermal treatment in a Teflon cup of Parr bombs (reactor) at 90°C for 9 hr. The synthesized product was washed thoroughly with deionized water in the reaction competition until the pH of the supernatant reached <10, then dried at 90 °C overnight and filtered through 100 mesh, followed by adsorption studies.

Characterization

The adsorption experiments were carried in bach wise manner with a specific weight of adsorbent dispersed in a 500mg/L dye solution. The % adsorption was estimated using equation 1, The UV-Vis spectrophotometer was used to measure the concentration of MB dye at a fixed wavelength of 664 nm. Adsorption was performed with constant shaking for 60 min at room temperature with % adsorption measured at the interval of 10 min.

$$q_e = \frac{V(C_o - C_t)}{m}$$

Where, Co is the initial concentration; Ct is the concentration at any time.

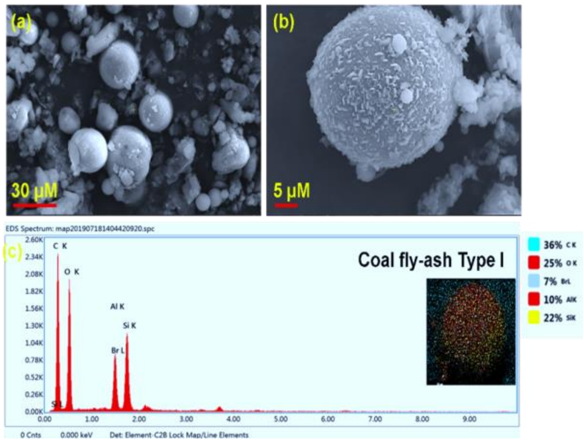
Results and Discussion

A simple hydrothermal method was used to make zeolites from CFA (Fig. 1) Typically, the resulting fly ash is hydrothermally processed in the presence of NaOH using tap water (TP) as a suitable solvent. XRF analysis was used to characterise the composition of CFA. Table 1 lists the major oxides and trace elements. According to ASTM Standard C618, the total amount of Si, Al, and Fe oxides in CFA is roughly 56.4 percent, and fly ash is categorised as Class C. Burning low-rank (lignite or sub-bituminous) coals produces this form of fly ash. Both fly ashes have a moderate calcium concentration, indicating that they might be used as zeolite precursors. High calcium content is associated with the induction of structural brittleness in the final zeolite. The presence of Fe (magnetite) has also been shown to be detrimental to zeolites. However, the low Fe content (< 4%) in CFAs is suitable for zeolite synthesis. The SiO_2/Al_2O_3 ratio, considered an indicator of the chemical ion exchange capacity of the final zeolite, was also determined. In this case, the SiO_2/Al_2O_3 ratio of CFA was 1.01; further confirming the possibility of obtaining low silica zeolites with high ion exchange capacity.

Table 1. XRF of coal fly ash

Major (oxides)	Content (wt %) CFA_1
Al_2O_3	27
SiO_2	27.4
Fe_2O_3	2
CO_2	38.2
MgO	0.2
CaO	2.1
Others	3.3
LOI	0.10
SiO_2/Al_2O_3	1.01

Fig. 2 shows the SEM images with corresponding EDX spectra for CFA. CFA particles are regularly spherical; however, some are not uniform in shape, covered with smaller particles and irregular layers. As evident, coal fly-ashes have particulate with sphere-like morphology with lumps of unburned carbon. The particles are smooth and spherical due to being covered by an amorphous glass phase. However, the average size of particles in both types of fly ash was 20 to 250µm.The size of the raw coal and the kind of combustion determines the physical qualities of fly ash. The finesses of the fly-ash particle are closely related with the pulverisation and heating process of the coal, as shown by the EDX spectra of the CFA with considerable Al, C, O, and Si as key elements.



Synthesized Zeolites

The CFA system was converted to zeolite using tap water as the hydrothermal solvent. SEM pictures and matching XRD patterns of zeolites produced at 95 °C with CFA and TW as solvents (Fig.2). Zeolites prepared using TW has significantly better particle quality with less aggregation between individual cubic units. The existence of peaks at 7°, 10°, 12°, 24°, 30°, 32°, and 35° assigned to type 4A zeolite was also verified by the matching XRD patterns (JCPDS card 43-0142).Therefore, optimally in the case of CFA with distilled water, the temperature is determined to be 95°C. The SEM images are evident that utilization of DW effectively facilities the zeolite growth as cubic-shaped with homogenous size distribution morphology was obtained at temperatures of 95°C, where proper cubic shape morphology. DW-produced zeolites, on the other hand, are extensively dispersed and aggregation-free, making them excellent for adsorption applications. Additional peaks attributed to the sodalities phase were seen in the XRD patterns of DW-treated zeolites. With the exception of type 4A reflecting the hydrothermal properties of DW, which were inconsistent in composition obtained after solvent use.

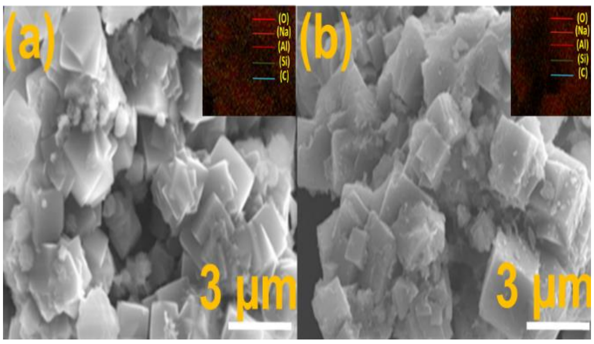


Fig. 1 SEM images and EDX of synthesized zeolite.

Adsorption Performance of Zeolite

The adsorption performance was measured for zeolites using MB as a standard organic toxin. The adsorption of MB can be easily observed using optical absorption spectroscopy owing to its absorption peak in the visible region. Figure 3 shows the UV-spectra of MB dye observed at the interval of 10 min when zeolite was used as an adsorbent. It can be seen that synthesized zeolite was capable of 50% MB dye within 70 min of adsorption time. This confirms the high adsorption capability of the zeolites.

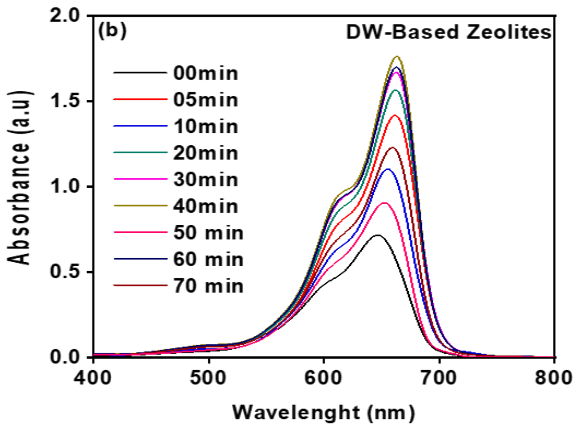


Fig. 2 Adsorption of dyes with synthesized zeolite.

Conclusion

It is concluded that zeolites could be made from fused fly ash utilizing tap water as a crystallization agent at 90°C. The benefits of using coal fly ashes provide an improvement in A- type zeolite production and reduce the cost of waste water treatments. The resultant zeolites are characterized by SEM, EDS, XRD, and XRF techniques to classify which synthetic zeolites are better than others. At the end of the experiment, zeolites are discovered: zeolite-TP. Adsorption methodology is easy to handle and effective for treatment process. Zeolites were used for industrial wastewater treatment after obtaining synthetic zeolite, and the adsorption capacities of the resulting zeolite were compared. The maximum adsorption capacity of MB by TP-based zeolite, as calculated by the optical absorption spectroscopy, is higher than or comparable with other commercial zeolites reported in previous studies. The method described may be a useful concrete alternative for commercially producing industrial goods from waste material.

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