BR05 - Bauxite Residue Supported Ag Nanoparticles: A Highly Effective and Recyclable Catalyst for Hydrogenation of p-Nitrophenol

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Abstract

Heterogeneously catalyzed reactions are one of the most important chemical processes exploited for the production of a large number of modern-day products. They have been used extensively in petroleum cracking, fine chemicals synthesis, environmental remediation and synthetic chemistry. Owing to their substantially large surface area, sizeable assembly of active surface sites and the existence of quantum confinement effects, metallic nanostructures have been used as heterogamous catalysts for range reactions. However, unprotected metal nanoparticles are usually suffered from various technical limitations such as irreversible agglomeration, catalyst poisoning and limited life cycle. To overcome these technical drawbacks, catalysts are usually dispersed on chemically inert materials such as mesoporous Al_2O_3, ZrO_2 and ceramics, and these materials are expensive. In the current paper, efforts have been made to develop a low-cost alternative catalytic material using bauxite residue, which is abundantly available. Considering these aspects, in the present work, we report hydrogenation of p-nitrophenol to p-aminophenol on bauxite residue supported silver nanoparticles. Supported silver nanoparticles are synthesized by chemical impregnation of nanosized silver particles on bauxite residue via reduction/precipitation technique. Phase and crystal structure of synthesized materials have been investigated by XRD. FTIR spectroscopy was employed to analyze the presence of surface molecules on the resultant material. SEM/TEM was used to investigate the morphology of the supported catalysts. Synthesized material has shown higher catalytic performance than unprotected Ag nanoparticles. Our investigation revealed higher catalytic activity of the Bauxite residue supported silver nanoparticles with possible potential for future industrial applications.

Keywords: Bauxite residue, silver, catalysis, hydrogenation, p-nitrophenol.

1. Introduction

Bauxite Residue (BR) or red mud is the solid residue from alumina production in the Bayer process [1,2]. Approximately 2–3 tonnes of bauxite are needed to produce 1 tonne of alumina, so the amount of BR produced can be estimated by applying the ratio of 1.5 to alumina production data [3]. The global stock of BR was predicted to reach approximately 4 billion tons in 2019, with a production rate of 0.15 billion tonnes per year [4]. Around 2 tonnes of caustic insoluble residue known as 'Bauxite Residue' or 'Red Mud' is generated by the NALCO alumina refinery at Damanjodi, Orissa for every tonne of alumina produced.

Aluminium metal is produced from aluminium oxide phases that constitute between 38 to 60% of the bauxite ore. The balance of bauxite is made up of Fe_2O_3, SiO_2, TiO_2 and other minor oxide phases. After the dissolution of bauxite in caustic soda, these impurities remain suspended until separated by settling after being washed and are then pumped as a slurry to the nearby Bauxite Residue Area (or Red Mud Pond).

BR poses environmental and disposal challenges. A major reduction in the quantity of BR deposited in storage areas is only possible through its utilization in one form or another. However, the inherent properties of BR poses difficulties for its bulk utilization. Prior to assessment of bulk utilization options for BR from the NALCO refinery, in-depth characterization is required. Rao et al. have reported the characteristics of sand residue from the NALCO refinery [5], but limited characterization of BR from this refinery has been published. BR has not been utilised in large quantities until now because of its alkalinity, technical and economic limitations, industrial conditions, public concerns about its potential health effects, and market demand [6]. The chemical and mineral composition of BR varies widely depending on the bauxite's origin and processing conditions, and consequently, no universal methods and standards are available for BR treatment [7,8].

BR storage areas occupy considerable land areas and may negatively impact local environments [9]. BR uses studied and applied to date include metal recovery, adsorbents, catalysts, building materials, and other applications [10].The BR utilization rate is less than 4% in China, so the majority of BR is left unutilized [11]. Although the safe disposal and storage of BR is an international issue and has been extensively researched, BR reuse appears a better alternative to the storage of BR and the risks it poses.

BR can be considered a valuable material instead of a waste due to its many potential reuse applications. The abundance of BR has led to extensive research into possible uses [12]. These include: recovery of Al, Fe, and rare earth metals [13,14]; a sorbent for treatment of contaminated water [15,16]; sequestration of CO_2 [17]; an additive to ceramics and building materials [18,19]; embankment construction [20]; and soil amendment [12,21–25], and all of these uses may play a role in reducing the storage of BR.

Noble metal nanoparticles (NPs) have received intensive attention in recent years, because of their fascinating physical and chemical properties that are considerably different from those of their bulk counterparts. In particular, nanoscaled metallic silver is of great research interest due to its high performance and relatively low cost in catalysis of a variety of chemical reactions [26–28]. For example, the reduction conversion of p-NP with borohydride catalyzed by Ag nano-catalyst to 4-aminophenol (p-AP) is of industrial and environmental importance. However, the practical use of Ag NPs is hindered by their severe aggregation during the catalytic process, unavoidably decreasing the active surface area, and degrading long-term of performance.

Considering the hazardous nature of p-NP, chemical industries are obliged to eliminate it from their effluent streams. Conventional methodologies for removal of p-NP from water such as coagulation, flocculation, ozonation, adsorption, and biological treatment are often chemically, energetically and operationally intensive, focused on small systems, and thus involve technical challenges during implementation and operation at large scale [29–34]. Catalytic reduction to amino-derivatives in the presence of suitable catalysts to eliminate the toxicity of p-NP is therefore considered one of the most preferred technologies.

In this context, this study reports a simple and fast catalytic reduction method for p-NP using bauxite residue with silver metal-based nanocomposite (NC), a novel material using BR with silver nanoparticles (Ag NPs). Using UV-Vis spectroscopy, the reduction of p-NP by BR@Ag NCs was measured at up to 99% in just ten minutes. Both materials are much cheaper than conventional metallic NPs and hence may find potential application as hydrogenation catalyst.

5. References

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