Purification of a Nigerian talc ore by acid leaching

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ABSTRACT

Talc by its intrinsic properties such as chemical inertia, softness, high thermal stability and low electrical conductivity, is extensively used in paints, cosmetic, paper and pharmaceutical industries. In this work, the purification of a Nigerian talc ore made up of actinolite and clinoclore with specific surface area of 0.15 m^2/g by acid leaching was investigated. The initial and leached talc products were characterized by Energy Dispersive X-ray fluorescence (EDXRF), X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) with Energy Dispersive spectroscopy (EDS), the Fourier Transform Infra-red Spectroscopy (FT-IR) and the N_2 adsorption techniques. The influences of acid concentration, temperature and particle size on the ore leaching as well as its surface properties were examined. The results of the dissolution rates were found to be influenced by hydrogen ion concentration, temperature and particle size. The dissolution mechanism was found to follow the shrinking core model for the diffusion controlled reaction. The leached product has a specific surface area (S_{BET}) increased from 0.15 m^2/g to 3.59 m^2/g at optimal conditions. The calculated activation energy of 31.2 kJ/mol supported the proposed mechanism. Finally, the product purity assessment by Energy Dispersive spectral data showed a decrease in the ore's Iron content from 3.75% to 0.36% and accounts for 90.4% process efficiency.

1. Introduction

Talc is a magnesium-rich phyllosilicate widely used in industries as paper, paints, cosmetics, plastics, rubbers, refractory materials, pharmaceuticals, pesticides, agro-industries and ceramics. These varied applications are possible due to its intrinsic properties such as chemical inertness, softness, thermal stability, low electrical conductivity, good absorption and adsorption properties, hydrophobicity and high density, crystallinity and high specific surface area. However, the presence of iron, both in the surface of talc, and in associated accessory minerals often reduces talc refractory properties and diminishes its whiteness, and thus gives it an undesirable colour especially during calcination (Helmy et al., 2005; Jamil and Palaniandy, 2010; Orosco et al., 2011).

It is important to note that talc surface is comprised of two types of surface area: the basal cleavage faces and the edges. The face surface has no charged group. Hence, it is believed that the talc faces are non-polar and hydrophobic, whereas the edges are hydrophilic due to the presence of charged ions (Mg^{2+} and OH^-) (Morris et al., 2005; Ahmed et al., 2007). The major gangue minerals of talc ore include carbonates, magnesite, dolomite, serpentine, chlorite and calcite. These gangues are usually hydrophilic, which often contribute to the production of undesirable characteristics in talc ore. These undesired features are responsible for talc ore not meeting some specific industrial applications (Castro, 1996). In order to make the talc ore economically feasible for industrial uses, these aforementioned impurities must be removed.

Interestingly, several workers have proposed various purification techniques for the talc ore treatments in the literature. The flotation technique, wet attrition and magnetic separation have been reported in the treatment of talc ore to obtain talc suitable for industrial applications (Kho and Sohn, 1989; Piga and Marruzzo, 1992; Yehia and Al-Wakeel, 2000; Perez-Maqueda et al., 2005; Hojamberdiev et al., 2010).

However, these techniques have fall short of the aim of producing purified talc to meeting various industrial uses due to the presence of considerable amount of accessory minerals, high cost, environmental-consideration and even availability of such facilities in developing countries (Rizk et al., 2001; Castillo et al., 2011; Orosco et al., 2011). Therefore, acid leaching technique has been reported to be effective in gangue minerals removal in talc ore. Talc is usually inert in most chemicals and the beneficiated product can be recovered with minimal ease. The acid leaching technique is environmentally friendly with relative economic feasibility. Hence, the acid leaching technique was exploited in the purification of a Nigerian talc ore to obtain purified talc product suitable for possible industrial uses.

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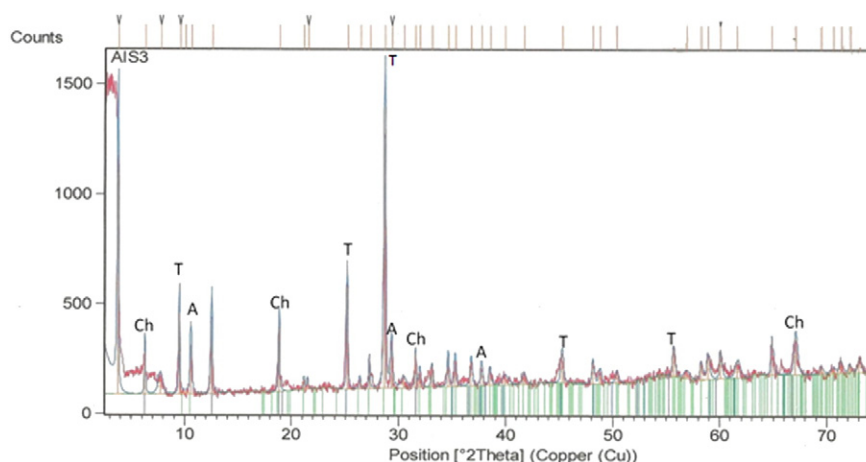
Fig. 1. X-ray diffraction pattern of raw talc ore showing the identified mineral phases: T = talc, A = actinolite, Ch = chlorite.

2. Experimental

2.1. Materials

The talc ore used for this study was sourced from Isanlu area of Kogi State, Nigeria. The talc ore was initially crushed and reduced to fine particles using an acetone-rinsed mortar and pestle. The pulverized ore was sieved into three different particle sizes: −90 + 75, −112 + 90, and −250 + 112 μm using American Society for Testing and Materials (ASTM) standard sieve. Hydrochloric acid was used as the leachant. All experiments, unless otherwise stated were performed using the −90 + 75 μm particle size fraction due to its high surface area.

2.2. Leaching experiments

Leaching experiments were performed in a 250 mL Pyrex glass reactor equipped with a mechanical stirrer. The required temperature of the reactor contents within ± 0.5 °C was adjusted by a thermostatically controlled electric heating mantle. The reactor was filled with 100 mL leachant (hydrochloric acid) with predetermined concentration ranges (0.1–3.0 mol/L). For every leaching experiment, 10 g/L of talc ore was treated with freshly prepared solution mixture heated from 25 °C to 75 °C between 5 and 120 min. Trial experiments were performed in order to assess the optimal leaching conditions. The concentration that gives the maximum dissolution was used for the optimization of other leaching parameters including temperature, and particle size. The residue after leaching was washed with acidulated hot water and then with deionised water. The product was allowed to cool, filtered and dried to constant weight at 80 °C overnight before being analysed.

For each experimental run, the fraction of the talc ore dissolved was evaluated from the initial difference in weight of amount dissolved or undissolved at various leaching times in intervals up to 120 min. The product residue at optimal leaching was accordingly characterized for monitoring the extent of iron removal (Sarquis and Gonzalez, 1998; Yang et al., 2006; Ahmed et al., 2007 and Castillo et al., 2012).

2.3. Characterization

The ground and leached talc residues at optimal leaching were characterized using the MINI PAL 4 EDXRF spectrometer, EMPYREAN X-ray diffractometer, the FEI Nova NanoSEM 230 with an Oxford X-max EDS detector using INCA software to analyse the spectra and the Buck M530 Fourier transform-infrared spectrophotometer for qualitative and quantitative analyses. The spectra obtained in the range of 400 to 4000 cm^{-1} running 100 scans at a resolution of 4 cm^{-1} using the KBr disc technique. Nitrogen gas adsorption–desorption isotherms were measured at − 196 °C using a micromeritics BET, Tristar II 3020. The measurements were performed after degassing overnight at 90 °C. The specific surface area (SSA) of the talc ore was calculated using the Brunauer–Emmet–Teller (BET) method (Brunauer et al., 1938) and the Barrett–Joyner–Halenda (BJH) method was used for determining the pore size distribution from the adsorption–desorption isotherms (Barrett et al., 1951). The total pore volume (V_p) of the raw and leached talc ore was obtained from the maximum amount of N_2 adsorption at a partial pressure (P/P$_0$) of 0.99. The raw and the leached product were further subjected to hydrophobicity/hydrophilicity tests using deionized water and n-hexane, while their specific gravity was also determined (Castillo et al., 2012).
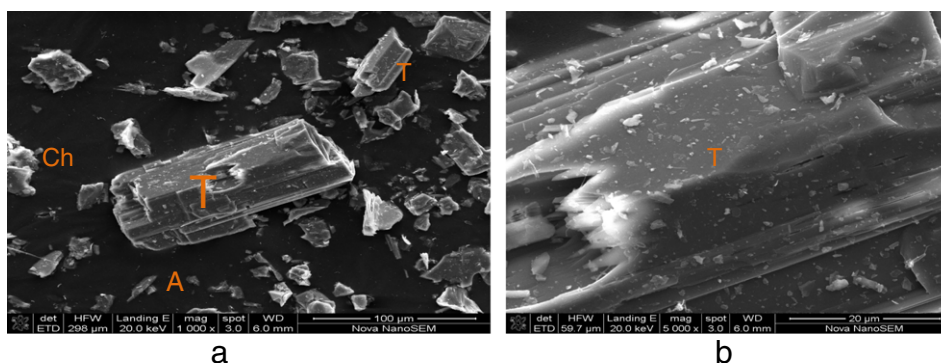

Fig. 2. SEM images of raw talc ore showing the constituent talc (T), actinolite (A) and chlorite (Ch) at different magnifications.