



Aggregation of nickel laterite ore particles using polyacrylamide homo and copolymers with different charge densities



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ABSTRACT

In this work, the effect of polyacrylamide mono and copolymers with different charge densities on the aggregation of nickel laterite ore particles was studied. The methodology involved settling tests, characterisation of the flocs using microscope, and evaluation of the flocs stability. The flocs resulted from the nonionic polyacrylamide were found to be bigger and more stable, than the high charged or low charged ionic copolymers. The settling of particles was also faster when nonionic polyacrylamide was used. On the contrary, the flocs resulted from the high charged density copolymer were small, with very slow settling rate. The size of the flocs obtained experimentally was in a good agreement with those calculated theoretically using Stokes' law.

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1. Introduction

Nickel is an important metal with the total global consumption of about 2 million tons per year. Nickel is sourced from two different types of ores, sulphide and laterite. These days nickel laterites are more attractive for production of nickel as the amount of high-grade nickel sulphide ores has been diminished [1]. Therefore more economic processes to recover nickel from these resources should be developed.

Very limited upgrading of nickel in laterite ores has been achieved by traditional physical separation techniques [2,3]. Therefore, leaching is often used for beneficiation of laterite ores. However, in the early period of commercial heap leaching, percolation within the heap is often a major problem when the ores contain considerable amount of fine particles. The fine particles migrate down and eventually block the pores within the heap [1]. Therefore, aggregation of laterite particles is a critical step for successful heap leaching of nickel laterite ores [4]. For example, effective aggregation has been named as the key to success for the Murrin-Murrin nickel laterite heap leaching in Australia [5].

In principle, flocculation of all minerals should be possible by controlling the ionic composition of the pulp or by using proper polymers [6]. The majority of flocculants employed in mineral processing are polyacrylamide-based high molecular weight polymers. Polyacrylamide is nominally a nonionic uncharged polymer (Fig. 1, top). However, anionic copolymers of polyacrylamide are often used in industry (Fig. 1,

bottom). The ratio of the number of acrylic monomer units to the total number of acrylic and acrylamide units is known as the degree of anionicity. It should be mentioned that while high molecular weight polyacrylamide has been used as flocculant, polyacrylamide (both non-ionic and anionic copolymers) with low molecular weight of 10 to 20 Da have been used as dispersant in mineral industry [7,8].

Zhong et al. [9] used polyacrylamides to flocculate hematite, cassiterite, calcite, quartz, ilmenite and feldspar. McGuire et al. [10] have also used polyacrylamide to flocculate iron oxide minerals. Anionic polyacrylamide copolymers have been reported as the most suitable flocculant to aggregate cement particles [11]. While basic mechanisms governing such aggregation or dispersion in simple mineral systems are well understood, very little is known about the behaviour of complex ores such as nickel laterites. Therefore, the aim of this study is to understand the aggregation of nickel laterite ore. Three different types of polyacrylamide homo and copolymers with different charge densities were used for this purpose. The settling rate, floc structure and stability of the flocs were investigated for each polymer system.

2. Material and methods

The nickel lateritic ore used in this study comes from a laterite deposit in South East Asia and it has a very fine texture. The laterite ore was classified in different size fractions (using sieves) and the fine fraction (i.e. less than 36 µm) was chosen for this study.

The chemical analysis was obtained using X-ray fluorescence technique (XRF) and the ore sample was found to contain 2.5% and 28.9%

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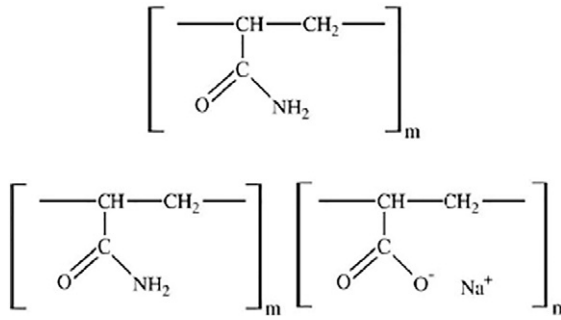


Fig. 1. Chemical structure of standard non-ionic polyacrylamide (top) and anionic copolymer (bottom).

Table 1
Properties of the tested polyacrylamide homo and copolymers.

Polymer	Charge density	Molecular weight, Da [40]
N100	Non-ionic	3.6×10^6
A100	Low, 8%	3.9×10^6
A185	High, 88%	4.0×10^6

Ni and Fe, respectively. The other minor elements were found as 0.2% Co, 0.5% Mn and 0.5% Cr. Nickel was found, more or less, at the same level in all size fractions of the laterite ore sample in the current study. This is different from the result of a previous study where much less Ni content has been reported for the coarse fraction of the laterite ore from an Australian deposit [2]. In the current ore, nickel is distributed in serpentine mineral in the ore sample which in fact counts for about 80% of the ore. This adds more complexity to the physical separation of nickel in the studied lateritic ore. However, it helps us to better investigate the aggregation of the ore particles since serpentine is the major mineral phase. Otherwise, the correlation between mineralogy, structural and behaviour of the laterite ores is quite complex [12,13]. Laterite particles have been even named as complex and high swelling clay minerals [14]; obviously this should not be considered as a general

definition of laterite systems as it can be only valid for those which include high content of swelling clays.

CYFLOCTM samples from Cytec were used as flocculant in this work, namely A185, A100 and N100. The latter is a standard high molecular weight nonionic polyacrylamide (i.e. with no charges) while A100 and A185 are copolymers with low and high charge density, respectively. The trade names and charge densities of the polymer samples as given by Cytec are listed in Table 1. The molecular weights in Table 1 shows the general description of the samples having similar high molecular weights. The samples were obtained as dry, waxy granules (about 1 mm diameter) and were used as received.

Aggregation of the laterite ore sample with different polymers was conducted using a laboratory scale jar test as provided by Cytec (*Laboratory Test Procedure for Flocculants*). In each test, 2.5 g ore sample was suspended in a 50 mL measuring cylinder and 2% polymer was added under agitation. After that the particles were let to settle. Photos were taken at various times during the settling, and the time of settling was measured. Consequently, the rate of settling for each test was determined.

The ore sample, before and after treating with the polymers, as well as the polymer samples were also analysed using Infrared Spectroscopy. Diffuse reflectance (DRIFT) spectra are recorded with a 2 cm^{-1} spectral resolution using a Fourier transform infrared spectrometer (BRUKER IFS 55) equipped with a large-band mercury cadmium telluride (MCT) detector cooled at 77 K and associated with a diffuse reflectance attachment (Harrick Corporation). Sample preparation involves mixing 50 mg of sample with 320 mg of KBr. The absorbance unit used corresponds to the decimal logarithm of the ratio R_{KBr}/R_s where R_{KBr} is the reflectance of the finely powdered KBr used as a reference, and R_s is the reflectance of the sample. Each sample was scanned 200 times (90 s).

The size distribution of the ore sample with or without polymer was estimated using Malvern Mastersizer (Malvern, UK). In each case, 0.5 g of the ore sample was dispersed in water, and the pH was adjusted by NaOH or H_2SO_4 dilute solution if needed. The sample was sonicated for 60 s at 50% ultrasonic power before the measurement when needed. Pump and stirring speeds of 1000 rpm and 450 rpm, respectively, were used during the measurement (unless otherwise stated). Each

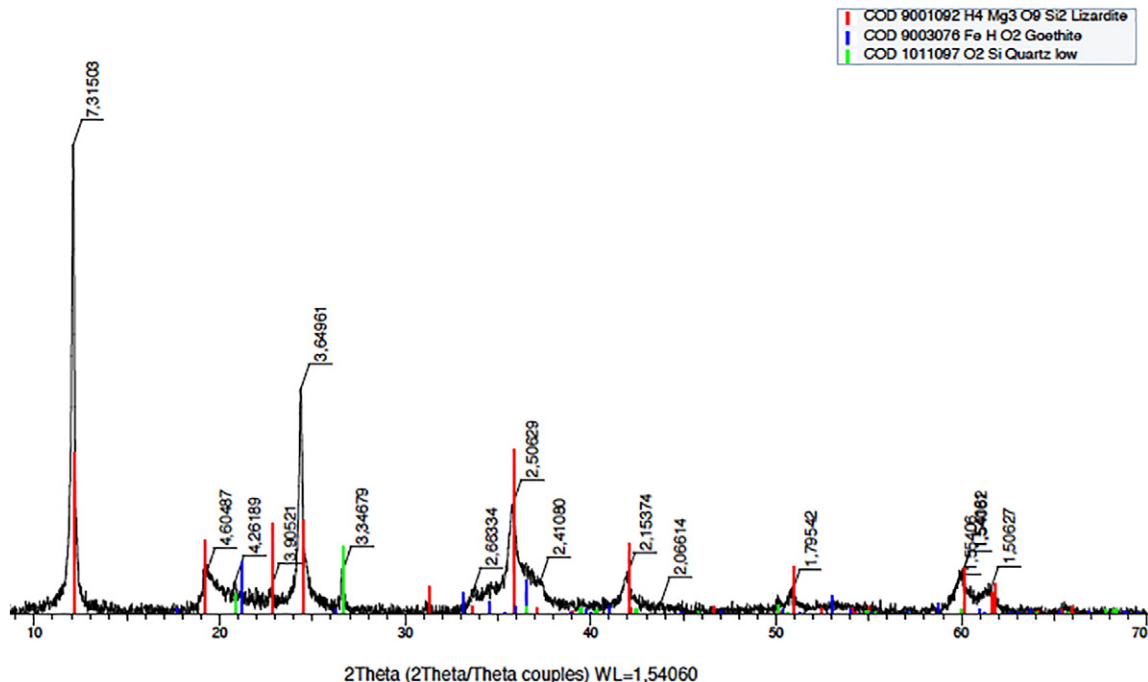


Fig. 2. XRD spectra of the laterite ore sample.

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