

FLOCCULATION OF FINE FLUORITE PARTICLES WITH *CORYNEBACTERIUM XEROSIS* AND COMMERCIAL LONG CHAIN POLYMERS

Lisandra N. Rigo; Angela Maria Pinto; Norimar D'Avila Denardin; Ivo André H. Schneider*

Faculdade de Engenharia e Arquitetura, FAMV, Universidade de Passo Fundo, Passo Fundo, RS, Brasil

Submitted: January 17, 2002; Returned to authors for corrections: April 08, 2002; Approved: September 24, 2002.

SHORT COMMUNICATION

ABSTRACT

This work aimed to study, comparatively, the flocculation of fluorite particles with *Corynebacterium xerosis* cells and three commercial long chain polymers. Best flocculation results were obtained with cells of *C. xerosis* and with an anionic polyacrylamide. Both were effective in solids removal and water clarification, although flocculation with *C. xerosis* cells requires a higher dosage of reagent per mass unit of processed ore.

Key words: *Corynebacterium xerosis*, flocculation, fluorite, polymers

Thickening of mineral/water suspensions is a common operation in the mineral processing industry. The efficiency of such gravity settling operations can be substantially increased by aggregation of the mineral particles, which can be carried out with the aid of long chain synthetic flocculants (4). There is a wide range of flocculants available including polyacrylamides, polyethylene oxides, and polyimines (5,6). These vary in chemical, ionic charge, molecular weight, cross-linking branching, and physical form (e.g. emulsion, gel, powder, or bead). The most common polymeric flocculants used in the mineral processing operations are high molecular weight ($> 10^6$) polyacrylamides (1). These reagents are very efficient even when applied in low dosages (7).

In previous papers, it was shown that the bacterium *Corynebacterium xerosis* is also an excellent flocculant for the minerals fluorite and calcite (2,3). The best cell concentration was determined and the effect of the medium pH was evaluated and discussed. The mechanism of flocculation was proposed to occur by cell bridging. The cells adhere to the solid surfaces, aggregate the minerals, and improve the settling rates of the particles.

However, the use of microorganisms to flocculate minerals is a new technology and it is necessary to evaluate its competitiveness with common flocculants used in the mining industry. Thus, the aim of this work was to study, comparatively,

the efficiency of flocculation of fluorite particles with *C. xerosis* cells as well as with commercial long chain polyacrylamides.

To carry out the experimental work, fluorite crystals (99% CaF_2) were obtained from a mining company (Criciúma - Santa Catarina, Brazil). The crystals were ground in a laboratory mill to particle size below 37 μm (400# Tyler).

The bacterium *Corynebacterium xerosis*, from Caroline Biological Supply Company - USA, was grown for 72 hours in nutrient broth. The bacterium cultures were produced in 300 ml flasks, continuously shaken at 37°C. Cells were harvested by centrifugation, washed twice in distilled water, and suspended in water to give a 2 g/l suspension (dry basis). This stock cell solution was kept at 5°C and used in flocculation studies within 24 hours.

The polymeric flocculants included in this study were an anionic polyacrylamide (Nalco® 9915), a cationic polyacrylamide (Nalco® 8589), and a non-ionic polyacrylamide (Nalco® 4032), supplied by "Nalco do Brasil Ltda" as dry powder polyacrylamides of high molecular weight. The polymers were prepared in stock solution concentration of 0.5 g/l and all solutions were used within 24 to 48 h after preparation.

Flocculation studies were carried out using a standard "Jar Test" apparatus. Settling tests were performed with 1000 ml suspensions containing 10 g/l of fluorite suspended in distilled water at pH 6.0 \pm 0.5. The suspensions were stirred for 1 min at

* Corresponding author. Mailing address: Universidade de Passo Fundo, Faculdade de Engenharia e Arquitetura, FAMV, Campus I, Bairro São José. 99001-970, Passo Fundo - RS, Brasil. Tel.: (+5554) 313-8424. Fax: (+5554) 316-8211. E-mail: ivoandre@upf.tche.br

250 rpm to promote a uniform distribution of the flocculant. The stirrer speed was reduced to 50 rpm for 2 min, to create low shear conditions and allow floc formation. Particles were then allowed to settle under gravity and samples were collected 1 minute after mixing from 10 cm below the water surface. After this, the medium pH was measured and the flocculation efficiency was evaluated by the following parameters:

- naked eye and microscope observation of the floc quality;
- residual turbidity in nephelometric units of turbidity (NTU);
- solids removal from water.

The tests with each one of the reagents were conducted with three replications and the results were expressed by the mean (\bar{x}) and the standard deviation (σ_x).

Table 1 shows the results of flocculation with three long chain polymers and with *C. xerosis* cells. Flocculation was attained with *C. xerosis* cells as well with the anionic and the cationic flocculants. In all these systems, solids removal efficiency was over 96%. However, better flocculation was obtained with *C. xerosis* cells and with the anionic flocculant. It was observed qualitatively by naked eye examination of the floc size and by the residual turbidity of the water. Poor flocculation results were obtained with the non-ionic flocculant.

These results confirm the role of the electrostatic mechanism on adhesion of the bacteria or the flocculant onto mineral particles. At pH 7.0, the fluorite has a high positive charge (about + 60 mV) and the best flocculation results were attained with the negative bacteria (about – 30 mV) (2) or the negative charged flocculant.

Although flocculation with the anionic polyacrylamide was similar in solids removal and residual turbidity to that provided by *C. xerosis* cells, some important differences were observed. *C. xerosis* cells provide larger flocs and higher settling rates. However, the residual turbidity is more variable (see standard deviation results). Bacteria cells not attached to the flocs remain in the water and sometimes it is difficult to determine the best dosage and stirring speed to achieve optimum flocculation and minimum residual turbidity. The results associated with flocculation by the anionic polymer are less sensitive to mechanical and dosage variables.

The dosage of *C. xerosis* cells required to flocculate fine fluorite suspensions is higher than that of long synthetic polymers. Flocculation with *C. xerosis* cells needs about 40 mg/l (or 4 kg/t). Long chain polyacrylamides flocculates the same suspension at concentrations in the range of 2 to 20 mg/l (or 0.2 to 2 kg/t). However, microorganisms can be potentially produced at a lower cost than most of the commercial synthetic flocculants.

Microorganisms are potential low cost flocculants for solid-liquid operations in mineral processing. Further studies concerning the production on large scale of *C. xerosis* are necessary to investigate its competitiveness, and this is now the subject of our current research.

Table 1. Solids removal and residual turbidity after fluorite flocculation with commercial long chain polymers and with the bacterium *Corynebacterium xerosis*. Dosage applied: 40 mg/l of *C. xerosis*, 2 mg/l of polymers and 1 minute settling time.

Flocculant	Solids Removal (%)		Residual Turb. (NTU)		Equilibrium pH		Flocculation quality
	\bar{x}	σ_x	\bar{x}	σ_x	\bar{x}	σ_x	
None	12.2	2.1	99	1.4	6.85	0.06	Null
<i>C. xerosis</i>	97.3	0.2	33	16.2	7.30	0.10	Excellent
Polymer-Anionic	99.2	0.7	31	1.7	6.91	0.12	Excellent
Polymer-Cationic	96.6	1.6	43	12.4	6.86	0.17	Good
Polymer-Non-Ionic	50.3	3.8	88	1.6	6.92	0.16	Fair

RESUMO

Floculação de partículas de fluorita com *Corynebacterium xerosis* e com polímeros de cadeia longa comerciais

O objetivo do presente trabalho foi estudar, comparativamente, a floculação de partículas de fluorita com células da bactéria *Corynebacterium xerosis* e com três polímeros flocculantes comerciais. Os melhores resultados foram obtidos com *C. xerosis* e com uma poliácridamida aniônica. Ambos sistemas são eficientes em termos da remoção de sólidos e na clarificação da água, porém a floculação com *C. xerosis* requer uma dosagem mais elevada de reagente por unidade de massa de minério processado.

Palavras-chave: *Corynebacterium xerosis*, floculação, fluorita, polímeros.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial support provided by the following Brazilian institutions: FAPERGS (process 96/1789.5), CNPq (process 511968/96-8), and CNPq-PADCT (62.0185/98-8).

REFERENCES

1. Besra, L.; Sengupta, D.K.; Roy, K. Flocculant and surfactant aided dewatering of fine particle suspensions: a review. *Min. Pro. Ext. Met. Rev.*, 18: 67-103, 1998.
2. Haas, S.R.; Nascimento, F.R.; Schneider, I.A.H.; Gaylarde, C. Flocculation of fine fluorite particles with *Corynebacterium xerosis*. *Rev. Microbiol.*, 30: 225-230, 1999.
3. Haas, S.R.; Nascimento, F.R.; Schneider, I.A.H. Flocculation of fine calcite particles with *Corynebacterium xerosis*. XXI International Mineral Processing Congress, Rome, 2000, V.A.; p.57-61.
4. Hogg R. Flocculation and dewatering. *Int. J. Miner. Process.*, 58: 223-236, 2000.
5. Kitchener, J.A. Flocculation in mineral processing. In: Ives, K.J. (ed.) *The scientific basis of flocculation*. Alphen aan den Rijn, Netherlands, 1978, p.283-328.
6. Smith, R.W. Liquid and solid wastes from mineral processing plants. *Min. Pro. Extr. Met. Rev.*, 16: 1-22, 1996.
7. Somasundaran, P. Principles of flocculation, dispersion, and selective flocculation. In: Somasundaran, P. (ed.). *Fine particle processing*. New York, AIME, 1980, p.947-976.