BIOFLOTATION OF HEMATITE AND QUARTZ – FUNDAMENTAL STUDIES

L.M.S. Mesquita[1,2], *M.L.Torem*[2] ,*C.A.Lima*[1], *F.A.F.Lins*[1]

[1] CETEM – Center for Mineral Technlogy , CTM – Mineral Processing Coordenation
Av. Ipê 900, Ilha da Cidade Universitária, Rio de Janeiro, R.J. – 21941-590, Brazil
lmesquita@cetem.gov.br
[2] PUC-Rio , Catholic University of Rio de Janeiro
Department of Mterials Science and Metallurgy
Rua Marquês de São Vicente,225,Gávea, Rio de Janeiro, R.J. – 22453, Brazil
torem@dcmm.puc-rio.br

ABSTRACT

The interaction between a bacterial lineage and mineral samples of hematite and quartz was studied through experiments involving zeta potential and contact angle measurements and microflotation tests in modified Hallimond tube. The results showed a strong interaction between the microbial cells and the mineral particles, particularly on the hematite, that presented significant alterations in its surface properties.

INTRODUCTION

The developments in biotechnology have been demonstrating that the use of microorganisms in processes as the bioleaching and in unit operations of treatment of residues originating from of the metallurgical industry are viable (Smith and Misra, 1993). Recent studies come aiming a new area of microorganisms application in the mineral section, the bioflotation. The bioflotation would be a flotation process, in which, microorganisms would act as reagents, collectors or modifiers, making possible the selective separation of a representative mineral of interest of a ore (Deo and Natarajan,1997; Smith et al, 1993).

The presence of functional non-polar groups (hydrocarbon chains) and polar groups (carboxyl, hydroxyl, phosphates) in the microbial cellular surface (cellular wall, capsules, wrappings), give to the microorganisms similar characteristic of the surfactants molecules, what comes to facilitate the employment of some species as collectors or modifiers, substituting them total or partially, in operations of flotation of mineral particles (Dubel et al, 1992).

The recent literature demonstrates the possibility of use microbial species as flotation reagents in the separation hematite-quartz, corundum-quartz (Deo and Natarajan,1998), apatite-dolomite (Zheng et al, 1998) and pyrite-coal (Raichur et al ,1996). It was observed that the interaction between the microbial cells and the mineral particles took to significant changes in the chemistry of surface of the same ones. Such alterations can be possible due to the adsorption of the cells on the mineral surface particles, through electrostatic and chemical interactions.

It is well known that flotation is intimately related with the surface properties of the minerals involved. Therefore, it is essential to understand the mechanisms and the resulting consequences of the microorganism-mineral interaction.

In this work, fundamental studies were accomplished, where possible changes on the surface properties of pure samples of quartz and hematite, were appraised through contact angle and zeta potential measurements and microflotation tests, after interaction with a non-pathogenically bacterial strain previously selected.

EXPERIMENTAL

Mineral samples

Mineral samples of hematite and quartz of high purity were obtained from the Center for Mineral Technology (CETEM).

Ray-X diffraction and scanning electron microscopy (SEM) analysis showed a high purity in both hematite and quartz samples.

Bacterial culture

A bacterial strain denominated RRO 1879 was characterized as a non-pathogenically lineage, gram positive, with a high hydrophobicity degree (contact angle: $70^0 \pm 5$). It was obtained from the collection of the culture of the Fundação André Tosello – SP, Brazil. The strain was growth in culture medium with the following composition: glucose, 8 g/L; NaCl, 5 g/L; $MgSO_4$, 0,2 g/L; KH_2PO_4, 1 g/L; $(NH_4)_2HPO_4$, 5 g/L.

After 48 hours of incubation, in a rotating shaker at 28 °C, the culture was centrifuged and washed with deionized water. The cells were resuspended in a 10^{-4} M NaCl solution of well-known volume. The concentration of the cellular suspension was quantified through dry weight and to follow maid in the tests described to proceed.

Zeta Potential Measurement

The zeta potential values of hematite and quartz samples, as well as, the microbial cells were measured using a Malven ZetaMaster S. The mineral samples (-400 mesh fraction) were dispersed in a 10^{-4} M NaCl solution, and the pH was adjusted for different values being used diluted solutions of HCl and NaOH.

In the accomplishment of the tests, the mineral samples were analyzed before and after interaction with the microbial cells. The interaction time was of 15 minutes with a cellular suspension of 600 ppm in different pH values.

Contact Angle Measurements

The measures of contact angles were accomplished being used a Goniometer model 100-00-115 Ramé-Hart-Inc. The top of the pastille for each mineral sample was carefully polished using distilled water and alumina powder. The samples were clean with jets of distilled water to remove small stuck particles.

The methodology used for contact angle evaluations was the same used by Raichur et al (1996). Some drops of cellular suspension in the concentration of 600 ppm were placed on the polished surface of the pastille and left in rest by 10 minutes. After this time, the samples were washed with 10^{-4} M NaCl solution so that remove the bacterial cells not stuck. The pastille was dry in a Sotelem to vacuum, for approximately 15 minutes to 45 °C.

The measures of contact angle were made being used the method of the captive bubble on the surface, after 5 minutes of equilibrium. The ionic force was maintained with 10^{-4} M NaCl solution. The pH were adjusted for the same values of the cellular suspension previously used.

Microflotation Tests

The microflotation tests were performed in a modified Hallimond tube. About 1.0 gram of mineral sample (-150+200 mesh fraction) was used. The mineral sample was conditioned by 10 minutes in 135 mL of cellular suspension of well-known concentration, for different pH values, adjusted with diluted solutions of NaOH and HCl. The flotation was conducted during 5 minutes under a air flow rate of 0,7 mL/min. After this time the mineral particles floated were recovered, dried and weighted. The flotability corresponds to the percentage flotation recovery.

The detailed experimental procedure is described elsewhere (de Mesquita, L. M. S., 2000)

RESULTS AND DISCUSSION

Zeta Potential Measurements

The Figure 1 presents the curves of zeta potential for cells of RRO 1879, and for the hematite and quartz samples, as a function of the pH values.

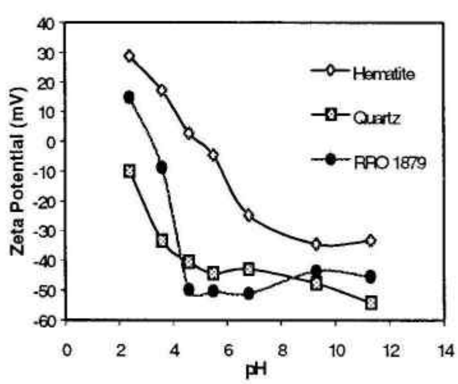

Figure 1 – Zeta potential as a function of the pH for hematite, quartz and RRO 1879 cells. Ionic Force: NaCl 10^{-4} M.

It is observed that RRO 1879 cells come carried negatively over a wide range of pH, with its isoeletric point (IEP) corresponding to a pH value around 3.2. In the case of the mineral samples, it can be verified one IEP corresponding to a pH value of approximately 2.0 for the quartz, and 5.1 for the hematite.

In the Figures 2 and 3 are presented the zeta potential curves for hematite and quartz, respectively, before and after interaction with the microbial cells.

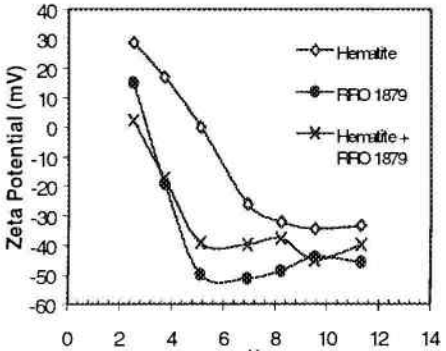

Figure 2 – Zeta potential for hematite before and after the interaction with a cellular suspension of RRO 1879. Ionic Force: NaCl 10^{-4} M.

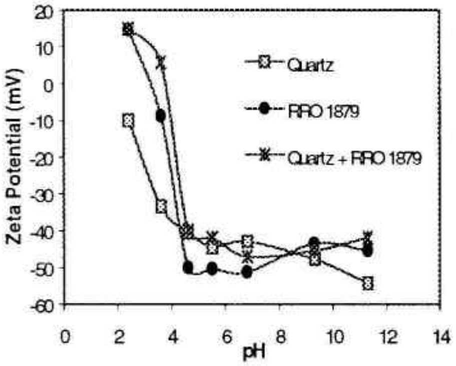

Figure 3 - Zeta potential curves for quartz before and after the interaction with a cellular suspension of RRO 1879. Ionic Force: NaCl 10^{-4} M.

It is observed a change in the surface properties after interaction with the cells of RRO 1879, for both minerals. There was a displacement in the pH values corresponding to isoeletric points, that moved from 5.1 to 2.6 in the case of the hematite, and from about 2.0 to 3.7 in the case of the quartz. It is interesting to notice that the zeta potential of the minerals assumed close values to the cells, indicating an adsorption to the surface of the mineral particles, mainly for hematite. The shifts in the IEP values is characteristic of a specific mechanism of adsorption (Lyklema, 1983).

For values of pH between 3.2 and 5.1 the cells adsorption on hematite samples would be a result of the electrostatic interaction, since the hematite particles come opposite loaded in relation to the cells of RRO 1879. The same statement can be attributed for the particles of quartz, that is opposite loaded to the microbial cells, for pH values between 2.0 and 3.2.

Similar alterations in the electrokinetic profile, were also observed by Deo and Natarajan (1997) for calcite, quartz, dolomite, corundum and hematite samples, after interaction with cells of Bacillus Polymyxa.

Contact Angles Measurements

The effect of the bacterial adhesion in the contact angle of hematite and quartz particles was studied regarding the pH values. The results are presented in the Figure 4.

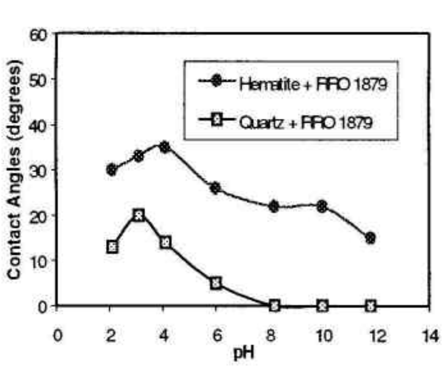

Figure 4 - Contact angle for hematite and quartz as a function of pH, after conditioning with cells of RRO 1879.

In the case of the hematite, it is observed that the effect of RRO 1879 cells stuck to its surface, for all studied pH range. Before the interaction with the microorganism, the surface of the hematite was completely hydrophilic, since its likeness for the air bubble was completely null (values of contact angle such as zero). However, after the interaction, a hydrophobic character could be verified in the hematite, checked by the increase of the contact angle. We can also notice that, for pH values between 2.0 and 4.5, the values of contact angle are higher demonstrating a larger interaction between the microbial cells and the mineral sample in this pH range.

For quartz sample, it was realized that after the microbial interaction, the surface that, initially presented contact angle values close to zero, begun to present angle values between 13 and 20 degrees. However, this change only happened for acid pH values. Nevertheless, the contact angle reached a zero value again for pH above 7.0.

Microflotation Tests

The influence of the cellular concentration and of the pH in the flotability of the hematite and of the quartz, are related in the Figures 5 and 6, respectively. It is observed that, for both minerals, there is an increase of the flotability with the increase of the cellular concentration.

In the Figure 5 we can highlight a good flotability for hematite, about 87%, in pH values around 4, and about 70% for pH values between 6 and 12, when a cellular concentration of 450 ppm was used.

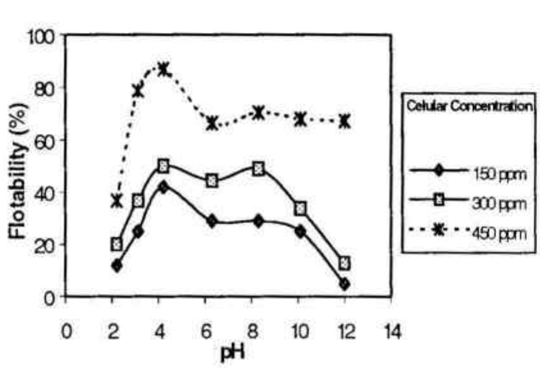

Figure 5 – Flotability of hematite as a function of RRO 1879 cells concentration and pH.

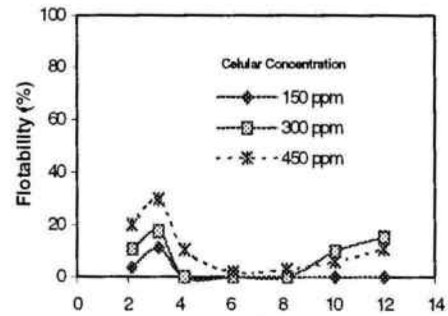

Figure 6 - Flotability of quartz as a function of RRO 1879 cells concentration and pH.

The curves presented in the Figure 6 demonstrate a best, although it lowers (about 30%), flotability for pH values around 3. Practically any flotability for the other pH values was observed.

Those results, allies to the results obtained in the measures of contact angle and zeta potential, indicate a different interaction between the cells of RRO 1879 and the hematite and quartz samples, mainly for pH values above 4.

The hematite particles and quartz present polar surfaces (high likeness for molecules of water), characterizing its hydrophilic character. However, the interaction mechanisms between the cells and the minerals samples seem to be different. In the case of the quartz, the adsorption of the cells to the mineral surface would happen mainly by means of electrostatic interactions among particles opposite loaded, in values of acid pH.

For hematite, besides the physical adsorption (electrostatic interactions), chemical adsorption (hydrogen bonding, chemical interaction forces) would be involved in the bacterial-mineral interaction (van Loosdrecht et al, 1989), resulting in a hydrophobicity of surface and high flotability (about 70%) when pH values above 7.0 are used.

CONCLUSIONS

The results demonstrated a strong interaction among the cells of RRO 1879 and the mineral particles, mainly on the hematite.

The measures of contact angle and flotability indicate that different mechanisms of interaction are involved, mainly for pH values above 4, independent of the concentration cellular used.

For a constant ionic force, 10^{-4} M NaCl, the alterations in the surface properties were shown strongly dependent of the pH values.

The flotability of the hematite particles (about 70%) after conditioning with cells, indicate a possible application of the culture of RRO 1879 as a flotation collector, in the separation between quartz and hematite, for pH values between 7 and 12.

ACKNOWLEDGEMENTS

The author would like to acknowledge CNPq, CAPES and the Center for Mineral Technology (CETEM) for their support.

REFERENCES

de Mesquita, L.M.S., "Bioflotation of hematite and quartz- A Study of Selectivity", Doctorate Thesis, PUC-RIO, 93p., 2000 (in portuguese).

Deo, N., Natarajan, K.A., "Studies on interaction of Paenibacillus polymyxa with iron ore minerals in relation to beneficiation", Int. J. Miner. Process., 55:41,1998.

Deo, N.; Natarajan, K.A., "Interaction of Bacillus polymyxa with some oxide minerals with reference to mineral beneficiation and environmental control", Minerals Engeneering, 10,12:1339,1997.

Dubel, J., Smith, R.W., Misra, M., Chen, S. "Microorganisms as chemical reagents: the hematite system", Minerals Engineering, 5:547,1992.

Lyklema, J. Adsorption of small ions. In: Partiff, G.D. and Rochester, C.H., Adsorption from solution at the solid/liquid interface. Academic Press Inc., p.223,1983.

Raichur, A.M., Misra, M., Bukka, K., Smith, R.W. "Flocculation and flotation of coal by adhesion of hydrophobic Mycobacterium phlei", Colloids and Surfaces B: Biointerfaces, 8:1,1996.

Smith, R.W., Misra, M. "Recent develops on the bioprocessing of minerals", Minerals Processing and Extractive Metallurgy Review, 12: 37,1993.

Smith, R.W., Misra, M., Chen, S. "Adsorption of a hidrophobic bacterium onto hematite: implications in the froth flotation of the mineral", Journal of Industrial Microbiology, 11:63,1993.

van Loosdrecht, MCM; Lyklema, J.; Norde, W. and Zehnder, A.J.D., Bacterial adhesion: A physicochemical approach. Microbiology Ecology, 17, p.1, 1989.

Zheng, X.P., Smith, R.W., Mehta, R.K., Misra, M., Raichur, A.M. "Anionic flotation of apatite from dolomite modified by the presence of a bacterium", Minerals & Metallurgical processing, 15, 2:52,1998.