Processing Tincal Ores using Ultrasonic Waves

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ABSTRACT: In this study, effects of ultrasonic sound waves have been studied on the processing of tincal ores using ultrasonic baths producing 35 kHz frequency and 1.24 W/cm^2 intensity. Tincal ores (24.37 *90B2O3)* were processed in saturated solutions for 15 minutes and a concentrate containing 35.29 % B2O1 was obtained with 95.69 % recovery. During ultrasonic treatment boron minerals were found to corrode to a small extent. These findings showed that efficiency of dispersion process was proportional to directly treatment time and indirectly to the sample quantity, solids density and particle size.

1. INTRODUCTION

Ultrasonic energy consists of vibrations or sound waves above the frequencies (18000 Hz) normally heard by the human ear. An ultrasonic generator is used to produce high frequency alternating electrical current which is transformed into mechanical vibrations by a transducer.

In non-elastic media such as continuous transition occurs when the intensity of the sound is relatively low (Figure 1).

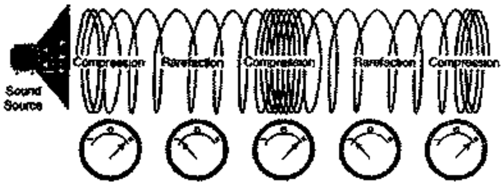

Figure 1. The coils of a spring to represent individual molecules of a sound conducting medium.

As amplitude'is increased, however, the magnitude of the negative pressure in the areas of rarefaction eventually becomes sufficient to cause the liquid to fracture because of the negative pressure, causing a phenomenon known as cavitation (Figure 2).

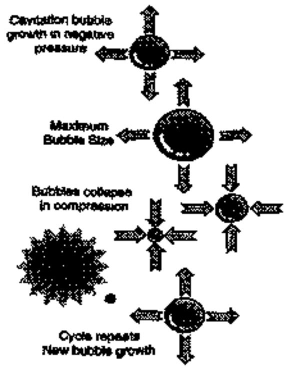

Figure 2. Cycle of cavitation in a liquid medium under ultrasonication.

Cavitation bubbles are formed at sites of rarefaction as the liquid fractures or tears due to the development of negative pressure by the sound wave. The cavitation bubbles oscillate under the influence of negative pressure eventually grow to an unstable size. This leads to the release of high degree of pressure and temperature in the cavity. The violent collapse of the cavitation bubbles then results in radiation of shock waves from sites of the collapse (Figure 3). After collapse of cavity, shock waves and high velocity micro jets of liquid are formed (Leucker, 1998).

Figure 3. Picture of the collapse of a bubble.

In cavitation near surfaces, the implosive collapse is not spherically symmetric and a localized micro jet of liquid is driven into the surface at extremely high velocities (Figure 4). These produce impacts on solid surfaces, thus erode them (Neppiras, 1984). In addition, the resultant shock waves may also fracture friable solids. Acoustic streaming, a microscopic turbulence which enhances liquid-surface mass transport, also occur under such conditions. (Suslick, 1987).

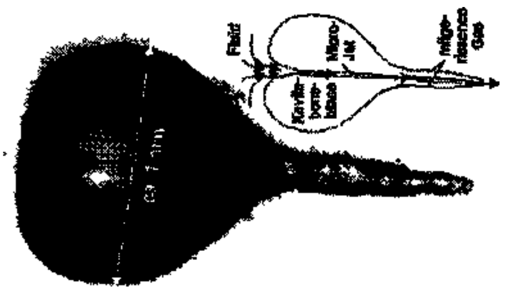

Figure 4. Collapsing of a cavity with the formation of micro jet of liquid.

Cavitation develops most easily on solid-liquid interfaces, since solid-liquid interactions are weaker than liquid cohesion forces. The importance of cavitation in processes such as cleaning and dispersion is largely attributed to the very high pressure locally produced as a result of the collapse of the cavities. There for ultrasonic sound waves may be potentially used in many applications of mineral processing (Brown, 1965).

The change of flotation properties under the influence of ultrasonic energy was reported by several investigators (Kowalski and Kowalska, 1978; Nicol et all, 1986; Slaczka, 1987; Djendova and Kovatcheva, 1996; Özkan and Veasey, 1996; Çelik et all, 1998; Gaidarjiev and Stoev, 1994). These studies suggested that ultrasonic energy can be used to improve the kinetics, selectivity and recovery of useful minerals during flotation.

Intensive ultrasonic vibrations can effectively disperse and disaggregate fine-grained materials (Gibson, 1963). Ultrasonic energy could be used successfully to separate the grains with minimum physical contact. Ultrasonic energy with acoustic power input between 55 and 100 watts per cm^2 and a frequency of 10 to 20 kHz can be successfully used to disaggregate friable to moderately cemented sandstone. Lower frequencies and higher intensities promote disaggregation and reduce the time required. Rate of disagregation is a function of the type of cementing materials involved and may be controlled by the shape and volume of irradiation chamber and the pressure within the chamber (Overbey, 1970).

Boron minerals occur often as associated with clay and carbonate minerals. The clayey and micro granulate structure could be disintegrated by ultrasonic waves to recover boron minerals (Alp, 2000). In this study, effects of ultrasonic waves on the processing of a tincal ore were studied.

2. EXPERIMENTAL

2.1. Material

Samples used in the study were obtained from Kırka Tincal Concentrator. The chemical composition of the ore sample and size fractions are shown in Table 1 and 2 (Alp, 1998).

Table 1. The chemical composition of the sample.

Compound	Amount, %
B_20_3 (Ha)	24.80
B2O3 (H_20)	24.66
SİO2	6.56
R2O3	1.11
CaO	6.36
MgO	6.00
Moisture	5.10

Table 2. B2O3 contents and distributions with respect to the size fraction of the sample.

Particle Size mm	Amount %	»fr	Distribution %
-6.0+1.0	67.30	23.36	64.95
-1.0	32.70	25.95	35.05
Total	100.00	24.20	100.00

Mineralogical analyses of the samples were carried out using X-Ray Difractometer and a microscope. Montmorillonite, tincal, calcite and dolomite were identified in the samples (Figure5).

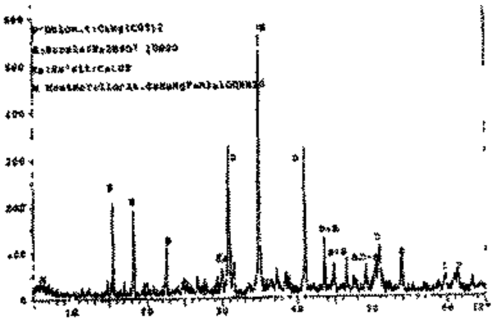

Figure 5. XRD profile of the tincal ore sample

2.2. Experimental procedure

The instrument used in the study was the Ultrasonic Cleaner (Retsch URG). The Ultrasonic Cleaner combines frequency generator and bath of stainless steel in a single housing. The ceramic oscillator generates high energy oscillations underneath the bath, and thus, a cavitation effect in the entire bath fluid (Figure 6). It has an average power output (at the transducer) of 250 watts at 35 kHz frequencies. The intensity of the ultrasonic field in the liquid phase inside the vessel was 1.24 W/cm^2. Cleaner was designed as a tank with 24 cm in diameter, 13 cm in depth and an effective capacity of 61.

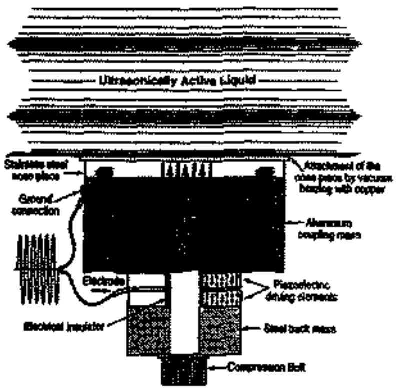

Figure 6. Coupling between the transducers and the liquid medium.

In the experiments, samples were placed in the bath and certain amount of water was added. The ultrasonic generator was turned on and allowed to run for a predetermined period of time. After irradiation period, samples were washed and decanted to remove fine materials.

Ultrasonically dispersed materials filtered, dried and then separated into size fractions and weighed. In each treatment stage, B2O3 content of each product was analyzed and distribution of B2O3 was determined.

Effects of ultrasonic irradiation time (0-20 min.), sample quantity (250-1500 g), solids density (10-30% by weight) and particle size (-6 mm) were investigated. Experiments were conducted at 18-20°C under atmosphere pressure.

3. RESULTS AND DISCUSSION

Initially, effect of treatment time on the removal of clay from ore particles was examined and the results are shown in Figures 7-10. The B2O3 content of +0.037 mm fraction was observed to increase with increasing treatment time and it was recoded to be 36.12 % B2O3 over treatment period of 20 mm (Figures 7 and 9). This corresponded to a loss of 6.39 % B_2O_3 in to -0.037 mm fraction, which could be attributed to the corrosion of tincal under ultrasonic treatment (Figure 8-10).

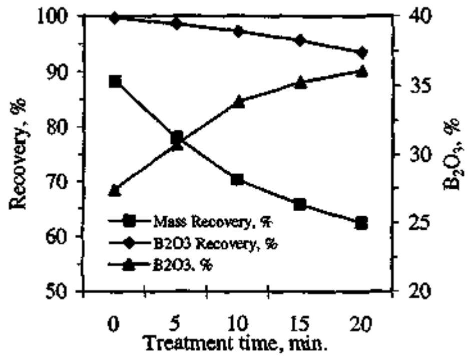

Figure 7. Effect of treatment time on the grade and recovery of B_2O_3 from tincal ore (250 g, -6 mm) at 20% w/w.

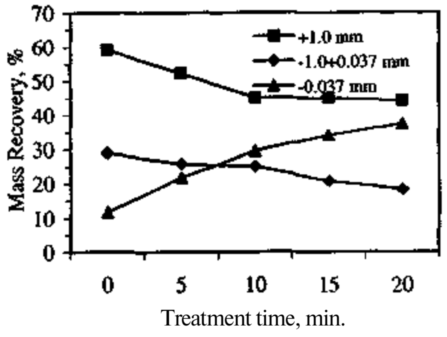

Figure8. Effect of treatment time on the mass recovery into the different size fractions (250 g, -6 mm at 20% w/w).

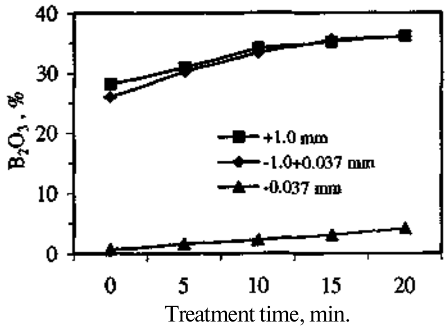

Figure 9. Effect of treatment time on the B_2O_3 content of the different size fractions (250 g, -6 mm at 20% w/w).

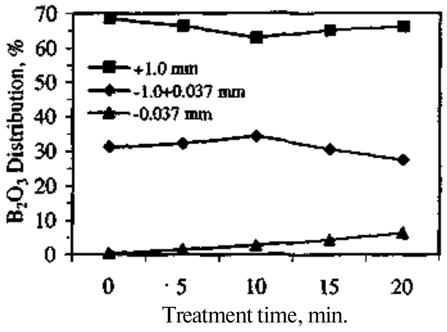

Figure 10. Effect of treatment time on the B_2O_3 recovery into the different size fractions (250 g, -6 mm at 20% w/w).

Figures 11-13 illustrate the effects of sample amount, percent solids and particle size on the removal of the clay particles. The increase in the amount of solids (at 20% w/w) (Figure 11) and solids density (Figure 12) was found to adversely affect the separation of clay fractions. Effect of particle size on the recovery and content of B_2O_3 was noted to be insignificant (Figure 13).

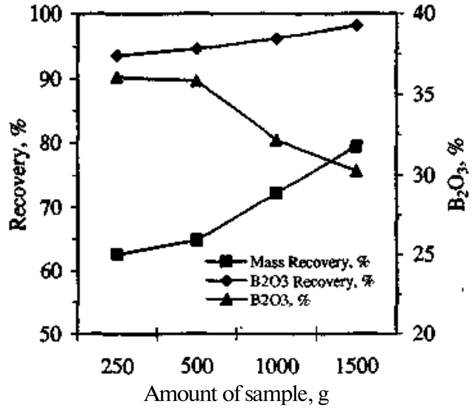

Figure 11. Effect of sample amount on the grade and recovery of B_2O_3 from tincal ore at 20% w/w (-6 mm, 15 min.).

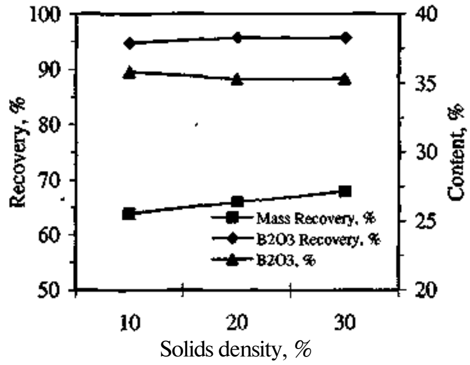

Figure 12. Effect of solids density on the grade and recovery of B_2O_3 from tincal ore (-6 mm, 250 g, 15 min.).

SEM analysis of the sample before and after ultrasonic treatment showed the impact of ultrasonic cavitation on solids surfaces where the development of pits was apparent (Figure 14).

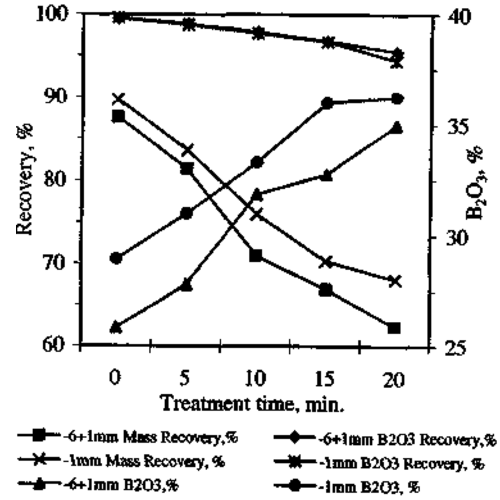

Figure 13. Effect of particle size on the grade and recovery of B_20_3 from tincal ore (250 g, 15 rain, 20% w/w).

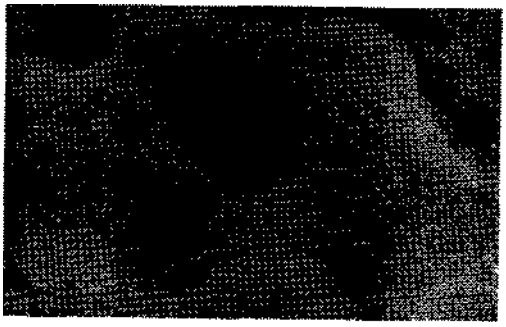

Figure 14. A SEM photograph showing a clayey particles after ultrasonic treatment.

4. CONCLUSIONS

Ultrasonic energy has great potential for the improvement of the kinetics and effectiveness of mineral processing techniques. This study has shown that ultrasonic waves can be used to aid the removal of clay particles from tincal ores. Solids density, amount of sample appear to adversely influence the removal process while the increase in treatment time improves the separation of clay from tincal.

Further studies should focus on the increasing cavitation intensity to enhance the effectiveness of ultrasonic treatment on clay removal process. Cavitation intensity can be increased by modulating properties of the conducting liquids: temperature, dissolved gas, surface tensions, viscosity, ultrasonic power, ultrasonic frequency.

REFERENCES

Alp, t, 1998. Investigation of usebility of ultrasonic sound waves in mineral processing, PhD Thesis, Osmangazi University, Eskişehir, (in Turkish).

Alp, I. & Özdağ, H., 2000, Investigation of the processing of colemanite tailings by ultrasonic sound waves, Mineral Processing on the Verge of the 21st Century, Özbayoğlu et al. (eds), Balkema, Rotterdam, pp. 693-696.

Brown, B.& Goodman, E.J., 1965. High intensity ultrasonics: Industrial applications, Diffe Books Ltd., London.

Çelik, M.S., et al., 1998. Effect of in-situ ultrasonic treatment on the floability of slime coated colemanite, Proceedings of 7th International Mineral Processing Symposium, Istanbul, Turkey, pp. 153-157.

Djendova, S.D. & Kovatcheva, V.K., 1996. Application of tube hydrodynamical sound-generator for water treatment in the flotation process, Proceedings of 6th International Mineral Proc. Symposium, Kuşadası, Turkey, pp. 271-277.

Gaidarjiev, S. & Stoev, S., 1994. Separation by ultrasonic degassing of flotation pulps, Proceedings of 5th International Mineral Processing Symposium, Ankara, Turkey, pp.173-177.

Gibson, M., 1963. Ultrasonic disaggregation of shale, Journal of Sedimentary Petrology, 33, 4, pp. 955-958.

Kowalski, W. & Kowalska, E., 1978. The ultrasonic activation of non-polar collectors in the flotation of hydrophobic minerals, Ultrasonics, 3, pp. 84-86.

Leucker, R., 1998. Cavitation, iww.kavitation.html

Neppiras, E.A., 1984. Acustic cavitation: an introduction, Ultrasonic, 6, pp. 25-28.

Nicol, S.K., et al, 1986. Fine particle flotation in an acoustic field, Int. J. Min. Proc, 17, pp. 143-150.

Overbey, W.K., 1970. Disaggregation of sandstones by ultrasonic energy, Journal of Sedimentary Petrology, v 40, n 1, p. 465-472.

Özkan, Ş.G. & Veasey, T.J., 1996. Effects of simultaneous ultrasonic treatment on colemanite flotation, Proceedings of 6th. International Mineral Processing Symposium, Turkey, pp. 277-281.

Slaczka, A., 1987. Effect of an ultrasonic field on the flotation selectivity of barite from a barite-fluorite-quartz ore, Int. J. Min. Process.. 20, pp. 193-210.

Suslick, K.S. et al., 1987, Effects of high intensity ultrasound on inorganic solids, Ultrasonic, 25, pp. 56-59.