REMOVAL OF FINE PARTICLES FROM WASTEWATER USING INDUCED AIR FLOTATION

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Abstract: The suspended solids must be removed from effluent prior to re-using or discharging into environment. In order to remove the fine particles, large basins are needed to provide sufficient retention time due to the extreme low settling velocities, therefore flocculants or coagulants have to be added to increase the settling velocity and efficiency of settling basins. For removing suspended particles from wastewaters, flotation and floc-flotation methods are getting attention recently due to their advantages over the other methods. In this study, IAF process (Induced Air Flotation -Jameson Flotation) was applied to synthetic wastewater containing fine quartz particles. Preliminary results of flotation experiments which were carried out by Jameson flotation cell were given. Effect of particle size and solid/liquid ratio on the turbidity removal efficiency was researched. The synthetic wastewater samples containing suspension of very fine quartz particles was pre-treated with/without anionic flocculant addition and then introduced to the Jameson flotation cell with cationic type collector (amine). Reasonable turbidity removal efficiencies were obtained for the particles larger than 20 µm, however the results were not good as for the -20 µm particles. The experimental works have shown that over 90 % turbidity removal efficiency of -20 µm particles was possible at the lowest solid/liquid ratio (0.06 %) tested when floc-flotation studies was applied by Jameson cell.

Keywords*:* Wastewater treatment, flotation, flocculation, induced air flotation, Jameson cell.

INTRODUCTION

A large amount of wastewater from industrial and municipal usage has been generated due to the faster development of urbanization and technology, and hence, the increase in production and consumption. These wastewaters have been given to the nearest rivers, lakes, seas, etc. From this point of view, the necessity of wastewater control before disposing them to the environment is a very important topic (Russel, 2006). The wastewater containing fine particles is generally pretreated through sedimentation, filtration and flotation methods prior to discharge or recycled to reuse the treated wastewater instead of fresh water (Şener, 2007). In order to remove fine particles flocculation and coagulation methods are commonly applied to provide sufficient retention time to settle the slow settling fines (Gregory, 2005; Bratby, 2006).

Selection of wastewater treatment process is generally based on several factors such as the wastewater characteristics, the effluent standards to be met and the cost of treatment. The settling tank is designed for an overflow rate of 1-2 m/h. This may be considerably increased by the use of polymers as flocculants. An alternative to traditional settling is the use of flotation. Flotation tanks are designated for much higher overflow rates (5-15 m/h) and they can give a better separation results since smaller particles may be removed (Odegaard, 2001).

The flotation experience in the mineral processing area has been extended to wastewater treatment for many decades, broadening its potential for wastewater treatment (Rubio at al., 2002;

Rosa and Rubio, 2005). Finely dispersed air bubbles are brought into contact with the chemically conditioned wastewater stream where particle bubble attachment occurs. The particle ladened bubbles float to the surface where they are removed from the wastewater stream being treated (Jameson, 1999; Orr, 2000; Kotze, et al., 2001; Yan and Jameson, 2004).

In mineral flotation the particles are quite large, typically having diameters of 50 µm or more (Matis and Zouboulis, 1995). Therefore, bubbles have to be large usually of the order of 1 mm, while the solid content in the pulp is normally high, of the order of 25 % by weight and a high selectivity between solids is generally wanted (Matis and Zouboulis, 1995). In effluent treatment by contrast, the particles are typically small (less than 20 µm in diameter), close to neutral buoyancy, and present in very dilute concentrations, often as low as 50 mg/L or 50×10^{-4} % w/v (Matis and Zouboulis, 1995). Since the particles in the feed of wastewater flotation are usually very small and often within the colloidal range, depending on the density, since larger particles are more easily removed by a simple gravity settler. To increase the mean particle size and thus increase the rate of collection by the air bubbles, the particles are usually treated with a flocculant or coagulant (Jameson, 1999).

Many flotation methods were developed in wastewater treatment and developments have been still continuing. The dissolved air flotation (DAF) is more common in the treatment of wastewater (Colic at al., 2007). Recently, the other flotation method offering many advantages over DAF is induced air flotation (IAF). In IAF, the air can be entered to the system without needing a compressor. In DAF, the size of the bubbles generated when the pressure of the air-saturated feed is reduced is very small (100 µm<). While such bubbles very effective in the collecting flocs and small particles, they also have correspondingly small terminal velocities, leading to relatively large equipment sizes. The use of larger bubbles are found in IAF, can lead to the development of flotation systems which are much more compact, provided proper attention is paid to the surface chemistry of the particles or flocs to be floated (Jameson, 1999).

The air bubbles occurred in classical IAF is much bigger than those needed for wastewater flotation and do not suitable for the process. Jameson developed an improved version of IAF (Jameson, 1988). The Jameson IAF cell was developed initially for the flotation of fine coal and metallic ores (Evans, et al., 1995). It has been adapted for the treatment of wastewater in 1994. Some of the most important advantages of Jameson IAF over DAF are: the flocs generated are floated in a short time period, the sludge floated contains higher solid ratios, the device has more compact design (much smaller than DAF) and it can be operated at higher degrees (up to 70 ^{0}C) (Jameson, 1999; Yan and Jameson 2004).

The aim of this study was to research the potential usage of Jameson flotation cell in removal of suspended quartz particles. Previously, the studies about quartz flotation in Jameson Cell has been published by us (Taşdemir et al., 2007) using the cationic collector of aeromine and by Çınar et al. (2007) using dodecylamine system. These studies were based on recovery of quartz removal containing high particle concentrations and higher particle sizes. In this research, we tried to float the quartz particles from synthetically prepared wastewater suspensions which have very low particle concentrations. Synthetic suspended wastewater samples were prepared at different size fractions and different solid/liquid ratios. The samples which were pre-treated with or without using anionic flocculant were subjected to flotation tests in Jameson cell by using cationic type collector (amine). Preliminary results of turbidity removal experiments are given here.

MATERIALS AND METHOD

Synthetic wastewater samples containing fine quartz particles for flotation were prepared. The pure quartz sample used in the experiments was obtained from the Milas-Çine region of Turkey. The sample was sized to three fractions as -53+38 µm, -38+20 µm and -20 µm.

To search the relation between solid/liquid ratio and turbidity of quartz particles used in the experiments, turbidity measurements were carried out for different size fractions. Turbidity values of suspended quartz particles at different size fractions are given in Fig.1 as a function of solid ratio. As it is seen in this figure, turbidity increases with increasing solid ratio in the wastewater sample as expected. There are exponential relation between the solid ratio and turbidity. Different turbidity values were obtained at same solid ratios for different size fractions. As the particle size decreases, higher turbidity values are obtained for the same solid ratio in the samples. Therefore, higher turbidity values are obtained for the -20 µm with the same quantity of powder compared to larger sizes.

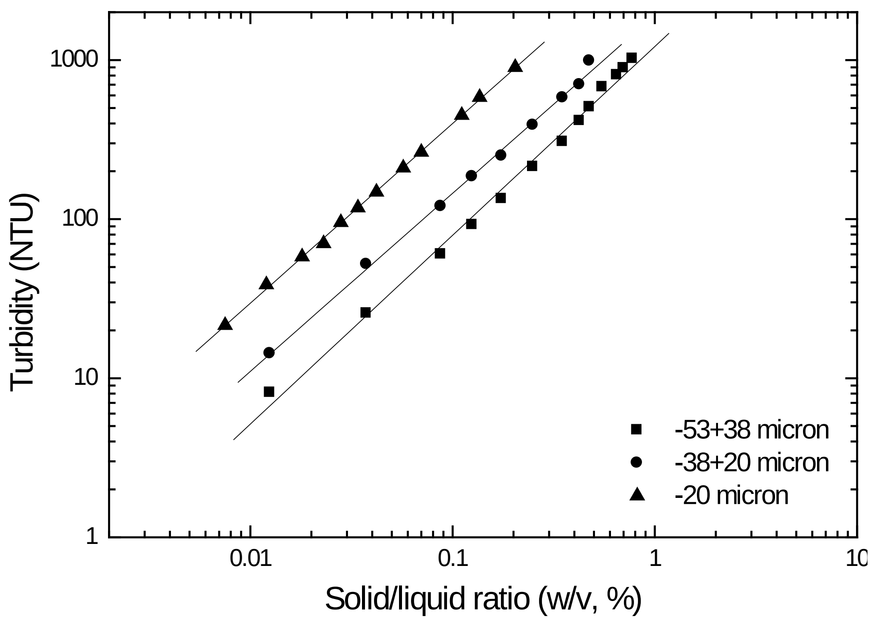

Figure 1. Turbidity values of different sized quartz particles in synthetically prepared wastewater samples as a function of solid ratio.

An experimental setup used in this study is shown in Figure 2. It consists of a separation tank (145 mm), downcomer (25 mm), a conical type nozzle (3 mm), pressure gauge on the feed line, air flow rotometer on the air line, conditioning tank with stirrer. The separation tank and the downcomer were made of transparent plexiglas. Wastewater and reagents were conditioned in the tank before flotation. After conditioning, wastewater feed is delivered to the nozzle under the high pressure by means of a peristaltic pump. The pulp comes out of the nozzle with a great speed and takes the air with it to the pressure difference. The air broke up into fine bubbles and created a very favorable environment for collision of particles and bubbles. The bubbles which are loaded with particles disengage from the wastewater and rise into the froth layer.

In the flotation tests, the feed flow rate was controlled with control panel of feed pump; thus, desired flow rates of feed slurry can be adjusted. Similarly, a peristaltic pump with a control panel for the end of cell was used for the recirculation of the cleaned effluent to the feed tank. The system was operated at closed circuit through the experiments at a steady state. The floated sludge did not circulated to the feed tank again and obtained as separately, but the residual slurry in the separation tank was sent to the feed tank. After 10 minutes of flotation time, the residual turbidity was measured as NTU (Nepheleometric Turbidity Unit) by using HF Scientific turbidimeter which has 0-1000 NTU measurement ranges. The turbidity removal efficiencies were calculated as a result.

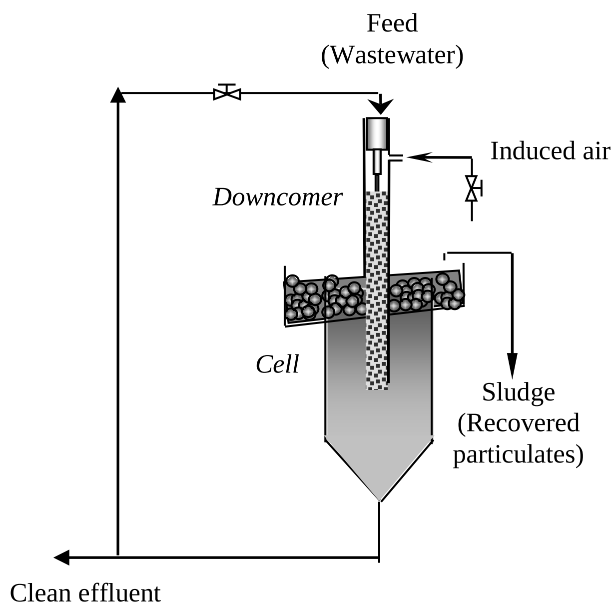

Figure 2. Experimental setup of Jameson cell

EXPERIMENTAL

The synthetic wastewater prepared by using different sized quartz samples at different solid/liquid ratio was treated by a laboratory scale Jameson cell. Experimental conditions of flotation tests are given in Table 1. Feed flowrate, feed pressure, jet length, jet velocity conditioning time and pH were held constant in all experiments. In each case, the conditioning tank was filled with 20 liters of water and sized quartz to achieve a certain percent solid. The collector (Aeromine produced by Cytec in the Netherlands and the frother (Aerofroth 65 produced by Cytec in the Netherlands) dosages were held constant as 500 gr/t and 20 ppm respectively during the experiments. The collector was added and conditioned for five minutes. The frother was added and conditioned for a further two minutes.

Table 1. Experimental conditions of flotation tests

Immersion depth of downcomer (cm)	70
Nozzle diameter (mm)	3
Jet length (cm)	3
Feed pressure (KPa)	110
Feed flowrate (L/min)	7
Jet velocity (m/sec)	16.5
Conditining time (min)	5
pH	8
Frother (AF65) dosage (ppm)	20
Collector (Aeromine) dosage (g/t)	500
Flocculant (Anioic) dosage (mg/L)	0.06 ; 0.1; 0.5
Particle size (µm)	-53+38; -38+20;-20
Solid/liquid ratio (%)	0.06; 0.1; 0.5

RESULTS AND DISCUSSION

The first preliminary flotation tests were carried out without flocculant addition. The preconditioned feed slurry having different size and solid ratio was introduced to the Jameson cell. The comparative results of residual turbidity measurements obtained are given in Fig.2. It is seen that solid ratio and the particle size are very important parameters during flotation in Jameson cell, with increasing solid ratio leading to higher turbidity removal recoveries in all size fractions (Fig. 3). The low turbidity removal results at low solid ratios are mainly due to the low probability of bubble-particle collision. The turbidity removal efficiencies for particles larger than 20 µm are higher compared to -20 µm particles. This is due to the fact that as the particles are getting smaller the collision probability between air bubbles and the particle's surface decreases. However, turbidity removal efficiency decreases with increasing of particle size (>38 µm) for lower particle concentrations. The main reason for poor flotation recovery of coarse particles is the high probability of detachment of particles from the bubble surfaces. In general, collision probability increases with increasing particle size and decreasing bubble size. In general, the size of bubbles in Jameson Cell varies between 300-600 micron (Evans, et al., 1995). Fine particles have low probability of collision with bubbles and are thus difficult to catch by bubbles. This is the main reason for the low flotation rate of fine particles.

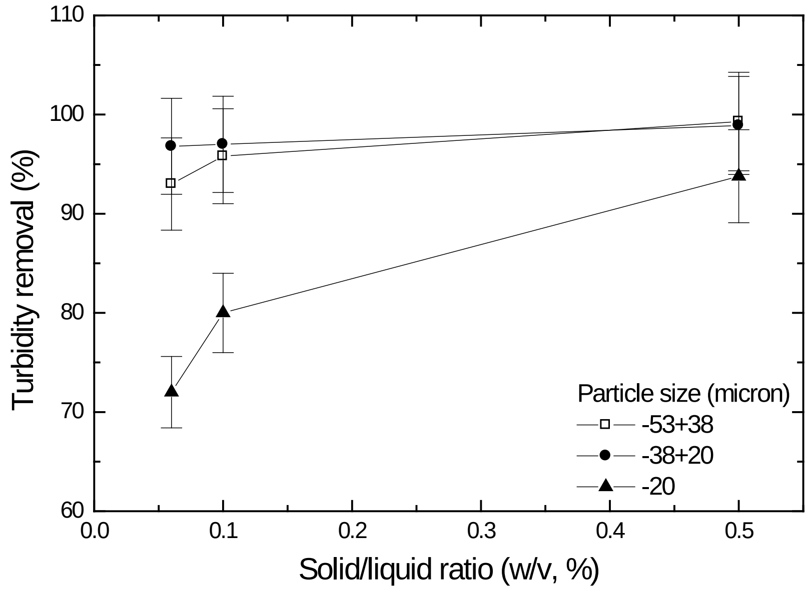

Figure 3. Effect of solid ratio and particle size on turbidity removal without flocculant addition.

To improve the turbidity removal efficiency of -20 µm size fraction, two stage flotation experiments were carried out at different solid ratios. In two stage flotation experiments, the residual wastewater was floated after adding the collector and conditioning 5 minutes, then this conditioned slurry was subjected to Jameson cell for additional flotation. The results of residual turbidity measurements obtained from the single and two stage flotation tests are shown in Fig. 4. Applying two stage flotation increased the turbidity removal efficiency for all solid ratios of -20 µm. These indicate that better turbidity removal efficiency of suspended particles can be achieved when the two stage flotation was applied. The lowest turbidity removal efficiency was achieved about 85 % for the 0.06 % solid ratio.

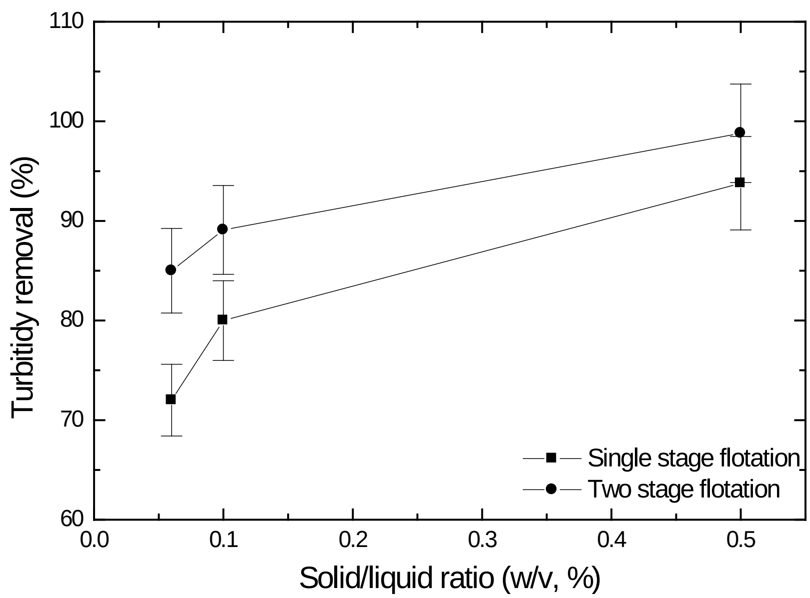

Figure 4. The turbidity removal results of -20 µm size in the single and two stage flotation at different solid ratios without flocculant addition.

Floc-flotation experiments were also made for the -20 µm size fraction to search the effect of flocculation process on the turbidity removal efficiency. In a previous study (Taşdemir and Erdem, 2010), the effects of some flocculation parameters such as flocculant type, molecular weight of flocculant, flocculant dosage, pH of suspension and mixing speed on flocculation process were examined in details for synthetic wastewater samples containing pure quartz particles. According to that study, the best result was obtained when anionic flocculant having high molecular weight was used at pH 8.

The samples containing different solid ratios were preconditioned with anionic type flocculant (SPP 508) which was supplied from Süperkim Chemistry Co. According to jar tests which made for -20 µm size fraction, the optimum dosages of the flocculant was determined as 0.06 mg/L, 0.1 mg/L and 0.5 mg/L for 0.06 %, 0.1 % and 0.5 % solid ratios respectively.

Flotation results of Jameson cell obtained are given in Fig. 5. The turbidity removal efficiency was very high for the particles preconditioned by flocculants than non-flocculated particles. Over 90 % turbidity removal efficiency was achieved for the lowest solid/liquid ratio (0.06 %). The results better for the higher solid/liquid ratio samples. After flocculating the fine particles, the collision probability between the flocs and bubbles generated would increase compared to non-flocculated particles.

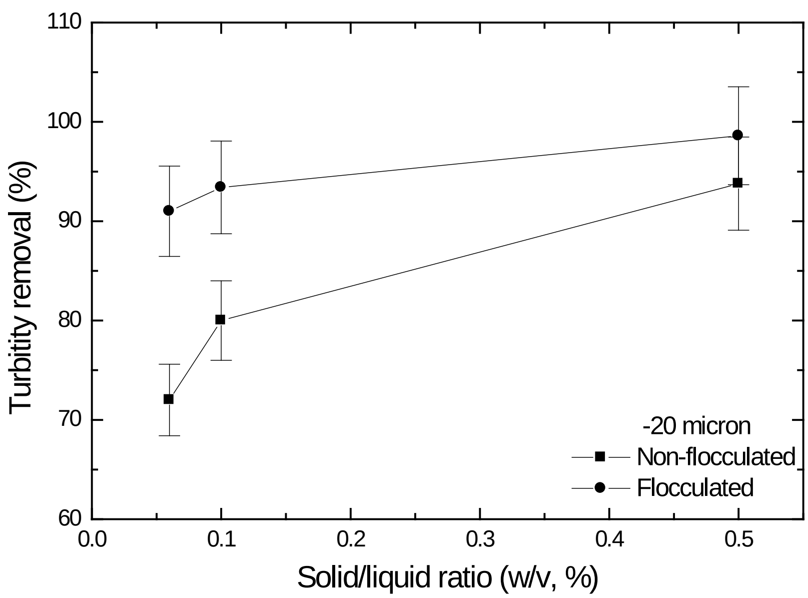

Figure 5. Effect of flocculant on turbidity removal of -20 µm size fraction at different solid ratios.

Based on the zeta potential measurements, the surface charge of quartz is found negative after pH 3 in literature (Viera and Peres, 2007). Achieving high turbidity removal efficiency with anionic type flocculant cannot be explained by physical adsorption of flocculant molecules on the quartz surface. It can be troughed that cationic flocculant might give better results with quartz removal since the surface charge of quartz at pH 8 is negative. But according to results anionic type flocculant gave better results than the cationic flocculant for quartz flocculation (Taşdemir and Erdem, 2010). This is due to different flocculation mechanisms of flocculants and here the bridging mechanism is effective for the quartz flocculation with anionic flocculant. Bridging is considered to be consequence of the adsorption of the segments of flocculant macromolecules onto the surfaces of more than one particle (Tripathy and Ranjan 2006; Şener, 2007).

CONCLUSIONS

Induced air flotation based on the Jameson cell technology has been applied successfully to the removal of synthetically prepared suspended particles in wastewaters. With proper condition of the feed water, the particles which are greater than 20 µm in the wastewater samples can be removed effectively by a single flotation stage without using flocculant. The increase in solid ratio increased the turbidity removal efficiency of all size fractions. Compared to larger particles, the results were not good for the particles smaller than 20 µm. Two stage flotations ensured to improve the results of this size fraction. When the -20 µm sizes of quartz samples was pre-conditioned by the anionic flocculant it was possible to obtain over 90 % turbidity removal efficiency in single stage flotation for the lowest solid ratio (0.06 %) and higher efficiencies for higher solid/liquid ratios tested. The main advantages of Jameson cell are rapid collection of particles in the downcomer and relatively small footprint, high throught, rapid start-up and low chemical usage, the ability to operate at elevated temperatures. Therefore it offers technical advantages over existing technologies for a range of new applications.

ACKNOWLEDGEMENTS

This study is a part of project which was supported by Eskişehir Osmangazi University Scientific Research Projects Committee (Project No: 200815020). The authors gratefully acknowledge the financial support from the organization.

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