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Ultrasonic aggregation for removal of fine particles from mine drainage treatment process.

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1. Introduction

Recent years, the treatment after developing mine and utilizing the resource is becoming the big issue. In the area near the dead mines, because of influence of the excavation for utilizing the resources(metal, coal etc.), water containing high concentration of unwanted material like metal elements flows out from the mine. The water is called 'mine drainage'. This highly contaminated water induce severe environmental problems directly connected the health of the local resident. Now, most of the countries are trying to purify the mine drainage by constructing the electrochemical and physicochemical treatment plant that is also used in the drinking water treatment. Although the purification methods are applied in the real system, the fine particles remain and come out with the effluent, which raise the secondary pollution such as 'yellow boy' phenomenon [1]. The fine particles suspended in the water are the main reason of the secondary pollution because it mainly consists of calcite($CaCO_3$) and goethite(FeOOH). Especially, the goethite can make the area colored into yellow and reddish brown. It is anticipated that the fine particles can be removed by applying the coagulation/flocculation process, which is ususally used for the removal of suspended solid in the water treatment plants.

According to some reports, some researcher found that irradiation of ultrasound in the water can generate some interesting effect. It is expected that the ultrasonic irradiation can mix the water mechanically and particle growth is occurred during the mixing, which lead the particle to be bigger and settleable [2-3]. Moreover, due to the wave characteristics, there are nodal points that collect and aggregate the particles in local points in the water [4-5]. Based on these mechanisms, ultrasound can aggregate the particles in the water and it seems that ultrasound can be applied for the removal of suspended solids instead of flocculation process.

In this study substitutional application of ultrasound for the aggregation of the particles (flocculation process, slow mixing stage) is investigated. The effects of the characteristics of ultrasound such as frequency and power were studied. Other experimental parameters were also studied to find out the most effective condition.

2. Materials and Methods

2.1 Materials

Alum($Al_2(SO_4)_3 \cdot 14\text{-}18H2O$, 51.0-57.5% SAMCHUN) is used as a coagulant. The solid form sludge particles from mine drainage treatment process(Hambeak mine, Korea) are ground and used as suspended solid particles in the water. Deionized water(Millipore Milli-Q) is used for making the solution.

2.2 Experimental Procedure

2.2.1 Devices and Reactor

Sonicators(500kHz, MX-1S50/1MHz, MX-1S100, MIRAE ULTRASONIC TECH.) are used for generating ultrasound. Water cooling type cooler (DH003AH, DAEHO) controls the temperature within ±1°C accuracy. For the simulation of precedent coagulation process, mechanical mixer (MS3060D, MTOPS) with propeller is used. Turbidimeter(HACH, 2100Q) is used for measuring the turbidity of the water. The ultrasonic reactor used in this study is composed of a round shape transducer at the side and a cubic tank (100mm × 51mm × 100mm, length × width × height, approximately 500mL) that can contain the water.

2.2.2 Procedure

First, 0.25g of ground sludge particles are put into the 500mL of deionized water to make turbid water with suspended solids. Before irradiation of the ultrasound, coagulation process is carried out. Initial turbidity values of the sample solutions are checked. For the experiment of investigating the effect of the ultrasound characteristics like frequency and power etc., applied coagulant dosage is 10mg/L. More alum can reduce more turbidity value. (If high dosage of alum is used, turbidity value is reduced almost by the effect of the coagulation process not by the effect of the ultrasound.) 5mg of Alum is put into the 500mL of the sample solution, and then using mechanical mixer, the solution is mixed for 1min, 120rpm. After mechanical mixing, the beaker with the solution is put into the ultrasonic reactor for the irradiation of ultrasound. The temperature during the sonication is 25±1°C. After solution is irradiated, 30 min is given for the settling and then turbidity of the solution is measured by turbidimeter. By analyzing turbidity change of the solution, the effect of the ultrasound is evaluated. For the comparison, experiments of no alum are conducted in same procedure.

3. Results and Discussion

3.1 Aggregation characteristic by sonication

Fig. 1. shows the results of the effect of ultrasound in the case of 1MHz with no alum. It indicates that there is fluctuation in turbidity values. Though no alum is added to the solution, there is possibility of the substitional usage for the coagulation/flocculation(1MHz, 15min, 60% of turbidity value decrease vs. Mechanical mixing, 30min, 62% of decrease). During ultrasonic irradiation, the bubbles are formed and collapsed because ultrasound generates the periodic pressure change in the water. Bubble behaviors(generating and collapsing) can act as mechanical forces that induce particle aggregation and deaggregation. In addition to the mechanical force, ultrasonic cavitation bubble can produce microjet [2], extreme condition(~5000K, ~500atm) and hydroxyl radical (·OH) [2,6]. Chemical effects caused by temperature, pressure change and radical generation etc. can also change the characteristics of aggregation of the particles. The presence of both good and bad effects on the aggregation can make the fluctuational change of the turbidity.

3.2 Effect of Frequency, Power and Reactor

Table 1 and Fig. 1**.** show the results of the conditions of 500kHz and 1MHz. In the case of 40W/cubic shape reactor, the performance of 1MHz, 4secs with alum is the most effective. For 1MHz /cubic shape reactor, 60W with no alum is better than 40W with no alum and 40W with alum. It seems that alum has adverse effect on the ultrasonic removal of suspended solid when irradiation time becomes longer. Theoretically, 60W, 1MHz is more effective than 60W, 500kHz and 40W, 1MHz. The possible reason is that higher frequency and power of the ultrasound generates the higher power of acoustic radiation force [5]. The particles are aggregated at the each of the nodal points. The number of collected particles at one nodal point is proportion to the power of the acoustic radiation force. The particles collected at one nodal point cannot make settleable flocs if there is no enough force to make a bond between the particles. Frequency affects the number of cavitation bubbles, which has a relationship with the chemical effect of the ultrasound and also mechanical force of bubbles in the water [2,6].

In the case of cubic reactor with side transducer, 40W with alum for both frequencies, the breakage of the flocs is detected when the irradiation time is longer than 1min. Cylindrical reactor, 40W with alum shows the best removal efficiency.

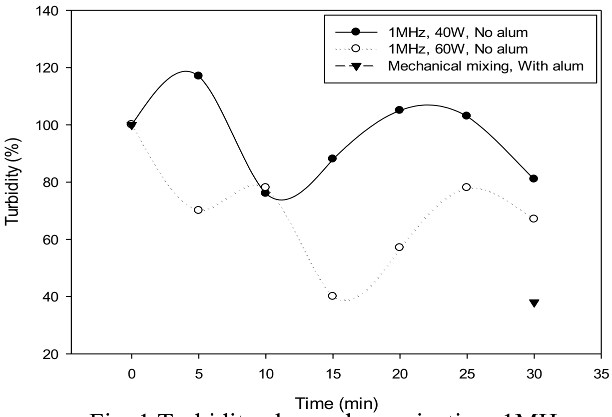

Fig. 1 Turbidity change by sonication, 1MHz

Table. 1 Turbidity values at different conditions

Turbidity with alum (NTU)				
Condition	40W, 500kHz 5mins	40W, 1MHz 5mins	**40W, 1MHz 4secs**	*40W, 500kHz 5mins
Initial	111	105	**117**	128
Final	110	160	**77.3**	48
Turbidity with No alum (NTU)				
Condition	40W, 500kHz 5mins	60W, 1MHz 5mins	**60W, 1Mhz, 15mins**	*40W, 500kHz 5mins
Initial	112	127	**108**	128
Final	98	89	**43.4**	56

*Different type of reactor is used for the experiment, cylindrical tank (Φ97mm × 161(H)mm) instead of cubic reactor.

4. Conclusion

Coagulant(Alum) has an adverse effect for the ultrasonic removal of suspended particles when the ultrasound density is too high(reactor with no reflector; alum is helpful agent.). Higher power and frequency has better performance. By comparing the results between ultrasonic and conventional tre-atment, ultrasound can be applied for the flocculati-on process but the effect of parameters should be studied further.

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