Color and suspended solid removal with a novel coagulation technology

D. Pak and W. Chang

Water Environment Research Center, Korea Institute of Science and Technology, PO Box 131, Cheongryang, Seoul 130-650, Korea (E-mail: *daewon@kist.re.kr*)

Abstract A novel coagulation technology using atomized molten slag with ferrous sulfate has been developed to treat a turbid and colored water or wastewater. The atomized molten slag is produced by atomizing the molten slag from the steel-making process. The atomized molten slag has magnetic iron oxide in its constituent molecules so that it is magnetized. In this novel coagulation technology, the atomized molten slag acts as nuclei for coagulation process and weighting agent for the resultant floc. In this study, this new coagulation technology was compared with metal hydroxide flocs such as $FeCl_3$ and PAC in treating textile wastewater. A batch settling test was conducted to investigate the settling characteristic of sludge formed with the atomized molten slag. The settling velocity of sludge formed with the atomized molten slag is almost ten times greater than that of sludge formed with $FeCl_3$ or PAC. The coagulation using the atomized molten slag showed a higher removal rate of color, suspended solid, TOC, COD, TKN and T-P. The atomized molten slag is capable of adsorbing organic substance, ammonia and phosphate. This characteristic leads to higher removal rate than $FeCl_3$ or PAC. The gel permeation chromatography of the wastewater treated using the atomized molten slag illustrated that this novel coagulation technology is more efficient in removing the particles with low molecular weight. The removal rates of color, suspended solid, COD, TOC, ammonia and phosphorous increase with increasing amount of atomized molten slag addition. Even though the atomized molten slag was overdosed, restabilization of particles was not encountered.

Keywords Atomized molten slag; coagulation; color removal; suspended solid removal; textile wastewater treatment

Introduction

A novel coagulation technology has been developed to remove color and suspended solids from wastewater. This technology utilizes weighted particles to enhance the action of primary coagulants such as ferrous sulfate. The particles can act as nuclei for the coagulation process and as weighting agents for the resultant floc. The particles are produced by atomizing the molten slag from the steel-making process. The atomized molten slag is cooled rapidly by spraying water on it. During the cooling process, metal ions in the molten slag combine with one another to construct a composite form having a structure of spinel-type such as CaO, Fe_2O_3 and Mg_2O_3. The structure of spinel type is a kind of crystal structure and makes slag chemically stable. Due to magnetic iron oxide in its constituent molecule, this particle is magnetized.

The magnetic particles have been used to enhance the coagulation of a turbid and colored water (Al-Qahtani, 1996; Coey and Cass, 2000; White and Amornraksa, 2000). The metal hydroxide flocs formed with magnetic particles settle rapidly because of high density. Coagulation using magnetic particles was reported to be effective in turbidity and color removal (Anderson *et al.*, 1980; Dixon, 1984; Kolarik, 1983). Because of high cost, attempts were made for the magnetic particles to be regenerated but complete regeneration could not be achieved (Anderson *et al.*, 1980; Dixon, 1984). In this novel coagulation technology, the slag wasted from the steel-making industry is atomized to be magnetic particles (otherwise it has to be disposed to landfill). This makes atomized slag particles attractive for being used as nucleating and floc-weighting agents.

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In this study, the atomized molten slag was tested to see if it was an effective nucleating and floc-weighting agent. Atomized molten slag was sieved to obtain particles of less than 0.1 mm size. Ferrous sulfate and synthetic polyelectrolyte were used in conjunction with the atomized molten slag. This novel coagulation technology was applied to textile wastewater treatment and compared with $FeCl_3$ and PAC.

Materials and methods

Batch coagulation test

The atomized molten slag was obtained from Ecomaister Co. and processed to provide particles of 0.1 mm. Batch experiments were carried out to test the effectiveness of this novel coagulation technique using the atomized molten slag with ferrous sulfate. Wastewater to be tested was obtained from a textile industry in Korea. To carry out the batch tests, wastewater was poured into 500 ml beaker at room temperature. Beakers were then mixed to ensure dissolution of coagulants.

Analyses

Before and after the runs, samples were withdrawn and analyzed for COD, suspended solid (SS), TKN, total organic carbon (TOC) and total phosphorus. COD, SS and TKN were analyzed according to *Standard Method*. TOC concentration was determined using a Shimadzu (5000-A) Total Organic Carbon Analyzer. In order to find molecular weight distribution in the wastewater, gel permeation chromatographic samples were analyzed at room temperature on a column (Shodex GF-310 HQ) in a chromatograph (Spectra System P2000) equipped with a detector (Shodex RI-71). The solvent was distilled water and its flow rate was 0.6 ml/min.

Results and discussion

Settling characteristic of sludge

The interface between the sludge and the clarified supernatant can be observed in a batch settling test. The interface height versus time curve is shown in Figure 1. The initial rate at which the interface subsides represents the settling characteristic of the sludge. The initial rate can be computed from the slope of hindered settling portion of the interface height versus time curve. Table 1 shows that the initial rate of sludge formed with molten slag is almost ten times greater than that formed with $FeCl_3$ or PAC. This indicates that the area required for clarification can be reduced compared with $FeCl_3$ or PAC.

Comparison with metal hydroxide

Figure 2 shows that, after application of 2,000 mg/l atomized molten slag with ferrous sulfate, color level of textile wastewater is markedly reduced from 4,740 CU to 60 CU. Excellent color removal may be attributable to the atomized molten slag. In the absence of atomized molten slag, an acceptable color removal was difficult to achieve. Color level was reduced to 610 CU and 505 CU with ferric chloride and PAC, respectively. This indicates that the atomized molten slag may adsorb the substance causing color. Figure 2 also shows that coagulation removes TOC of textile wastewater. Coagulation usually can remove particulate TOC. However the coagulation using atomized molten slag with ferrous sulfate

Table 1 Initial rate computed from the interface height versus time curve

Coagulant	Molten slag	$FeCl_3$	PAC
Initial rate (cm/min)	9.7	1.0	0.8

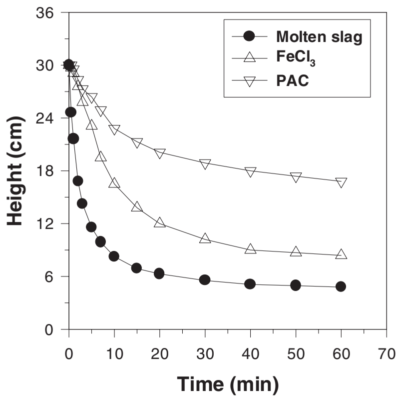

Figure 1 Interface height versus time curve in a batch settling test using 2,000 mg/l molten slag, $FeCl_3$ and PAC

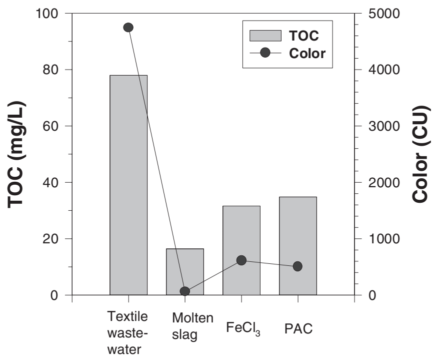

Figure 2 Color and TOC removal from textile wastewater by different coagulants

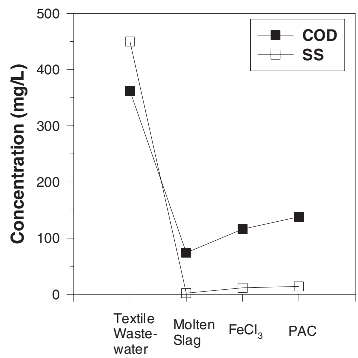

Figure 3 Suspended solid and COD removal from textile wastewater by different coagulants

removed TOC more than $FeCl_3$ or PAC. This again confirms the adsorption capacity of the atomized molten slag for soluble organic substance.

Figure 3 shows that suspended solid concentration is markedly decreased from 450 mg/l to 2 mg/l by coagulation using the atomized molten slag with ferrous sulfate. The removal efficiency of suspended solids is higher than $FeCl_3$ or PAC. The atomized molten slag particles can enhance the agglomeration of destabilized particles into bulky floccules. These bulky floccules with high density settle down in 2–3 minutes. This results into high suspended solid removal. As mentioned previously, the atomized molten slag may adsorb soluble organic substances. This leads to higher COD reduction rate of atomized molten slag than $FeCl_3$ or PAC as shown in Figure 3.

Figure 4 shows that the coagulation using the atomized molten slag is able to remove ammonia from wastewater. NH_3-N concentration was decreased from 23 mg/l to 12 mg/l by coagulation using the atomized molten slag. $FeCl_3$ or PAC was not able to reduce NH_3-N concentration. This is due to the adsorption capacity of the atomized molten slag for ammonia. The atomized molten slag was also efficient in removing phosphate from wastewater. Total phosphorus concentration was reduced from 6.78 mg/l to 0.13 mg/l. $FeCl_3$ and PAC are also efficient in removing phosphate from wastewater. The metal ions are known to react with phosphate for precipitation. However the adsorption capacity of atomized molten slag for phosphorus enhances its removal efficiency.

Figure 5 illustrates that the coagulation using the atomized molten slag is able to promote the formation of the floc. Floc is the agglomeration of destabilized particles after addition of

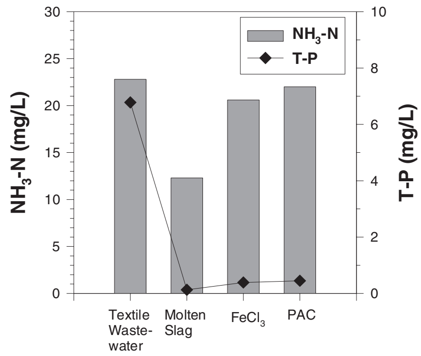

Figure 4 Comparison of ammonia and T-P removal from textile wastewater by different coagulants

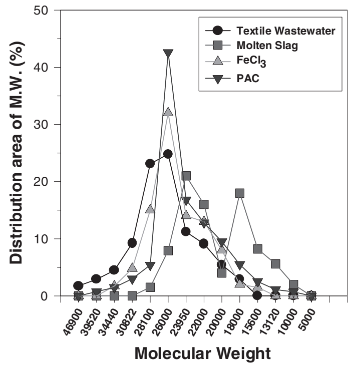

Figure 5 Molecular weight distribution of the substance in wastewater treated with different coagulants

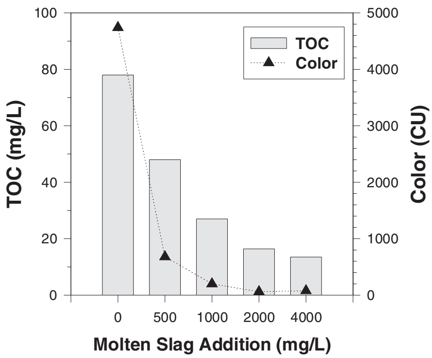

Figure 6 TOC and color removal from textile wastewater by molten slag addition

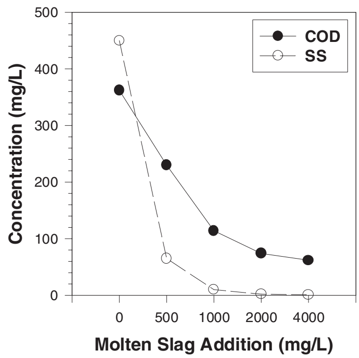

Figure 7 COD and SS removal from textile wastewater by addition of molten slag addition

coagulant. The atomized molten slag was able to help the particle of low molecular weight participate in the agglomeration of particles. Therefore the atomized molten slag was able to remove the particles of low molecular weight that $FeCl_3$ or PAC could not remove.

Optimization of molten slag addition

Figure 6 shows that TOC and color removal rate depends on the amount of atomized molten slag addition. The removal rates of TOC and color increase with an increase in molten slag addition. The amount of molten slag addition can be determined between 1,000 mg/l and 2,000 mg/l. Figure 7 shows COD and SS removal from textile wastewater after addition of atomized molten slag. Due to the adsorption capacity of the atomized molten slag for organic substance, COD removal rate increases with an increase in molten slag addition. SS removal rate increases as molten slag addition increases. Restabilization due to overdosing was not encountered during the experiment.

Figure 8 shows that the removal rates of ammonia and phosphorus are increase with an increase in molten slag addition. This indicates that the atomized molten slag has the adsorption capacity for both ammonia and phosphorus. It seems that the atomized molten slag adsorbs more phosphorus than ammonia.

Conclusions

A novel coagulation technology using the atomized molten slag with ferrous sulfate is more efficient than $FeCl_3$ or PAC in removing color and suspended solids from textile

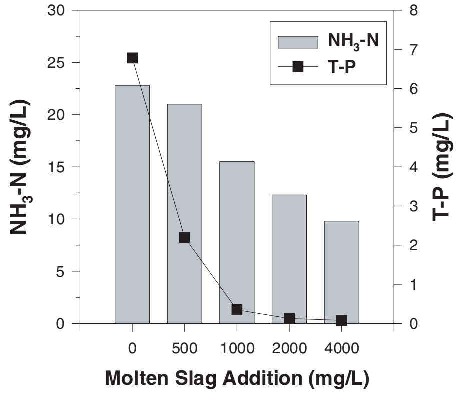

Figure 8 NH_3-N and T-P removal from textile wastewater after molten slag addition

wastewater. The atomized molten slag is capable of adsorbing organic substance, ammonia and phosphate. This characteristic leads to a higher removal rate than $FeCl_3$ or PAC. The settling velocity of sludge formed with molten slag is ten times greater than that observed with sludge formed with $FeCl_3$ or PAC. The removal rate of color, suspended solid, COD, TOC, ammonia and phosphrous, increases with increasing amount of molten slag addition. Even though the atomized molten slag was overdosed, restabilization of particles was not encountered.

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