Abstract

Mineral industry processes such as the washing of coals and the concentration of metalliferous ores involve wet processes that require substantial amounts of water. Under ideal practice the process water should be recycled, however, usually significant portion of this water is discharged into rivers. Among other undesirable environmental characteristics, the downstream portion of the process water contains high concentration of suspended solids, high turbidity, and sluggish settling rate. These effluents generally have harmful implications for the biological systems that depend on the water bodies.

The downstream plant water must undergo solid-liquid separation process prior to recycling or discharging it into rivers with a view to abate water pollution. Earlier, for solid-liquid separation, inorganic coagulants were used which were less effective. With the advent of polymeric flocculants since 1950s, mineral industry is also benefited through the use of polyacrylamide and its copolymers in the thickener systems. Polyacrylamide is, however, disadvantageous in terms of its shear degradability. A new class of graft copolymers has been developed as flocculating agents by grafting synthetic polymers, like polyacrylamide, onto natural polysaccharides such as starch and its ingredients, carboxymethyl cellulose, and sodium alginate. Such graft copolymers possess high flocculating efficiency by virtue of their better approachability to the solid particles. Due to the presence of the polysaccharide backbone, they are highly shear resistant and to some extent biodegradable too. A few earlier investigations in bentonite, kaolin, and iron ore slimes have indicated the prospect of the use of the graft copolymers in the treatment of mineral industry fines.

Improving the coal quality for the blast furnace applications by washing the coking and the semi-coking coals has been a practice in India. The washing of low-grade non-coking coals is rapidly emerging as a technique owing to the considerations of coal transportation and the environmental effects of fly ash and air pollution. Coupled with this, the mining of inferior ores and the increased beneficiation activity of coal put extra pressure on the already scarce water resources. The need for developing effective solid-liquid separation processes for
the mineral industry is therefore, justified and important. Further, the coal fines thus collected have attractive commercial value.

The efficacy of the flocculation process is assessed in terms of the solids settling rate, and the clarity of the supernatant liquid. The present study deals with an in-depth investigation into the aspects of flocculation by the laboratory developed graft copolymers and the commercial flocculants in the synthetic suspension of coking, semi-cooking, and non-cooking coal fines. Also studies have been conducted on some mineral fines suspensions, and some actual coal washery effluents.

Five graft copolymers, viz. starch-g-polyacrylamide (St-g-PAM), amyllopectin-g-polyacrylamide (Ap-g-PAM), amyllose-g-polyacrylamide (Am-g-PAM), carboxymethyl cellulose-g-polyacrylamide (CMC-g-PAM), and sodium alginate-g-polyacrylamide (SAG-g-PAM) were synthesised and used in this study. The procedure of synthesis of these graft copolymers was outlined. Sufficient proof was established for the high percentage of grafting, to the tune of 80%, that had taken place. These graft copolymers were characterised by viscometry, IR spectroscopy, thermogravimetry, and scanning electron micrography. Along with the graft copolymers, a number of commercially available flocculants were tested on suspensions of nine different coal samples, two coal washery effluents, and three mineral fines suspensions containing iron, chromite, and copper ores. The laboratory suspensions were made uniformly with ~200 mesh solids.

The samples of coal and mineral were characterised by proximate analysis, specific gravity measurement, particle size analysis, and zeta potential measurement. For the coal washery effluents, the solids content was determined, and the sieve analysis of the solids was carried out. Inferences from these studies are as follows. The specific gravity of the coal samples ranged from 1.4 to 1.9. No correlation was observed between the specific gravity and the type of coal. There was no significant variability in the size distribution of the coal samples. The zeta potential value for all the coals and the mineral samples were negative. The absolute value of the zeta potentials were higher for the non-cooking coals, than for their counterparts. In the absence of polymer addition, the thickener of one washery produced overflow with 3.7 wt% of solids, whereas, the inflow contained 5.0 wt% solids. In another washery thickener, the use of polymer resulted in negligible wt% of solids in the overflow.

For all the synthetic suspensions, as well as the field effluents, natural settling tests in one litre measuring cylinders, flocculation-settling tests in specially designed columns, and standard flocculation jar tests were carried out. Some basic studies were performed to determine the influence of the experimental parameters
including the settling time, rate of stirring, mode of polymer addition, solids content, and particle size, on the jar test. The floc volume measurement, and the relative floc size analysis was also done. The data generated through these studies is intended to serve as reference material for individuals dealing with flocculation as a means of solid-liquid separation of coal and mineral effluents. The significant findings from these investigations are summarised below.

- Coking and non-coking coal fines behave quite differently in terms of natural settling. The hydrophilic nature and high zeta potential of non-coking coals leads to much higher turbidity and more stable suspension which take longer settling time under natural process.

- Flocculation of non-coking coals is much more difficult than coking coals. Jar test turbidity results in the absence of flocculant for coking coals is of the order of 12-20 NTU, whereas, the corresponding values for non-coking coals are 630-720 NTU. Even under optimum flocculation conditions, the NTU for the non-coking coals is 50 to 100 times higher than the coking coals. The optimum dosage itself, as with Ap-g-PAM, is 100-200 ppm for coking coals and 300-400 ppm otherwise.

- It is not correct that only anionic flocculants to be suitable for the settling of coal fines. While these flocculants work well for coking coals, for the non-coking coals it is the nonionic flocculants that have performed better.

- Among all the grafted flocculants and the commercial products tested, Ap-g-PAM was found to be the best, considering both settling velocity and supernatant turbidity for all the coal types.

- For the other mineral fines, Aquaset AS510 gave settling velocity values almost twice that for other flocculants. However the supernatant turbidity was inferior. Ap-g-PAM again produced results that are satisfactory both in terms of settling velocity and supernatant turbidity.

- Graft copolymers, particularly Ap-g-PAM, produced optimum flocculation conditions over a fairly wide dosage range. In a practical sense, their use is more attractive for the industry since the polymer mixing need not be very accurate.

- Express need exists for further research in the development of efficient flocculating agents for use with the hydrophilic non-coking coal fines, and also to scale up the present experience to an industrial pilot level.