Optimization of physicochemical process for pre-treatment of fine suspension by flocculation prior to dewatering

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ABSTRACT

In the design of process reactors, it is often necessary to tailor the separation technique to the dynamics and characteristics of the working slurry. This study reports the results of physicochemical optimization tests conducted on a model system prior to its pre-treatment in a Taylor-Couette device. The assessment of the flocculation performance was carried out on the basis of surrogate indicators such as sludge volume index I_{SV} and supernatant turbidity; which were chosen on the strength of a preliminary investigation and the particular solid–liquid separation method employed in this study. The results of this investigation showed that the lowest sludge volume index I_{SV} of 4.2 and residual turbidity of 7.27 NTU were obtained at the optimum polymer dose of 2 kg/t TS in single conditioning and 4 kg/t in dual additions. Theoretical charge neutralization of 48.4, 37.8, and 49.1% for the single conditioning and 32.1, 25.1, and 32.6% for the dual additions were recorded at the optimum conditions. The optimum dosage values confirmed polymer bridging as the primary flocculation mechanism. The analysis provides information on the slurry polymer dose response and will serve as a guide for polymer selection and subsequent performance optimization of the pre-treatment devices under development.

Keywords: Pelleting flocculation; Dual conditioning; Sludge index; Residual turbidity; Net surface charge

1. Introduction

Flocculation plays a very important role in the treatment of suspensions and fine particulate systems. This physicochemical process is highly indispensable in both upstream and downstream solid–liquid separation processes. It involves the destabilization and aggregation of charged particles in suspension using high molecular weight synthetic polymers [1–6]. A number of interfacial forces and interactions that play key roles in this

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process are well-understood in the light of classical and extended DLVO theories and have been extensively reviewed in several scientific publications [7–10].

The flocculation process essentially consists of two principal steps: the destabilization of charged colloidal particles, and the transport of these particles to close proximity of another particle leading to collision and final aggregation [11,12]. Several mechanisms have been attributed to the flocculation of charged particles in suspension such as charge neutralization; electrostatic patch-charge; polymer bridging; depletion flocculation; network flocculation; and polymer complex formation. However, the dominant concepts in the case of polyelectrolyte-mediated destabilization are surface charge neutralization (ion exchange), charge patch formation, and polymer bridging as illustrated in Fig. 1 [13–19].

Previous research work in this field has revealed that complete charge neutralization does not necessarily guarantee an optimal flocculation condition. An ideal flocculant is able to partially neutralize the surface charge responsible for particle repulsion, and adsorb with loops and tails extending into the solution for bridging with other particles [20–23]. In fact, the efficiency of any flocculation process will largely depend on several factors including the choice of flocculant type, dosage, ionic strength, total dissolved solids, and the size and distribution of colloidal particles in the suspension [24].

In the design of process equipment, it is of great importance to tailor the flocculation process to a particular solid–liquid separation method to be employed as the floc characteristics necessary for different separation methods are unique [25,26]. Therefore, the laboratory test should imitate the essentials of the full-scale operating conditions (e.g. settling, flotation, centrifugation, filtration, and sedimentation) as much as possible. [27]. For instance, sedimentation requires dense and large flocs with regular spherical shape;

centrifugation, on the other hand, requires strong, dense, and large flocs; while floatation requires low-density flocs with narrow size distribution [28]. However, filtration, which is also a common solid–liquid separation method when dealing with a very fine particulate system, requires porous, strong, and permeable flocs.

The control of aggregate or floc structure, as well as the choice of pre-treatment chemicals during the flocculation process, is a daunting task. This is due to the fact that the structure of the final aggregates is influenced by different parameters such as the throughput constraints, required outputs, polymer chemistry, polymer charge, particle surface charge, polymer dosage, and the mixing regime [29,30]. In general, the choice of separation method will determine to a greater extent the desired floc's characteristics; and as such, any flocculation optimization process must adequately take this into account. Table 1 provides a snapshot of conventional separation methods as well as the applicable laboratory testing methods and required floc characteristics. In most of these tests, the optimum flocculation condition is determined either by direct *in situ* observation such as particle counting, or using indirect indicators of flocculation performance.

The overall goal of flocculation as applied to solid–liquid separation is to enhance solids' settling characteristics so as to provide a clear effluent and to minimize the liquid content of the final solid product [31]. This is accomplished by careful manipulation of key parameters that govern the process of floc formation, breakup, and rearrangement [25]. Therefore, the first step in any physicochemical optimization process is to define specific performance criteria as well surrogate indicators. These criteria must be appropriate for the suspension and for the existing or proposed method of treatment in order to obtain the desired floc's characteristics at a reasonable cost [9,29,30]. Several flocculation monitoring and optimization
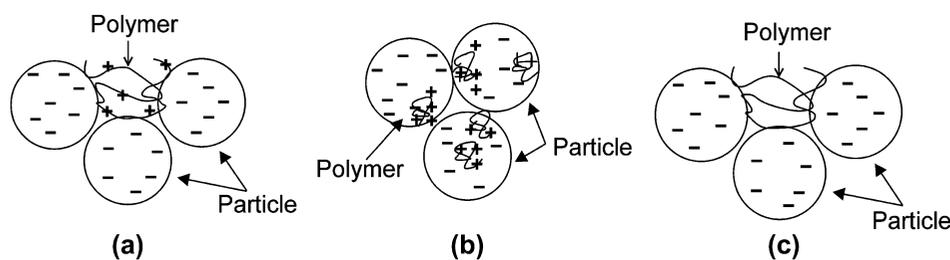
Fig. 1. A schematic representation of dominant flocculation mechanisms (a) charge neutralization (b) charge patch formation (c) polymer bridging. Adapted from Ref. [19].

Table 1
Common laboratory test methods and the desired floc characteristics

Separation method	Laboratory tests	Desired floc properties
Sedimentation	Jar test, cylinder test, charge analysis	Dense, strong, large, regular in shape (spherical)
Thickening	Jar test, cylinder test	Dense, strong, large, regular in shape (spherical)
Vacuum filtration	Buchner funnel test, CST test	Porous, strong, permeable flocs
Centrifugation	CST test	Strong, dense, large flocs
Floatation	Jar test, floatation test	Low density, strong, narrow size distribution
Filtration	Jar test, Buchner funnel test	Porous, strong, permeable flocs
Clarification	Jar test, cylinder test, charge analysis	Loose, large, high permeability with charge reversal

techniques have found to be useful in applications such as the treatment of suspensions and particulate systems. For instance, the conventional cylinder or Imhoff cone and jar tests, electrokinetic measurements, colloid titrations, and non-conventional procedures such as H NMR spectroscopy and fiber optic sensor technique, have all been successfully employed to assess the flocculation efficiency [9,32–50].

The main drawback of many of these tests is the difficulty in adapting them to a wider range of solid–liquid separation techniques and other emerging separation methods. The aim of this study is to determine the optimum polymer dose for the pre-treatment process in an existing Taylor-Couette device and new rotary plate batch flow reactor under the expected flocculation conditions. Future studies will address the performance of these devices under the predicted dosage conditions with a view to establish variations in actual and predicted performance. The selected indirect indicators (sludge volume index I_{SV}, residual turbidity) reflect the suitability of the effluent for reuse (clarity) and the settled flocs for pelletization (settleability and, compactness,) in the shear devices.

2. Materials and method

2.1. Kaolin slurry

High quality paper coating grade kaolin powder (Caminauer Kaolinwerk GmbH, Sachsen, Germany) was used in the preparation of the model suspension. It contains particle sizes below 20 μm, with a median size d_{50} of 6.5 μm (Mastersizer, Malvern Instruments, UK), and density of 2.55 g/cm^3 measured with a pycnometer (Table 2, Fig. 2).

2.2. Synthetic polymers

A number of synthetic polymers Zetag® 7692, Sedipur® CF-2501 (BASF GmbH, Germany), Praestol® 611BC (Stockhausen GmbH, Germany), and Superfloc®

Table 2
Physicochemical properties of the kaolin slurry

Properties	Characteristic values
Streaming potential, ΔU, mV[a]	−770
Median particle size, d_{50}, μm	6.5
Total solids content, % wt.	2.0
pH (at solids content of 2% wt.)	6.2
Conductivity, μs/cm	30
Dry solids density, g/cm^3	2.55
Specific surface charge, C/g[a]	−0.55

[a]C: Coulomb, particle charge detector measurement *(BTG Instruments GmbH, Germany)*.

N-300 (Kemira Oyj, Finland) with different charge densities, but similar molecular weights selected after preliminary screening based on knowledge of the substrate and the application performance criteria [25] were used as bridging materials in this study. Their charge densities and cationic charge demand of the synthetic raw sludge were quantified by colloid titration using standard solutions of poly-dadmac–poly-dimethyldiallylammonium chloride (0.001 N, 0.04% wt.) and PES-Na–polyethylene sulfonate (0.001 N, 0.013% wt.) supplied by BTG Instruments GmbH, Germany (Table 3, Fig. 3).

3. Preparation and characterization of samples

Synthetic sludge (conc. 20 g/L) was prepared under laboratory conditions for this investigation by dispersing kaolin powder in deionized water. The mixing was done using a mechanical overhead stirrer Heidolph RZR 2102 (Heidolph Instruments GmbH, Germany) in a 500 mL plastic beaker equipped with baffles. All experiments were conducted using a freshly prepared kaolin suspension. Stock solutions of the polyelectrolytes (0.1% wt.) were prepared by dissolving the polymer granules in deionized water and storing them for 24 h to allow aging of the
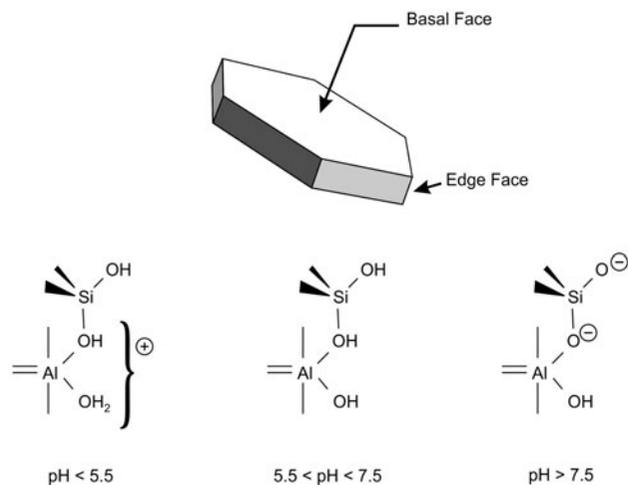
Fig. 2. The structure of kaolin clay platelet and pH-dependence surface chemistry of the edge face. Reproduced from Ref. [51].

solution. A working solution was prepared at least one hour before each experiment to obtain a desired concentration. The stock polymer solutions were stored for a maximum of one week. The determination of the isoelectric point (IEP) was carried out by adjusting the pH of the slurry from 6.2 to 10. This was achieved by dropwise addition of 0.1 M HCl or NaOH solution (Fig. 4).

Surface charge of the slurry and charge densities of polyelectrolytes was determined using colloid titration, 702 SM Titrino (Metrohm AG, Herisau, Switzerland) and particle charge detection, Mütek PCD 03 (BTG Instruments GmbH, Herrsching, Germany). A 10 mL sample of the slurry (2% wt.) or polymer solution (0.05% wt.) as specified by the manufacturer was placed in the measuring cell of the particle charge detector. The charge in the samples was determined using either 0.001 N PES-Na or 0.001 N poly-dadmac as a standard titration solution. The automated system allows the titration parameters such as dosing rates and equivalence end points to be pre-selected for a particular titration regime. The specific charge (µeq/g) is automatically determined by the software. The final charge quantity was obtained thereafter in (C/g) by multiplying the specific charge (µeq/g) by the Faradays constant (96,485 C/eq) with an error margin of about ± 2%.

4. Agglomeration unit

The slurry pre-treatment device is a conical Taylor-Couette reactor with two coaxially arranged cones. The inner cone acts as a stirrer with the reaction chamber forming an annular gap between the fixed outer cone and the rotating inner cone. The operation of the reactor provides a rotational flow in which the pellet flocs migrate from top to bottom of the reaction chamber. The sludge suspension and flocculants are introduced into the chamber using a static mixer so the suspension is fully destabilized by the time it reaches the annular gap. There is a provision for the mechanically stable pellets of certain size and strength to be discharged at the lower end of the conical structure (Fig. 5). This apparatus was employed to gauge the polymer dose response during the actual separation process using optimum flocculant dosage obtained from the flocculation tests.

5. Flocculation tests

Flocculation experiments were carried out using a conventional jar test apparatus *Floculateur* 11198 (Bioblock Scientific, France) equipped with time adjustable speed mixer. Two-hundred and fifty milliliter of the working slurry was pre-treated in the flocculator

Table 3
Characteristics of flocculants

Characteristics	Manufacturer data					Experimental
Polymer trade name	Supplier	Appearance	Ionic character	Molecular weight (g/mol)	Charge activity (mol %)	Charge density (C/g)[a]
Zetag® 7692	BASF	Powder	Cationic	5×10^6	~10	133
Sedipur® CF-2501	BASF	Powder	Cationic	6×10	~5–10	104
Praestol® 611BC	Stockhausen	Powder	Cationic	5×10^6	~3–10	135
Superfloc® N-300	Kemira	Powder	Nonionic	4.5×10^6	~0	−1.997
Poly-Dadmac	BTG	Liquid	Cationic	1×10^5	~100	597.43
PES-Na	BTG	Liquid	Anionic	2.2×10^4	~100	−742.19

[a]C: Coulomb, particle charge detector measurement *(BTG Instruments GmbH, Germany).*
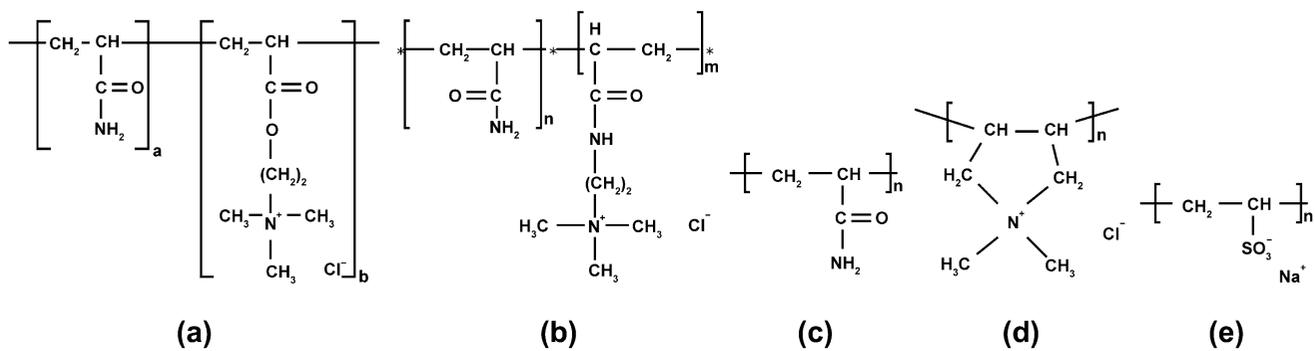
Fig. 3. The molecular structures of the synthetic flocculants (a) Zetag[®] 7692, Sedipur[®] CF-2501—DMAEA-Q or DMAEA-MeCl, (b) Praestol[®] 611BC—MAPTAC, (c) Superfloc[®] N-300—PAM, (d) Poly-Dadmac, and, (e) PES-Na [27,52,53].

by adding 50 mL each in single addition (Z-7692, CF-2501, 611BC) and 25 mL each in dual additions (Z-7692 + N-300, CF-2501 + N-300, 611BC + N-300) of dilute solution of polyelectrolytes of varying concentrations (0.1–0.8 g/L) in order to achieve a polymer combination ratio of 1:2. This combination was found to be more effective in preliminary tests performed prior to this investigation. A rapid mix of about 45 s at 200 rpm was followed by 10 min of slow mixing at 40 rpm to promote the aggregation of flocculated particles. The suspension was then transferred into a 250 mL graduated cylinder and allowed to settle undistributed. Samples of the supernatant were drawn with a pipette from 2 cm below the surface for residual turbidity measurements using Turbiquant[®] 3000IR (Merck Millipore GmbH, Hessen, Germany), while the sludge volume index I_{sv} was determined according to Eq. (1) after 30 min and 24 h of quiescent settling, respectively.

$$I_{sv} = \frac{V_s}{\rho_T} \qquad (1)$$

I_{SV} is the sludge volume index (mL/g); V_S is the sludge volume (mL/L) after 30 min and 24 h of settling taken as an average of two measurements; ρ_T is the concentration of dry solids in the slurry (g/L), Table 4.

6. Results and discussion

6.1. Particle–polymer interactions and selection of optimum dose

The structure of kaolin clay is comprised of pseudo-hexagonal platelets with differing surface chemistry occurring at the basal face and the edge face [19,51]. The basal face has a net negative charge that is usually unaffected by the pH. However, the charge on
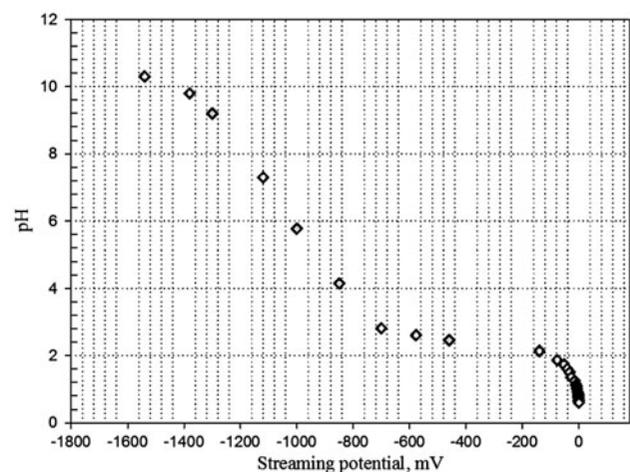
Fig. 4. Variation of the slurry net surface charge with pH (2% wt.).

the edge face can be positive, neutral, or negative, depending on the pH of the suspension (Fig. 2). This behavior of kaolin platelets in aqueous suspension stems from proton gain or loss of surface hydroxyl groups and this strongly influences their flocculation properties [55].

The aggregation of dispersed kaolin particles in suspension can proceed with the polymer adsorbing either in an edge-to-face (EF) or face-to-face (FF) manner depending on the prevailing flocculation conditions. At a pH value lower than 6.7, edge-face electrostatic interaction predominates among the clay particles and a "card-house structure" emerges. In this model, the mineral particles are held together by EF contacts [19]. In the presence of nonionic polymer, the FF association is favoured due to the larger surface area of the face compared to the edge of the kaolin particle [52].

The kaolin slurry used in this study was conditioned at a pH between 6 and 7 using different
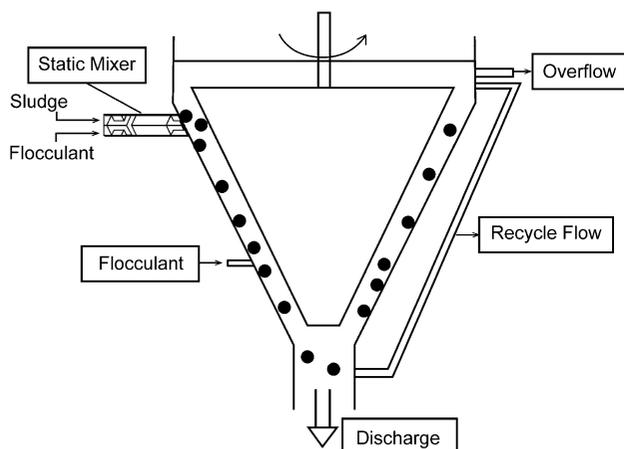
Fig. 5. A schematic illustration of the pelleting device. Adapted from Ref. [54] with permission.

polymer combinations. The optimum polymer dose was thereafter determined based on the lowest observed values of the supernatant turbidity and sludge volume index I_{sv} after 30 min and 24 h of settlement. However, choice of optimum flocculant dose might sometimes necessitate a compromise between the performance indicators (sludge volume index I_{sv}, or supernatant quality). In the case of the chosen separation process (pelleting flocculation), it is assumed that in full-scale operations, residual water can be recycled back into the municipal sewer network.

Hence, the supernatant quality—clear water with low turbidity, is therefore a secondary criterion.

6.2 Polymer dose response in single polymer treatment

Zetag® 7692, Sedipur® CF-2501, and Praestol® 611BC are medium to high molecular weight cationic polymers with low charge densities (Table 3). Figs. 6–8 show the results of the flocculation test with respect to the supernatant turbidity and sludge volume index I_{sv}. The choice of the polymer dose range reflects the regions of underdose and overdose [56]. There was a significant reduction in turbidity with all the polymer doses, and this trend generally appears to decrease as the polymer dose increases with the exception of Sedipur® CF-2501.

In the case of Sedipur® CF-2501, there was a slight reduction in turbidity when the polymer dose was increased from 1 to 2 kg/t TS and thereafter increases with the increase in dosage (Fig. 7). The sludge volume index I_{sv} shows a somewhat similar trend with two clear zones of underdose and overdose of polymers and this is consistent with similar studies reported elsewhere [10,32,54]. In the conditioning experiments, the optimum dosage of 2 kg/t TS roughly corresponds to the region of lowest turbidity and sludge volume index I_{sv} values. This value can be deemed sufficient to obtain a good flocculation performance in terms of the two indicators.

Table 4
Summary of results for flocculation tests in single and dual-polymer treatment

Polymer type	Performance indicators	Polymer dose (kg/t TS)				
		1	2	4	6	8
Z-7692	Sludge volume index $I_{SV\ 30}$	6.6	5	5	6.4	6.6
	Sludge volume index $I_{SV\ 24}$	6.2	4.8	4.8	6.4	6.2
	Turbidity	6.65	12.92	38.13	63.32	64.39
CF-2501	Sludge volume index $I_{SV\ 30}$	5.6	4.4	5.2	5.6	6.8
	Sludge volume index $I_{SV\ 24}$	5	4.2	4.8	5.6	6.4
	Turbidity	10.80	9.68	29.87	54.81	62.72
611BC	Sludge volume index $I_{SV\ 30}$	5.4	5.2	5.4	7	6
	Sludge volume index $I_{SV\ 24}$	5.2	5	5.2	6.6	5.6
	Turbidity	7.65	15.82	43.93	57.79	64.51
Z-7692 + N-300	Sludge volume index $I_{SV\ 30}$	5	5.4	4.8	4.8	6
	Sludge volume index $I_{SV\ 24}$	4.6	5.2	4.4	4.4	5.6
	Turbidity	20.04	9.79	18.23	38.92	62.67
CF-2501 + N-300	Sludge volume index $I_{SV\ 30}$	6	5.6	4.8	6	5.6
	Sludge volume index $I_{SV\ 24}$	5.6	5.6	4.6	5.6	5.2
	Turbidity	31.87	23.89	7.27	19.56	39.69
611BC + N-300	Sludge volume index $I_{SV\ 30}$	6.4	5.8	5.2	5.6	5.2
	Sludge volume index $I_{SV\ 24}$	6.2	5.6	5	5.6	5
	Turbidity	55.65	16.83	17.20	27.34	47.72

In the underdose range, increasing polymer dose improves the flocculation performance; however, once the optimum dosage condition is attained, additional polymer dose results in deterioration of flocculation efficiency. For instance, increasing the polymer dose from 1 to 2 kg/t TS leads to a decrease in the turbidity and sludge index to lowest values with the exception of Zetag® 7692 (Fig. 6) and Praestol® 611BC (Fig. 8) which show a slight increase in turbidity. Increasing the dosage beyond 2 kg/t TS shows a rapid increase in the observed values of the two indicators.

The response of the kaolin slurry to the physico-chemical treatment can be explained using an appropriate conceptual model. The results of the experiments from this study confirm charge neutralization and polymer bridging as the two flocculation mechanisms with polymer bridging being more dominant. For large molecular weight polyelectrolytes with a charge density less than 15%, the governing phenomenon is polymer bridging. Whereas, for low molecular weight flocculants with an ionicity greater than 30%, charge neutralization predominates [23]. The increase in turbidity at a higher dosage can be attributed to increasing polymer adsorption beyond the optimum which results in lower particle aggregation. The increasing coverage of the particle surface by the polymer molecules beyond the optimum level gradually leads to steric stabilization [23].

Similarly, increasing polymer dose results in higher sludge volume index I_{sv} owing to the weakening of the polymer bonds and formation of loose and bulky flocs [23]. A theoretical charge reduction of approximately 48.4, 37.8, and 49.1% for Zetag® 7692, Sedipur® CF-2501, and Praestol® 611BC, respectively, at the optimum dose of 2 kg/t TS. This confirms that optimum flocculation performance does not require a complete charge neutralization [16].

6.3 Polymer dose response in dual-polymer treatment

Superfloc® N-300, a nonionic high molecular weight flocculant was used in combination with Zetag® 7692, Sedipur® CF-2501, and Praestol® 611BC in dual-polymer conditioning. The results of the sequential additions are shown in Figs. 9–11. There are apparently two clear regions of underdose and overdose, with a generally good flocculation performance especially in turbidity reduction. This is, however, achieved at a somewhat higher polymer dose (4 kg/t TS) when compared to the single polymer addition.

In terms of the sludge volume index I_{sv} and the turbidity, the dual additions show that in the underdose range, increasing the flocculant dose generally results in an improved flocculation performance except in the case of Z-7692 + N300 (Fig. 9). Increasing
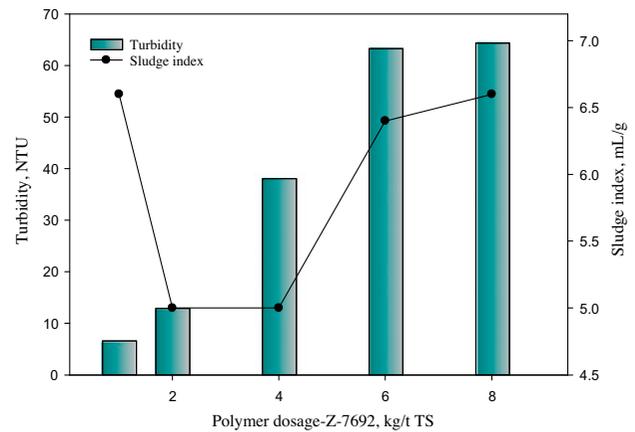
Fig. 6. Relationship between Z-7692 dosage and flocculation performance.
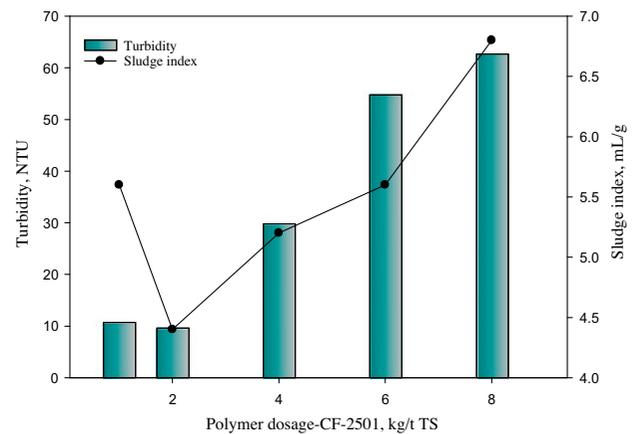
Fig. 7. Relationship between CF-2501 dosage and flocculation performance.
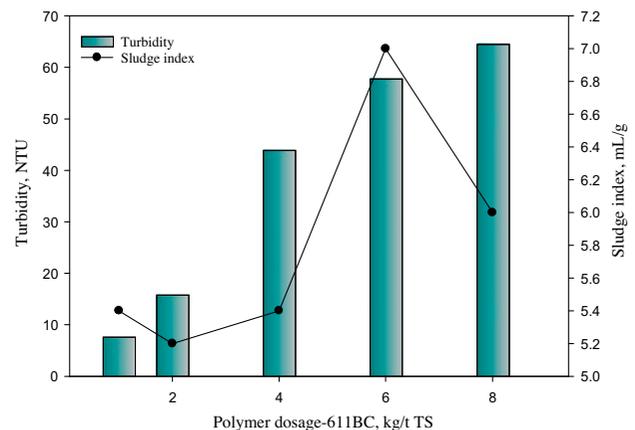
Fig. 8. Relationship between 611BC dosage and flocculation performance.

the polymer dose beyond 4 kg/t TS, however, shows a rapid deterioration in the flocculation efficiency as shown by the increase in the observed values of the two indicators. This region shows a significant increase in the turbidity and sludge volume index I_{sv} values indicating an overdose of flocculants. These optima trends appear to be consistent with similar dosage optimization results reported elsewhere [10,15,22,24,27,32].

The dual additions show a somewhat comparable flocculation efficiency albeit at twice the polymer dosage. For instance, CF-2501 + N300 combination shows a lower turbidity at optimum dosage as compared to the single addition (Fig. 10). In terms of the sludge volume index I_{sv}, the observed values in single polymer flocculation are generally lower. This might be attributed to the fact that in dual systems, larger and stronger flocs are formed [17]. The two flocculation schemes implemented in this study, however, generally show a good correlation in terms of the flocculation performance.

In addition, it does seem that the dual additions scheme produced stronger and shear tolerant flocs as a result of the additional bridging effects, but this could not be directly verified in this study. However, studies have shown that the sequential addition produces a synergistic effect that might result in stronger and more compact flocs due to the enhanced bridging effect of the nonionic polymer [57,58]. Further investigation in the Taylor-Couette apparatus also revealed that the dual addition gives more stability to the flocs. A conceptual model of the interaction mechanisms in dual-polymer flocculation was presented by Lee and Liu [17]. A theoretical charge reduction of approximately 32.1, 25.1, and 32.6% for Zetag® 7692 + Superfloc® N-300, Sedipur® CF-2501 + Superfloc® N-300, and Praestol® 611BC + Superfloc® N-300, respectively, were recorded at the optimum dose of 4 kg/t TS in dual-polymer combinations.

6.4. Effect of polymer characteristics on supernatant clarity

The effect of polymer characteristics, especially molecular weight, is a critical factor in the polymer-mediated flocculation of kaolin slurry. It has been shown that polymer bridging is the dominant flocculation mechanism in the case of nonionic or low charge cationic polymers [52]. Polymer molecules can adsorb onto both the face and edge sites of the kaolin particle with FF association more probable in the case of high molecular weight flocculants [52]. Fig. 12 shows the effect of polymer types on the supernatant turbidity at the respective optimum dose. The lowest turbidity of 7.27

NTU was recorded with Sedipur® CF-2501 + Superfloc® N-300 polymer combination in the dual additions. It does appear that the dual-polymers have a slightly superior overall turbidity reduction over the single additions, although at a higher optimum dosage.

In terms of the individual flocculants, Sedipur® CF-2501 gives the highest turbidity reduction with an observed value of 9.68 NTU. This might probably be attributed to its slightly higher molecular weight when compared to other flocculants, as it has been shown that this performance criteria is a function of the polymer molecular weight [55]. A similar trend can be seen in its combination with Superfloc® N-300, which gives the lowest observed turbidity value for the dual-polymers. It appears that this trend seems to be consistent with all the other polymer combinations with Zetag® 7692 and Zetag® 7692 + Superfloc® N-300, giving the second lowest values in single and dual additions schemes, respectively.

6.5. Effect of polymer characteristics on sediment compaction

The characteristic of the settled flocs is an important factor in many solid–liquid separation processes as the appearance of the flocs' structure is an indication of flocculation efficiency (Table 1). The aim of pelleting flocculation as a pre-treatment technique is to produce compact pellet flocs with high solids content, shear resistance, and better dewaterability. The sludge volume index is a simple and effective indicator to assess the settleability characteristics of sludge and the flocculation performance. Fig. 13 shows the effect of flocculant types on the sludge volume index I_{SV}.
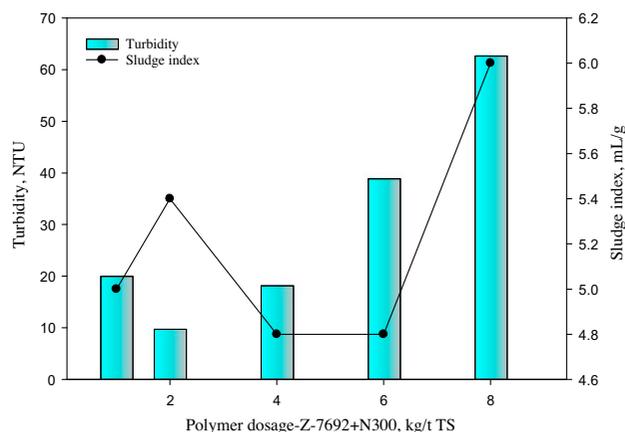
Fig. 9. Relationship between Z-7692 + N300 dosage and flocculation performance.
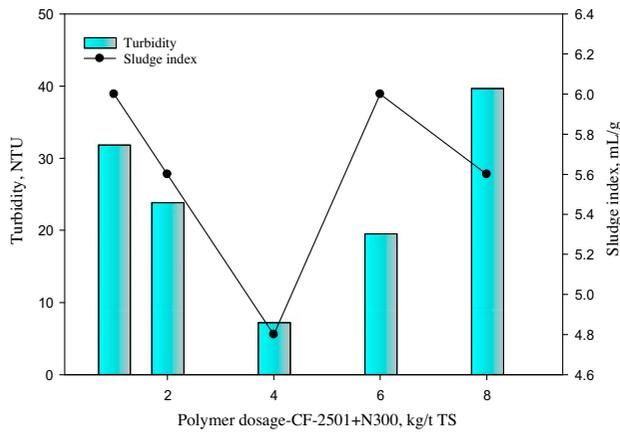
Fig. 10. Relationship between CF-2501 + N300 dosage and flocculation performance.

Fig. 11. Relationship between 611BC + N300 dosage and flocculation performance.
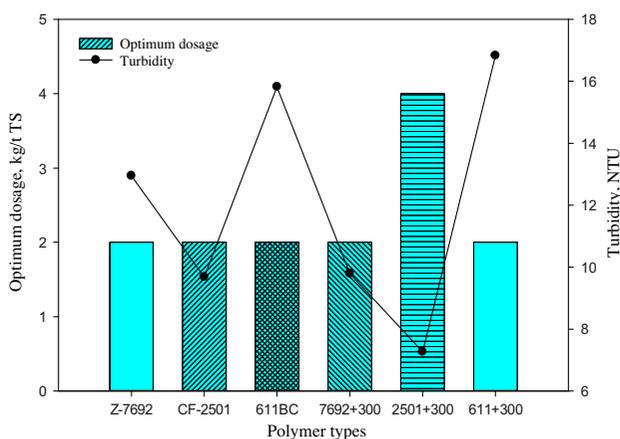
Fig. 12. Effect of flocculation types on supernatant clarity at optimum dosage.

Fig. 13. Effect of flocculation types on sediment compaction at optimum dosage.

The lowest observed sludge index value of 4.4 mL/g was obtained with Sedipur® CF-2501 in the single polymer conditioning. This might be a result of the flocculant's higher molecular weight as polymer bridging is a function of molecular weight in the case of low charge cationic polymers. In the case of dual additions, the lowest observed sludge index value is 4.8 mL/g for both Zetag® 7692 + Superfloc® N-300 and Sedipur® CF-2501 + Superfloc® N-300 polymer combinations. This slightly higher value obtained at a higher optimum dose indicates that the dual additions produce less settleable flocs. However, the shear resistance of the flocs, which is another critical factor, was not directly measured in this study.

7. Conclusions

Flocculation optimization studies were conducted using kaolin slurry as a model suspension in order to glean information about the slurry polymer dose response. This initial physicochemical test is intended to serve as a tool for an effective dosage selection for a new pre-treatment device. The chosen flocculation performance criteria as well as the performance indicators reflect a trade off between best possible separation efficiency and lowest possible cost of conditioning chemicals. The results of this study show an optimum dose range of 2.0–4.0 kg/t TS for the conditioning schemes and physicochemical criteria investigated. A lower polymer dose of 2 kg/t TS was, however, required to attain the optimum condition for residual turbidity when compared to the sludge volume index I_{SV} (2–4 kg/t TS) in both addition schemes. The dominant flocculation concepts in this study are polymer bridging and charge neutralization, with the

polymer bridging effect observed to be more pronounced owing to the low charge activities (ionization) of the synthetic polymers. It is anticipated that future investigations will address the performance and process optimization in a new pre-treatment device under the predicted dosage conditions.

Acknowledgment

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