The destabilization characteristics of talc were investigated in distilled and fresh water containing Ca\(^{2+}\), Mg\(^{2+}\), Na\(^+\) and K\(^+\) ions. The stability of the talc suspension remained almost constant in distilled water at all pH values, while it sharply decreased with these cations (i.e. in fresh water) at pH values above 10.5. In addition, the effects of A-95 (anionic), C-521 (cationic) and N-100 (non-ionic) flocculants on the destabilization of the suspension were also investigated in distilled and fresh waters. In fresh water, anionic and non-ionic flocculants were very effective on the talc suspensions at pH 7.2 and at pH values greater than 10.5. The stability of talc suspension was decreased by flocculation and also coagulation effect at pH levels greater than 10.5. The cationic flocculant caused weak destabilization of the suspension with distilled water in acidic conditions. However, this polymer was ineffective on the talc suspensions in fresh water at almost all pH levels.

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**Keywords:** Talc, destabilization, stability, cations, polymeric flocculants, magnesium silicate

Talc is a hydrous magnesium silicate with the theoretical chemical formula Mg\(_3\)Si\(_4\)O\(_{10}\)(OH)\(_2\). The chemical composition of talc ores found in nature, however, is quite variable\(^1\). Commercial talc may contain related sheet silicates such as chlorite and serpentine, and carbonates such as magnesite, dolomite and calcite\(^2\). When talc mineral is broken, two types of surfaces are formed, one surface results from the easily broken layers and the other from the rupture of ionic bonds within these layers. These surfaces are called as ‘faces’ and ‘edges’, respectively. The faces are hydrophobic, while the edges are hydrophilic. The ratio of hydrophilic and hydrophobic surface sites affects the electrokinetic properties and thus flotation, flocculation and other wetting related processes of the mineral\(^3\).

Dispersion control is an important step in the processing of solid particle suspension. Some unit operations of particle processing require the fine particles suspended in liquid being stably dispersed, e.g. classification and fine particle separation. However, stable particle aggregation is needed for others, such as solid-liquid separation. Destabilization of fine particles can be achieved by neutralizing the electrical charge of the interacting particles, which is coagulation or by bridging the particles with polymolecules, called flocculation\(^4\). Bridging is considered to be a consequence of the adsorption of the segments of flocculant macromolecules onto the surfaces of more than one particle. Such bridging links the particles into loose flocs, and incomplete surface coverage ensures that there is sufficient unoccupied surface available on each particle for the adsorption during the collisions of chain segments attached to the particles\(^5\).

Polymeric flocculants are used very effectively to destabilize fine particle suspension. The advantage of polymeric flocculants is their ability to produce large, stronger flocs comparing to those obtained by coagulation. Theoretically, the flocculants may be applied either after destabilizing the suspension by coagulation, or without prior destabilization. The flocculants are known to be not very effective in treating stable suspensions and so the first option which involves prior destabilization by coagulation is always better\(^6\)\(^-\)\(^8\). Most flocculants are synthetic polymers based on repeating units of acrylamide and its derivatives, which may contain either cationic or anionic charge. Both anionic and non-ionic polymers can be manufactured with very high molecular weights, and thus are capable of forming large, rapid-settling, good-compacting flocs.
and they are widely used in mining and processing applications. Cationic polymers have lower molecular weight and rarely used in the mining area. Since most suspended particles are negatively charged, cationic polymers seems a common choice. But, the charge on a bridging polymer appears to be of secondary importance. High molecular weight polymers are extremely effective in promoting floc growth in suspensions. Elimination of charge barriers by pH control or the addition of a low molecular weight polyelectrolyte permits small flocs to form and the bridging action of the polymer serves to link these into substantially larger units.

In industrial water, calcium and magnesium ions are inevitably present. Ca$^{2+}$ and Mg$^{2+}$ ions are released by dissolution of carbonate and silicate minerals and they are present in their highest amount in the suspension at neutral pH range. While Ca$^{2+}$ and Mg$^{2+}$ ions are not very effective in the neutral pH range, the less hydrated Ca(OH)$_2$ and Mg(OH)$_2$ precipitate formed at high pH values are responsible for the coagulation of silicate suspensions. In addition, Ca$^{2+}$ and Mg$^{2+}$ ions are reported to enhance frother adsorption on talc surfaces, increasing floatability, so that it is noticed that the highest natural floatability is obtained in the neutral pH range. The talc flotation recovery, on the other hand, sharply decreases in the alkaline region. This behaviour is attributed to the presence of carbonate ions released from carbonate minerals in high amounts at such pH values. Since talc mineral has many uses as powdered form in the manufacture of paint, paper, roofing material, rubber as well as in cosmetics in the form of face and talcum powder and electrical appliances, etc., it is important to beneficiate the talc from most ores involving all steps of mineral processing.

The objective of this work was to determine the destabilization properties of talc mineral in distilled water, and fresh water containing Ca$^{2+}$, Mg$^{2+}$, Na$^+$ and K$^+$ ions. Therefore, this paper presents the findings of destabilization characteristics of talc and is expected to be consistent with the industrial applications.

### Experimental Procedure

#### Materials

Pure talc mineral obtained from Sivas, Turkey, was used in the experimental study. The chemical composition of talc sample is given in Table 1. The sample was dry ground in a laboratory size ceramic ball mill of 128 mm internal diameter and 2500 mL volume. The sample ground in the mill was taken out at certain grinding times and sieved to obtain -38 µm size fraction. Thus, the sample was not exposed to over-grinding and contamination of product due to abrasion of the balls was kept at a minimum level. Anionic (A-95), cationic (C-521) and non-ionic (N-100) Superfloc floculants, obtained from the American Cyanamid Company, were used for the flocculation of talc. These synthetic polymers are based on acrylamide and its derivatives. A-95 is basically a polymer of acrylamide-acrylic acid; C-521 is a polymer of acrylamide-quaternised aminoalkylacrylate and N-100 is polyacrylamide. The molecular weights of A-95 and N-100 polymers are in the range of 5-15×10$^6$ and that of C-521 is 2-6×10$^6$. The polymers prepared as 0.01% solutions were used in this study. Sodium hydroxide and sulphuric acid (Merck Company), were used for pH adjustment. In the experiments, mono distilled and fresh waters were employed. Natural pH values of distilled and fresh waters were 6.0 and 7.2, respectively. Specific conductance values of distilled and fresh waters were 6.0 and 7.2, respectively. Specific conductance values of distilled and fresh waters were determined as 7 and 203 µS/cm, respectively. The concentrations of dissolved cationic and anionic species in fresh and distilled waters are given in Table 2.

#### Method for destabilization studies

The destabilization experiments were carried out in a 600 mL cylindrical cell with four baffles using 0.5 g solid and 500 mL water. The dispersed suspension, adjusted to the desired pH, was first conditioned at 500 rpm for 5 min. The flocculant was added to the suspension at an impeller speed of 500 rpm. After 3 min, the stirring speed was reduced to 100 rpm for 2 min, to allow floc growth. After a settling time of 1

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**Table 1— The chemical composition of the talc sample used**

<table>
<thead>
<tr>
<th></th>
<th>SiO$_2$</th>
<th>MgO</th>
<th>TiO$_2$</th>
<th>Fe$_2$O$_3$</th>
<th>Al$_2$O$_3$</th>
<th>P$_2$O$_5$</th>
<th>CaO</th>
<th>Loss of ignition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>63.82</td>
<td>29.28</td>
<td>0.59</td>
<td>0.56</td>
<td>0.55</td>
<td>0.14</td>
<td>0.06</td>
<td>5.00</td>
</tr>
</tbody>
</table>
Table 2—Concentrations of dissolved cationic and anionic species in fresh and mono distilled waters

<table>
<thead>
<tr>
<th>Concentrations, mg/L</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>CO₃²⁻</th>
<th>HCO₃⁻</th>
<th>Cl⁻</th>
<th>SO₄²⁻</th>
<th>NH₄⁺</th>
<th>NO₂⁻</th>
<th>NO₃⁻</th>
<th>PO₄³⁻</th>
<th>Fe³⁺</th>
<th>F⁻</th>
<th>Zn²⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh water</td>
<td>4.03</td>
<td>0.41</td>
<td>46.10</td>
<td>5.05</td>
<td>4.50</td>
<td>105.90</td>
<td>4.90</td>
<td>0.009</td>
<td>0.02</td>
<td>2.10</td>
<td>0.041</td>
<td>0.006</td>
<td>0.55</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>Distilled water</td>
<td>0.15</td>
<td>0.02</td>
<td>0.96</td>
<td>0.21</td>
<td>0.005</td>
<td>0.22</td>
<td>0.85</td>
<td>0.20</td>
<td>0.01</td>
<td>-</td>
<td>0.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

min, 20 mL of supernatant was taken out, at a fixed distance of 5 cm below the air-liquid interface, by a special system for turbidity measurements. The turbidity of the supernatant was measured by an Orbeco-Hellige Model 966 turbidimeter. The destabilization experiments were carried out at 20±1°C. The experimental procedure of the destabilization tests is shown in Fig. 1.

The performance of the destabilization process was assessed using a formula [Eq. (1)], defined previously, and modified to allow for the measurement of supernatant turbidity:

\[
suspension\ stability = \frac{T_o}{T_n} \times 100 \tag{1}
\]

where \(T_o\) is the turbidity (nephelometric turbidity unit) of well dispersed suspension of talc at 1 g/L of solid concentration and \(T_n\) is the turbidity of supernatant when sedimentation is assisted by a flocculant or pH variation. \(T_n\) value was determined as 480 NTU.

Results and Discussion

Figure 2 represents the variation of supernatant turbidity with settling time to evaluate the natural stability of talc suspension in fresh water whose pH is 7.2. It is seen that turbidity value decreased rapidly for the first 10 min of settling time, thereafter it continued to decrease steadily reaching 32 NTU in 60 min. This turbidity value corresponded to approximately 7% of suspension stability.

The stability of talc suspension as a function of pH in distilled and fresh waters is shown in Fig. 3. As seen from Fig. 3, the stability of talc suspension increased slowly with increasing pH values in distilled water; however, it decreased sharply between a pH of 1.6 and 1.9. The stability of talc suspension increased in fresh water (i.e. with cations) increased with increasing pH between 7.2 and 10.5, and it reached a maximum value at pH 10.5. After this point, the stability of the suspension decreased sharply to 32% at a pH of 12.2. Particularly, the coagulation in the presence of Ca²⁺ and Mg²⁺ ions becomes significant at pH values beyond 10. The species distribution diagrams for calcium and magnesium ions are presented in Fig. 4. These diagrams seem to explain the results obtained for these ions in the destabilization experiments of talc. In
the high pH range, Ca\textsuperscript{2+} ion is specifically adsorbed on the negatively charged sites on the mineral. This reduces the negative surface charge and leads to coagulation of suspension. Mostly, suspended particles, including talc\cite{13,19,9}, are negatively charged\cite{7} and in general the particle surface charge becomes more negative with increasing pH value\cite{9}. Both calcium and magnesium ions exist as free ions at neutral pH range, but as the pH increases, the concentrations of these species decrease and hydrolysis products of these cations become significant. This firstly results in the formation of the monohydroxyl complex Ca(OH)\textsuperscript{+} in the suspension. As the pH increases, the concentration of this less hydrated Ca(OH)\textsuperscript{+} increases rapidly (Fig. 4). The less hydrated Ca(OH)\textsuperscript{+} specifically adsorbs on silicate surfaces and repulsive hydration forces are eliminated\cite{20}. In addition, Mg\textsuperscript{2+} ion, attached by heterocoagulation as Mg(OH)\textsubscript{2} precipitate (say above pH 10), were responsible for the coagulation of silicate suspension\cite{11,20}. In fact, a little adsorption of Ca\textsuperscript{2+} occurs throughout the pH range\cite{6} of 4 to 10. In acidic suspensions, stability of talc suspension in the presence of cations increases slowly with decreasing pH, but below pH of 2.1, the stability decreased slightly.

The effect of A-95 and N-100 polymers as a function of concentration on the suspension stability of talc in fresh water at pH 7.2 is shown in Fig. 5. It can be seen that both A-95 and N-100 had similar effect on flocculation of talc suspension at pH 7.2. The suspension stability decreased sharply with increasing flocculant concentration and approximately a constant value was reached beyond 0.1 mg/mL for both the polymers. In the experiments where the cationic polymer (C-521) was used, the flocculation of talc did not occur at pH 7.2. In addition, at higher concentration of C-521 (10-50 mg/L), talc suspensions were not flocculated and also these high concentrations caused the stabilization of talc suspension. These polymers also represented similar effects on the talc suspensions in distilled water at neutral pH.

The effect of pH on the suspension stability of talc by A-95, C-521 and N-100 polymers in distilled water is shown in Fig. 6. As seen from Fig. 6, N-100 polymer was not very sensitive to the pH change of the suspension. The suspension stability values increased with increasing pH in the alkaline region for A-95 polymer. C-521 polymer destabilized weakly the suspension in acidic region, but it caused the stabilization in alkaline region. It has been noticed\cite{9} that the pH range for cationic polymers can be quite variable, but often is on the acid pH side, non-ionic polymers are not much affected by pH changes and flocculation at high pH is difficult with anionic polymers, which need a certain amount of divalent or trivalent ions available in the particle system to act as a bridge between the negatively charged particle surface and the negative charge of the anionic polymer.
Figure 7 shows the effect of pH on the suspension stability of talc by A-95, C-521 and N-100 polymers in fresh water containing cations. As shown in Fig. 7, the lowest suspension stabilities of talc were obtained at pH 7.2 and above pH 10.5 for A-95 and N-100 polymers. When the pH was higher than 10.5, the destabilization of talc was assisted by the coagulation phenomenon, that is enhanced destabilization was caused by both the flocculant and the cationic promotion due to the presence of Ca$^{2+}$ and Mg$^{2+}$ ions. Hence, it can be said that the charge on the talc surfaces decreased and thus, the destabilization was supported by the coagulation effect due to decreasing repulsive forces between the particles. Except for pH values greater than 9, talc suspensions were not destabilized by C-521 polymer at almost all pH levels. The suspension stability values with C-521 above pH 10.5 were higher than the suspension stability values obtained with cations only. This was attributed to a decrease in the negative charge on the talc surfaces when cations are present in the Ca(OH)$^+$ and Mg(OH)$^+_2$ form, and eventually charge may be reversed from negative to positive. This has been found to be valid for many mineral systems, including talc.$^{10,12,16}$ Thus, it may be said that the stabilization occurred partially due to repulsive forces between the positively charged talc particles and the cationic polymer.

Conclusions

Industrial water always contains cations and their effects should be taken into account in mineral suspension systems. While the talc suspension was not destabilized in distilled water by the pH changes, it was strongly destabilized by coagulation mechanism due to hydrolyzed forms of cations in fresh water at pH values above 10.5. Calcium ion, adsorbed as Ca(OH)$^+$, and magnesium ion, attached by heterocoagulation as Mg(OH)$_2$ precipitate, were responsible for the destabilization of talc suspension in fresh water. Therefore, talc suspensions can be destabilized by use of simple additive such as lime in industrial applications. A-95 (anionic) and N-100 (non-ionic) polymers were more effective on the talc suspensions than C-521 (cationic) polymer in both distilled and fresh waters. In addition, the effects of A-95 and N-100 polymers varied depending on pH of the suspension in distilled and fresh waters. Particularly, the destabilization of talc suspension with these polymers was improved by coagulation effect in fresh water at pH values greater than 10.5. That is, these polymers were greatly effective in promoting floc growth in previously destabilized talc suspension by cations in fresh water.

References

OZKAN : DESTABILIZATION CHARACTERISTICS OF TALC