Polylysine biopolymer for coagulation of contaminated water

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ABSTRACT

During the past decades, contaminated water has been a major concern due to industrial and agricultural wastes. Therefore, the importance of waste treatment has been increasing. Coagulation and flocculation is one of the most widely used treatment technologies for the contaminated water, however, existing coagulants (e.g., polyacrylamide, polyaluminum chloride) have been known to have harmful influences to our environment and human health. As an alternative eco-friendly coagulant, this study suggests polylysine, a cationic biopolymer fermentated by *Streptomyces*. Experiments for various polylysine concentrations were performed, and the efficiency of polylysine was compared to natural settlement. Consequently, the performance of polylysine as a coagulant for soil was determined. Results indicates that polylysine functioned efficiently as coagulants. This paper suggests polylysine shows promising results and efficiency to be an alternative eco-friendly coagulant to remove chemical contaminants from soil and water.

1. INTRODUCTION

Coagulation, flocculation and sedimentation of soil suspension is used in a wide area of geotechnical engineering. Through these procedures, waste materials in ground water or soil can be removed (Zou, H., et al., 2006). Also, coagulation and sedimentation is an essential procedure in land reclamation to construct artificial islands through sedimentation processes.

Stable clay colloidal suspension transform into coagulated or flocculated systems as the negative electric charge on the particles neutralize with time. This phenomenon can be used to remove waste materials in ground water. (Sengco et al, 2001) To accelerate coagulation of clay suspension, coagulants are used in the suspension. Synthetic polymers, polyacrylamide, and mineral additives (aluminium sulfate, aluminium

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chloride, ferric sulfate and polyaluminum chloride) are the most commonly used coagulants. But these chemicals can cause negative effect on environment and human health, such as Alzheimer's disease. Recent researches found chitosan, a biodegradable polymer, as an alternative coagulant. (Pan et al, 1999, Pan et al, 2006, Roussy et al, 2005, Chatterjee et al. 2009). But due to its high price, US $ 30 -50 per kilogram, wide usage of chitosan for sedimentation purposes is not efficient in the economic aspect. Also, chitosan is insoluble in aqueous or alkali solvents because the amino groups of chitosan doesn't protonate at high pH. Therefore, the efficiency of chitosan decreases at high pH, even at the neutral pH of 7.0. (Chatterjee et al, 2005). To overcome the above mentioned limitations of chitosan, this study suggests ε-polylysine biopolymer as an alternative non-toxic coagulant. Polylysine is cheap, US $ 1.2~1.6 per kilogram, biodegradable and an environmentally non harmful biopolymer. Also, polylysine can dissolves in aqueous water. However, there are few studies on polylysine use as a coagulant to precipitate soil suspensions.

From sedimentation tests, the sedimentation volume for various ε-polylysine contents was measured and estimated. From the result, this study provides detailed explanation on the interaction between polylysine and clay and effect of polylysine in sedimentation procedure.

2. METHODS AND MATERIALS

2.1 Materials

ε-Polylysine

ε-Polylysine is a cationic polymer produced by the fermentation of the bacteria, *Streptomyces*. Due to its cationic charge, it can interact with negatively charged surfaces. As a result of this electrical interaction, polylysine is used as antimicrobial agents in the food industry and coating agents for tissue or drug in biotechnology. (Hiraki, et al, 2003, Mazia et al 1975, Park et al, 2006) ε-Polylysine can electrically interact with anionic charged surfaces in clay particles. From this interaction, the coagulated and sedimentation of clay suspensions can be accelerated. For this study, commercial ε-polylysine (BNF CO., LTD) was chosen as surfactants to coagulate clay particles.

Kaolinite Clay

In this study, kaolinite clay which has mineral composition Al_2O_3-$2SiO_2$ is chosen as a representative clay material. Kaolinite used was mined from Indonesia and the kaolinite was used in the powdered form with 3% moisture content. It was first mined then crushed into a powder. Kaolinite has a mean particle size D_{50} = 0.36 mm, specific gravity (G_s) of 2.65 and kaolinite is classified as clay of high plasticity, CH, in USCS.

2.2 Experimental Set up

Sedimentation

To estimate the coagulation efficiency of ε-polylysine, sedimentation tests of clay solutions were conducted. 80ml volume of clay suspension with a water content of 500% was poured in graduated cylinders. Afterwards, ε-polylysine at various concentrations, 0.0%, 0.1%, 0.5%, 1.0% and 2.0%, were poured into the suspension and thoroughly mixed. The sedimentation speed was measured with time until the sedimentation volume became constant.

Spectrophotometer

Spectrometer was used to measure the light beam absorbance properties of clay suspensions to test the clarity of the liquid solution. To estimate the efficiency of sedimentation process of each polylysine concentration, spectrophotometer tests was conducted in this study. 1 ml of the uppermost layer was sampled after the sedimentation process with the use of a micro pipet. The sample was then poured into curvet to fit in the spectrophotometer. Afterwards, visible light with a 640nm wave length, orange color, was used to measure the absorbance of the samples. Through light penetration procedure, absorbance for every case was measured.

3. RESULTS AND ANALYSIS

3.1 Sedimentation

3.1.1 Sedimentation volume

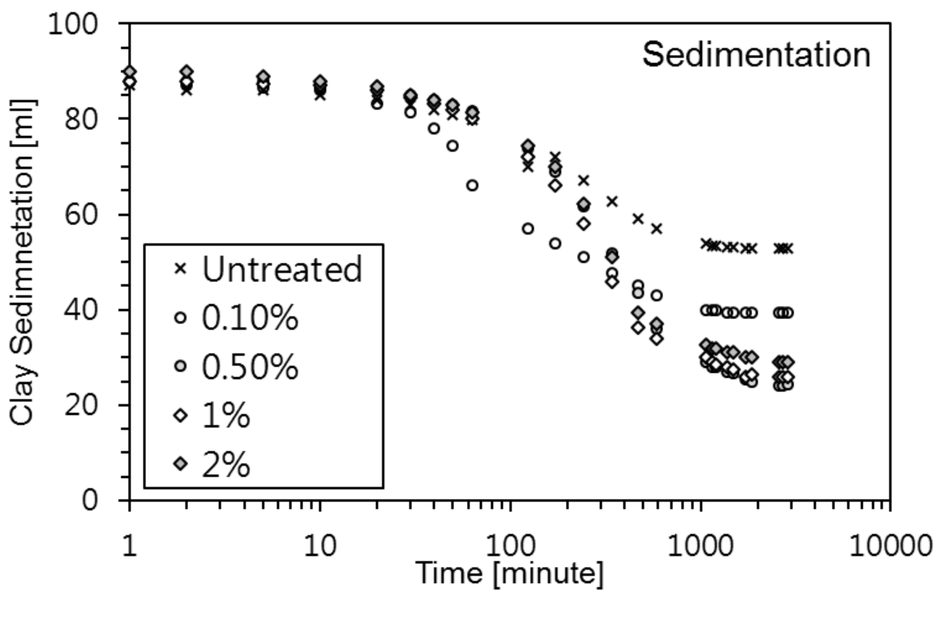

Fig 1. Sedimentation volume by time changes in various ε-polylysine content

Sedimentation test results when ε-polylysine is used as a coagulant is shown in Fig 1. Results showed that even 0.1% injection of ε-polylysine was capable of increasing the sedimentation efficiency. Also, it is shown that as injected amount of ε-polylysine increases, sedimentation efficiency increases. Due to the interaction between the positive charges on ε-polylysine and negative charges on clay particles, colloidal clay particles are neutralized and repulsion forces between colloidal particles decreases. This rheology in clay suspension increases the sedimentation efficiency.

3.1.2 Sedimentation properties

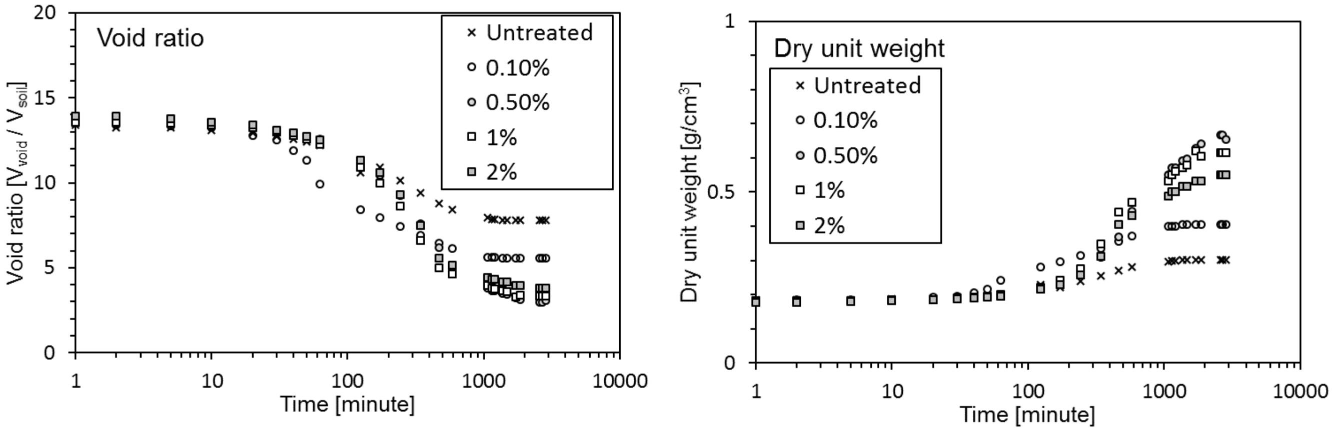

Fig 2. Sedimentation properties, void ratio(left) and dry unit weight(right) as time proceeds in various concentrations

As the sedimentation proceeds, soil properties, void ratio and dry unit weight, changes. During the suspension state, clay particles are not in contact and the repulsion forces between the clay particles is dominant, therefore its void ratio is large, over 100%. As sedimentation proceeds, the clay particles interact with each other and make denser structures, so the void ratio decreases. Due to decrease in void ratio, the dry unit weight increases. Using equations (1) and (2), the void ratio and dry unit weight was derived.

$$\mathrm{e} = \frac{V_{sed}}{Gs \times \gamma_{water} \times W_{soil}} - 1 \quad (1)$$

$$\gamma_{dry} = \frac{Wsoil}{V_{sed}} \quad (2)$$

Where e is void ratio, V_{sed} is sedimentation volume, Gs is specific gravity (2.65), W_{soil} is soil weight and γ_{dry} is dry unit weight. From the Fig 2, it is shown that coagulation by ε-polylysine improves the sedimentation density. As a result of the electrical interaction between ε-polylysine and kaolinite, its final void ratio decreases and dry unit weight increases. This tendency shows that the use of polylysine coagulants increases the sedimentation efficiency and stiffness of the soil.

3.2 Absorbance

To evaluate the efficiency in reducing the soil suspensions, the spectral absorbance of the remaining water for each samples were measured with a spectrophotometer. Absorbance refers to absorbed amount of spectra that penetrates the media. It is expressed as the common logarithm of the ratio of incident to transmitted spectral power. This study measures 640nm wavelength spectra, and the results are shown in Fig 3.

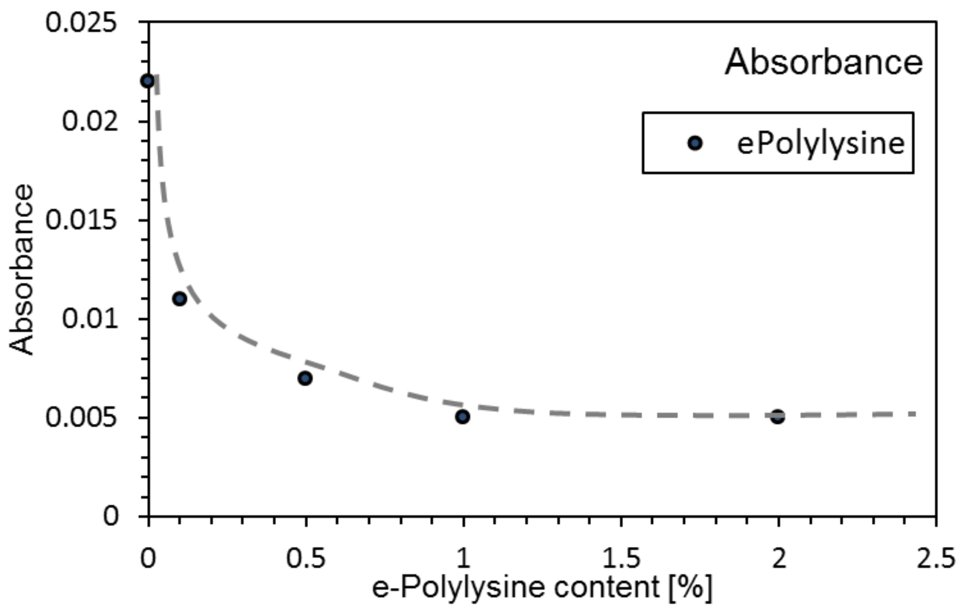

Fig 3. Absorbance of remaining water at various concentrations

From Fig. 3, it can be found that as polylysine content increases, absorbance decreases and levels off at an absorbance of approximately 0.005. It shows that polylysine can decreases the amount remaining clay suspensions in the water.

4. CONCLUSIONS

This study focuses on the electrical interactions between clay and polylysine particles, because this electrical behavior is the dominant reaction of polylysine-clay mixtures. Therefore, experiments were performed only with clay and polylysine mixtures. For a deeper understanding of the behavior of polylysine coagulants, it is essential to conduct further experiments considering more detailed conditions (i.e. clay, sand and coagulants like Hg2+, Cr6+, Cd2+ etc).

Nevertheless, the use of ε-polylysine biopolymers as coagulants in clay suspensions has shown that it can improve sedimentation efficiency by electrically coagulating clay particles in suspensions. Even at small concentrations, ε-polylysine efficiency in the coagulation of clay suspension significantly greater than untreated clay suspensions.

Additionally, this study has shown that polylysine decreases the turbidity of the remaining water after sedimentation. The use of a polylysine in clay sedimentation is highly promising.

Through this study, it is shown that polylysine is an effective, biodegradable and non-toxic coagulant. Also, it is seen that the use of polylysine shows promise in accelerating the formation of floc with contaminants. Overall the use of a polylysine coagulant shows great promise as a bio-degradable, eco-friendly contaminated ground water purification method and water reclamation accelerating agents.

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