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TURBIDITY REMOVAL BY MUCILAGE FROM *BASELLA ALBA*

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Abstract. Coagulation and flocculation are preliminary used in water treatment process for turbidity removal, which popularly use synthetic chemicals with health and environmental concerns. The use of natural flocculants has known to be a promising alternative due to their environmentally friendly behavior. This research investigated on turbidity removal efficiency of mucilage extracted from *Basella alba* - an indigenous plant in Viet Nam - in the role of a flocculant. The removal efficiency of mucilage was investigated in combination with polyaluminium chloride (PAC) or alum on To Lich river water by mean of Jar tests. PAC or alum alone can remove maximum 97 % and 90 % turbidity of To Lich river water at its original pH for the sedimentation time of 30 minutes, respectively. The combination of mucilage and PAC or alum showed an increase in the efficiencies of turbidity removal and a decrease in the amount of chemicals needed. The corresponding increases were maximum 7 % and 18 %, respectively; while the reduction of PAC/alum used was 75 - 80 %.

Keywords: turbidity removal, *Basella alba*, mucilage, coagulation, flocculation.

Classification numbers: 3.6.2, 3.4.2, 1.1.1.

1. INTRODUCTION

Maintaining water quality is essential to secure human life quality and protect other organisms since water is a must for survival. Turbidity, caused by suspended solids, is the first warning indicator of water quality. Reducing water turbidity is required due to its effects in removal of suspended solids, infectious agents (e.g. viruses, bacteria, protozoa), color and toxic compounds associated with suspended particles [1]. Turbidity removal is commonly achieved by coagulation and flocculation process [2].

The conventional chemical-based coagulants and flocculants, namely alum ($Al_2(SO_4)_3.18H_2O$), ferric chloride ($FeCl_3$), polyaluminium chloride (PAC) and polyacrylamide (PAM) are effective; However, their disadvantages include relatively high procurement costs, changes in pH of treated water, production of large sludge volumes and detrimental effects on human health [3]. There is also a strong evidence linking aluminium-based coagulants to the development of Alzheimer’s disease in human beings [4]. It is therefore desirable to decrease these chemical coagulants/flocculants with bio-based ones to counteract the aforementioned drawbacks.

The plant-based product is one of the most easily assessable bio-based products. So far, the most known plant-based flocculants are extracted from moringa and cactus species [3, 5]. In Viet Nam, scientists also investigated on plant-based flocculants from moringa and other plants (golden shower, purging nut, common bean, soybean) for treatment of different types of water [6 - 8]. The main advantages of using natural plant-based flocculants are high biodegradability, environmental friendliness, unlikely changed pH and cost-effectiveness [3, 9]. Cost-effectiveness is especially augmented if extracted from the plant, which is indigenous to a rural community.

Basella alba L. (commonly known as malabar spinach or climb spinach) is a fast-growing perennial vine, which is a widely consumed leafy vegetable in Viet Nam and other tropical countries such as India and Thailand [10]. This plant is the source of various classes of bioactive products such as carotenoids, saponins and flavonoids [11]. A significant amount of mucilage is contained in leaf and stem of *Basella alba*. *Basella alba* L. mucilage (BAM) is the mixture of monosaccharide (e.g. D-galactose) and polysaccharides (e.g. pectin) that has antioxidant and mucoadhesive activation [11,12]. BAM is used as thickening and gelling agent and binder in food industries and pharmaceuticals because its high viscosity reduces its creaming and coalescence velocity and favors its emulsifying ability [13,14].

This study is aimed to provide a scientific basis for the use of BAM as a flocculant in water treatment.

2. MATERIALS AND METHODS

2.1. Materials

Basella alba leaves were obtained from local market in Ha Noi as the input material for mucilage extraction.

To Lich river water was taken near the river bank at Khuong Dinh road, Thanh Xuan, Ha Noi (April 2017, morning 29 – 30 ^{o}C, broken cloud, humidity 90 %) for tests on turbidity removal efficiency of mucilage from *Basella alba*. It has pH of 7.5, turbidity of 90 NTU, TSS of 180 mg/L and COD of 250 mg/L.

2.2. Methods

2.2.1. Extraction and characterization of mucilage from Basella alba

Collected leaves were carefully washed and dried at 50 °C until constant weight. The dried leaves were grounded to pieces of about 1 mm size by a household blender. The small pieces were mixed with distilled water and heated in the water bath at 60 ^{o}C for 1 hour. After that, the cool mixture was filtrated through an 8-fold muslin cloth to obtain the filtrate. Acetone was added to the filtrate in order to precipitate the mucilage. The floating precipitation was separated by centrifugation, then further dried to constant weight at 40 °C in oven before being powdered and kept in a desiccator for further use. In the up-coming experiments, the mucilage powder was dissolved in distilled water to the desired dosage, so that it can be used as a flocculant.

The obtained BAM was characterized by Fourier transform infrared (Is50 FTIR, 4000-400 cm^{-1}, 0.47 mm interval, 16 scans) on solid phase and particle charge detector (PCD-05, Muetek) on solution of 20 mg/L mucilage.

2.2.2. Jar tests

Jar tests were applied to examine the turbidity removal efficiency of mucilage extracted from *Basella alba* in combination with PAC/alum. In this experiment model, turbidity was removed by a sequent coagulation and flocculation process using PAC/alum as coagulant and mucilage as flocculant. The general procedure of jar tests included consequently the adjustment of water pH (by HCl or NaOH), the addition of PAC at flash mixing period (200 rpm, 1 minute), the addition of mucilage at slow mixing period (30 rpm, 10 minutes), the sedimentation of the mixture in 30 minutes and finally the measurement of turbidity of water layer at 3 cm under the water surface. The pH of water was measured by pH meter (M200 easy, Easysense pH 33, InPro 3030/120, Mettler Toledo). The residual turbidity was measured by HACH 2100Q turbidity meter. TSS and COD of influent and effluent were measured following APHA 2540-D (2005) and APHA 5220-C (2005).

3. RESULTS AND DISCUSSION

3.1. Characteristics of mucilage extracted from *Basella alba*

3.1.1. Infrared spectrum

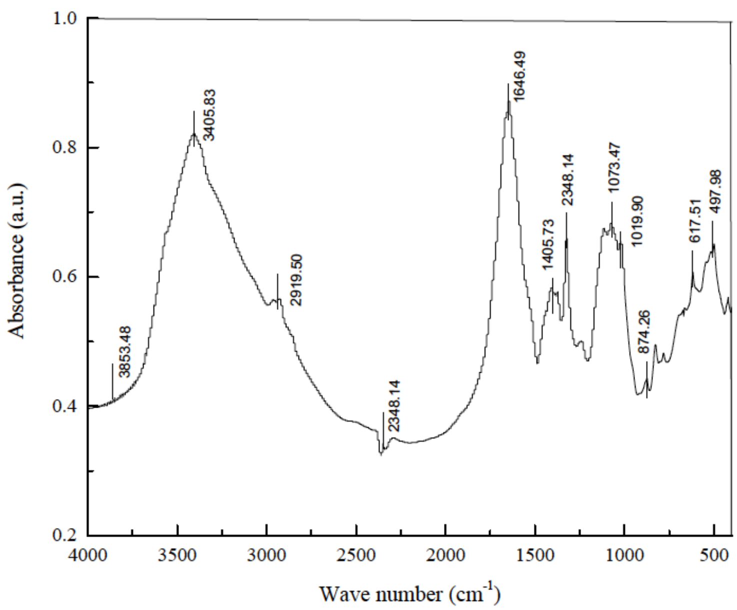

Figure 1. FTIR spectrum of mucilage extracted from *Basella alba.*

FTIR spectrum (Figure 1) shows typical function groups of mucilage, which are hydroxyl group (-OH stretching, 3405.83 cm^{-1}), cacbonyl group (-C-H stretching, 2919.50 cm^{-1}), keto group (C-O stretching, 1646.49 cm^{-1}), and alhydric and phenolic group (C-OH stretching, 1073.47 cm^{-1}). Various function groups on macromolecular structure of BAM can interact and adsorb counter ions. These functional group bands are also characteristic for polysaccharides including pectin, which is the major component responsible for viscosity of mucilage [11, 12, 15]. High viscosity makes BAM as useful as a thickening and binding agent [13].

This spectrum is almost identical with BAM spectra obtained by Pareek *et al*. [16] and Vishnu *et al*. [17]. They showed that Basella polysaccharide was composed of galactose, arabinose, glucose, galacturonic acid and rhamnose. The presence of galacturonic acid is the cause of the anionic nature of BAM. D-galacturonic acid provides active sites at polymeric chain for particle adsorption and encourage coagulation process [18,19]. Moreover its combination with arabinose, galactose and rhamnose brings about the ability to reduce turbidity of these sugars [20].

3.1.2. Zeta potential

Figure 2 shows that zeta potential of BAM was negative at its ordinary pH (6.32), and less negative at pH ranges of 2 - 4 and 11 - 12. Between pH 4 and 8, it was consistent and very close to the values obtained in pH 9 - 10. It was hypothesized that H^+ (plenty in pH < 4) and Na^+ ions (plenty in pH >10 conditions), which enveloped the mucilage surface, were responsible for the higher zeta potential of BAM solution. Stable zeta potential of mucilage at pH range of 4-8 indicates its stable performance in particle stabilization and adsorbate adsorption in a wide range of pH and this performance is less affected when water pH is up to 10. Nevertheless, particles in water commonly have net negative surface charge and the principle mechanism controlling particle stability is electrostatic repulsion [1]. Therefore, mucilage is ineffective in neutralizing negative charges of suspended particles, which is a significant mechanism of coagulants such as PAC or alum.

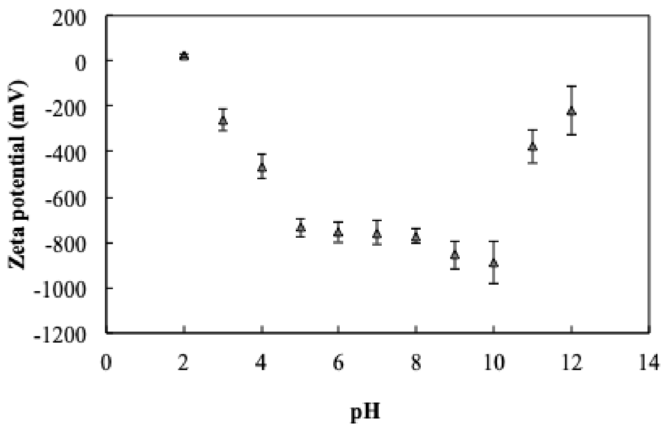

Figure 2. Zeta potential of mucilage extracted from *Basella alba*.

3.2. Turbidity removal by combination of *Basella alba* mucilage and aluminum-based coagulants

3.2.1. Turbidity removal in coagulation process by PAC and alum

In order to evaluate the turbidity removal of BAM in combination with aluminum-based coagulants, PAC and alum, the two most popular ones, were selected. The dependence of these two coagulants on To Lich river water conditions are shown in Figure 3. Figure 3a specifies suitable pH ranges for PAC and alum performance, which were 7.5 - 9 and 6 - 8, respectively. Meanwhile, the ordinary pH of To Lich river water was 7.5, implying that pH adjustment is not needed in coagulation process.

Optimal dosages of both PAC and alum lied between 300 and 400 mg/L with achieved turbidity removals of about 97 and 90 %, respectively (Figure 3b). Results also indicate that PAC performed better than alum at the same dosage. However, to assess flocculation effect of mucilage in combination with PAC/alum, dosages of lower turbidity removal were selected.

Effect of pH on turbidity removal of PAC and Alum are dependent on their hydrolyzates. Upon the addition to water, Al(III) will be hydrolyzed and polymerized, following by the adsorption of hydrolyzates at the interface. The destabilization of particles in water will be carried out by charge neutralization due to mutual electrical attraction or sweep flocculation [1, 21, 22]. Alum was reported to have an optimal performance in pH range of 6 - 8 and that of PAC is 5 - 8 because its activities are less controlled by pH due to pre-polymerized forms of Al. At pH range of 6 - 8, high polymeric positive hydrolyzates and amorphous $Al(OH)_3$ present in the solution [21]; leading to a favorable charge neutralization. High dosages of PAC and alum also led to the growth of amorphous precipitate, with entrapping capacity toward particles because nucleation of precipitate occurs on the surface of particulates. The entrapment mechanism is dominant in treatment of water with pH between 6 and 8 [1].

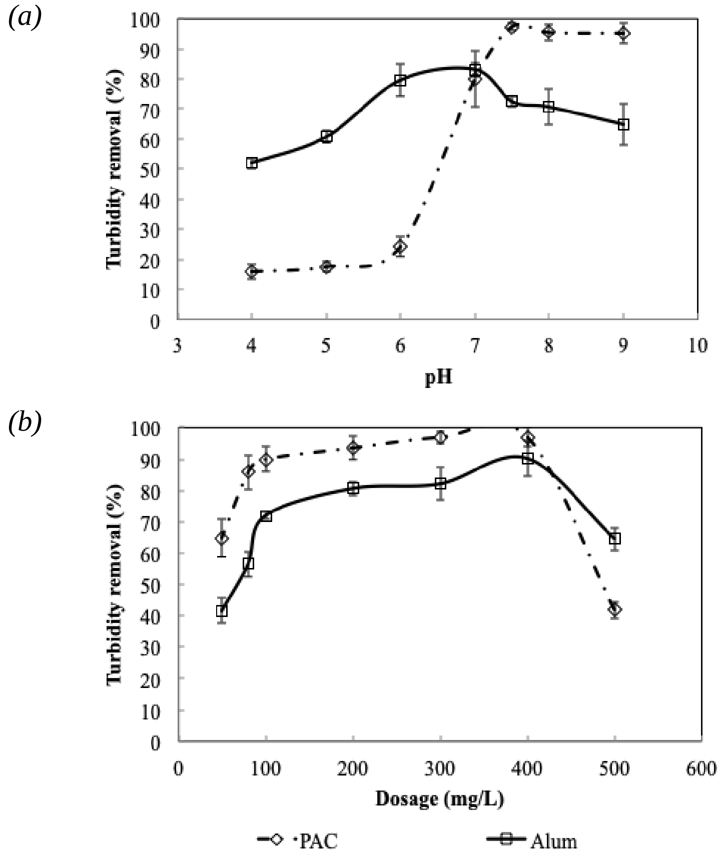

Figure 3. Coagulation conditions of PAC and alum on To Lich river water.

Superior performance of PAC compared to alum is generally recognized and explained [21 - 23]. The hydrolysis of alum produces different hydroxyl complexes but the majority are monomeric ones with a cation charge varying from +1 to +3; Meanwhile, PAC generates high concentrations of polynuclear Al_{13} with higher cation charge (+7). The activities of PAC is less impacted by temperature and pH of water and appear to be faster.

(a)

(b)

(c)

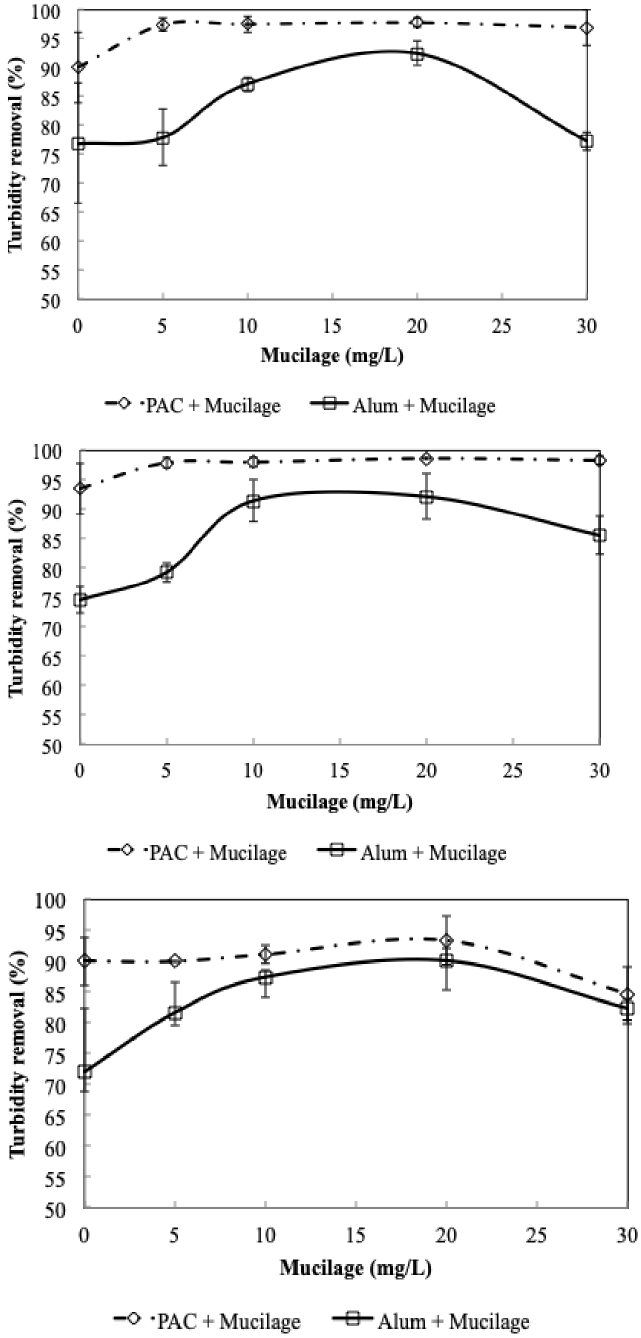

Figure 4. Turbidity removal by mucilage (BAM) in combination with PAC or alum at dosages of (a) 100 mg/L, (b) 120 mg/L, (c) 150 mg/L).

3.2.2. Turbidity removal by BAM in combination with PAC and alum

Turbidity removal of BAM in combination with PAC and alum with dosages of 100, 120 and 150 mg/L are illustrated in Figure 4. The addition of mucilage enhanced the turbidity removal of both PAC and alum. The corresponding increases ranged up to 7 % for PAC and 18 % for alum. These enhancements are found compatible to PAM [24]. The highest turbidity removal of BAM - PAC and BAM - alum combinations were 98 % and 92 %, in correspondence to the residual turbidity of 1.8 NTU and 7.2 NTU, respectively. The most effective dosages of mucilage for both combinations lied between 10 and 20 mg/L. To obtain comparative turbidity removal, PAC and Alum usage (without BAM addition) was 75 – 80 % higher than those used in the combination with BAM.

Under optimal working conditions, the combinations of BAM and PAC resulted in 96 % TSS removal and 66 % COD removal. Those removal efficiencies for TSS and COD achieved by the combinations of BAM and alum were 92 % and 61 %, respectively. As such, TSS of output water (7.2; 14.4 mg/L) was much lower and COD (85.0; 97.5 mg/L) was much higher than values regulated in column B1 (QCVN 08: 2015/BTNMT) for surface water quality. Turbidity of output water (1.8 and 7.2) was of surface water with high transparency since turbidity range of lakes and reservoirs water is 1-20 NTU [1]. Coagulation and flocculation process is the primary stage of water treatment procedure, hence normally further treatment stages are required to reach the quality of need.

The hydrocolloid characteristics of mucilage is the basis for its utilization as a bio-flocculant. Hydrocolloids are a group of water-soluble biopolymer, due to the presence of a large number of hydroxyl groups. They optimize the functional and rheological properties of various systems, including stabilization, emulsifying, gelling, thickening [25]. In fact, pectin is the major component responsible for the viscosity of mucilage. Pectin is a polysaccharide consisting mainly D-galacturonic acid units, joined in chains by means of a-(1-4) glycosidic linkage [15]. D-galacturonic acid provides active sites at polymeric chain for particle adsorption and encourages coagulation process [18, 19]. Adsorption and bridging were reported to be the predominant coagulation/flocculation mechanisms of mucilage [18, 20].

4. CONCLUSIONS

Effective elimination of turbidity from water could be achieved by using *Basella alba* mucilage (BAM) as a plant-based flocculant. The addition of BAM enhanced turbidity removal of both PAC and alum in the sequent coagulation and flocculation process with corresponding values of maximum 7 % and 18 %, when applied on To Lich river water. The use of BAM also resulted in the reduction of PAC and alum use at about 75 – 80 %, implying a positive environmental effect instead of aluminum based coagulants. BAM could be a promising natural flocculant to minimize health and environmental problems and a potential aid to farmers who grow *Basella alba*.

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