Removal of turbidity in water treatment using natural coagulant from *Lemna perpusilla*

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**Abstract.** *Lemna perpusilla* (duckweed) is aquatic plant that easily to spread. This plant contains of high protein. The ability of *L. perpusilla* to act as natural coagulants was tested using a synthetic turbid water. Active components were extracted from *L. perpusilla* using NaCl solution. Experiments was conducted in batch mode for initial turbidity such as 50 NTU (low turbidity), 150 NTU (medium turbidity) and 300 NTU (high turbidity). Jar test procedure with the coagulation time of 1 min and flocculation 15 min was optimized, irrespective of the initial turbidity. The optimum settling time for 300, 150, and 50 NTU water samples were 30 ppm. The influence of several parameters such as pH and coagulant dose and also its optimization were exploited. The highest value of turbidity removal were achieved at pH 11 and 30 ppmv in coagulant dose. This coagulant can removed 85.02% ; 88.98%; and 92.48% of turbidity from water having in turbidities of 50, 150 and 300 NTU, respectively. Thus, the natural coagulants extracted from *L. perpusilla* revealed to be effective for turbidity removal.

1. Introduction

Clean water is essential to sustain human well-being, livelihoods and a healthy environment for sustainable development. Currently, households in Indonesia are still lacking access to clean and drinking water. Regional Water Supply Company (Perusahaan Daerah Air Minum/PDAM) which is the main provider of drinking water supply in Indonesia is only able to serve 41.88% of the urban population, 13.94% of the rural population, and 27.05% nationally [1].

At present water scarcity is a serious problem and is not limited to dry areas. Population growth, climate change, industrialization, agriculture and urbanization are the causes of the decline in water quality, so the water cannot be directly consumed. Limited access to clean water resulted in utilization of turbid water to fulfil daily needs, such as river water.

Coagulation-flocculation is the main process in water and waste water treatment. Coagulation is process of destabilization of colloid particles, including bacteria and viruses using coagulants. Mixing is an important operation for the coagulation process[2]. Material that can be used in this process can be inorganic (chemical) coagulant or natural coagulant. Aluminium sulphate (alum) and poly aluminium chloride (PAC) are common chemical coagulants globally used in water treatment. However, the sludge obtained from treatment using alum lead to disposal problems such as aluminium accumulation in the environment, moreover, residual aluminium may be connected to Alzheimer’s disease[3]. It is therefore desirable to replace these chemical coagulants with natural coagulant to counteract the aforementioned drawbacks, which have to be safe for human health as well as biodegradable. The other advantages using natural coagulants are cost effective and low sludge production.
Natural coagulants can be derived from plants and animals. Studies of the use of natural coagulants have been carried out. *Moringa oleifera* is a plant-base coagulant that is most widely used in water and wastewater treatment. *Moringa oleifera* has been used to remove Congo Red dye on textile waste[4], to remove Chemical Oxygen Demand (COD) from wastewater in Mumbai[5], to treat palm oil mill effluent in Nibong Tebal, Penang[6] and to remove turbidity in water treatment[7,8,9].

*L. perpusilla* or duckweed is aquatic plant that easily to spread. Generally, *L. perpusilla* is used for additional fish feed, because it contains 38.10% of protein[10]. *L. perpusilla* can also be used as phytoremediator to adsorb nutrients in aquaculture media[11]. Present study was intended to remove turbidity in drinking water treatment using *L. perpusilla* as natural coagulant. The effect of various parameters like pH, coagulant dose and initial turbidity on coagulation process (turbidity removal) was investigated. The process optimization of coagulants dose and pH was also studied.

2. Material and Methods

2.1. Extraction of active component from *L. perpusilla*

*L. perpusilla* were collected from integrated multi trophic aquaculture located in Research Center for Limnology – Indonesian Institute of Sciences, Cibinong. *L. Perpusilla* were washed with water to remove the impurities and dried. The dried biomass of *L. Perpusilla* were crushed and powdered by using a laboratory mill and were sieved through 0.4 mm sieve. The fraction with particle size less than 0.4 mm was used in experiment[12,13].

Fifty grams of prepared powder was suspended in 1 L of 1 M NaCl solution and the suspension was stirred using a magnetic stirrer for 10 min to accomplish the extraction. The suspension was then gravity filtered through a rugged filter paper[12,13,14]. The solution named *L. perpusilla* stock solution. This stock solution prepared in this way was used the same day it was produced[14].

2.2. Preparation of turbid water

Synthetic turbid water for coagulation test was prepared by adding 1 g kaolin to 1 L tap water. The suspension was stirred for 1 h to achieve uniform dispersion of kaolin particles, and then it was allowed to remain for 24 h for completing hydration of the particles. The suspension was used as the stock suspension[12].

The suspension was diluted to 500 ml using tap water to prepare synthetic turbid water with various turbidity just before coagulation test. Suspension with three different initial turbidity of 50, 150 and 300 NTU were prepared by adding 25, 75 and 150 ml of stock kaolin suspension to 500 mL of tap water. The initial pH in the synthetic turbid water was adjusted to a desired value with 1 M NaOH or 1 M HCl[12,13].

2.3. Experimental design

Coagulation activity of *L. perpusilla* stock solution extract was determined by the jar test. Initial turbidity of 50 NTU made by adding 25 mL stock solution with 475 tap water. Adding 425 mL tap water into 75 mL stock solution yield 150 NTU initial turbidity and adding 150 mL stock solution into 350 mL tap water yield 300 NTU initial turbidity.

The synthetic turbid water (500 ml) of different initial turbidities was filled into the beakers (600 ml) and mixed at 200 rpm. Various doses of *L. perpusilla* stock solution extract were added into the beakers and mixed for 1 m. The mixing speed was then reduced to 60 rpm and was kept for 20 min. Then the suspensions were left for sedimentation. After 30 min of sedimentation, clarified samples were collected from the top of the beakers, and residual turbidity was measured. The residual turbidity of the sample was Tₜ. The same coagulation test was performed with no coagulant as the blank. The residual turbidity in the blank was T₉. The percentage of removal was calculated using the following formula:

$$\text{Coagulation activity (\%) } = \frac{(T_9 - T_S)}{T_9} \times 100\%$$

3. Results and discussion
3.1. Effect of pH
In the coagulation process, the factor of pH affect the surface charge of coagulant and also the stabilization of the suspension. The effect of pH on coagulation process with three different initial turbidities (50, 150 and 300 NTU) is shown in Figure 1. This experiment was carried out with coagulant dose of 30 ppm.

![Figure 1. Effect of pH on coagulation process](image)

From this graph, it is observed that turbidity removal was higher at alkaline condition, particularly at pH 11, while in pH range from 5 to 9 showed very low coagulation activities. The highest turbidity removal was 85.02%, 88.98% and 92.48% in the initial turbidity of 50, 150 and 300 NTU, respectively at pH 11. These results are sufficiently in accordance with observation that higher pH value are optimal for other natural coagulants viz. from Moringa oleifera[8], from cactus[15], from chestnut and acorn[13]. Figure 1 also showed that the turbidity removal at acidic almost the same as alkaline condition. At pH 3, the turbidity removal reached 51.56%, 76.80% and 82.84% % in the initial turbidity of 50, 150 and 300 NTU. This result is accordance with other research related to the application of Moringa oleifera to remove Congo red dye in waste water[4].

L. perpusilla is a macrophyta with a high protein content of around 38.1%[10]. Protein generally contains of three active groups namely amino acids, carboxyl and amides. Protein is amphoteric which has both acid and base groups. It can be supposed that the negative charged active component from natural coagulant could attracted bivalent cations from water and formed a net-like structure and removed from water by a sweep coagulation in the alkaline condition and vice versa[8]. Therefore, the particle destabilization by L. perpusilla could be explained by charge neutralization mechanism. pH is highly influential at lower turbidity conditions.

3.2. Effect of coagulant dose
Coagulant dosage is one of the most important parameters that has been considered to determine the optimum condition for the performance of coagulation and flocculation processes. Insufficient dosage or overdosing would result in the poor performance in flocculation process. Therefore, it is also important to determine the optimum dosage in order to minimize the dosing cost and sludge formation and also to obtain the optimum performance in water treatment. The effect of coagulant doses (10 – 120 ppm) maintaining pH 11 and initial turbidity 150 NTU was represented in Figure 2.

From Figure 2, it can be seen that there is an increase in turbidity removal efficiency proportional to the increase in coagulant dose to 30 ppm. The highest turbidity removal could reach 91.65% at that condition. Coagulation activity did not run efficiently at coagulant dose of more than 30 ppm because
of the failure of floc formation. The mechanism that occurs is that the polymers in the natural coagulant will cover the entire surface of the colloidal particles so that there is no place for the end chain to stick and the flocculation process does not occur. As a result, colloidal particles return to stable or unable to bind with other particles[7].

![Figure 2. Effect of coagulant dose on turbidity removal](image)

Surjana seed powder (SSP), Maize seed powder (MSP) and Chitosan as natural coagulant methods for Congo Red (CR) dye removal has been investigated[4]. The highest removal of CR was found to be 69.8%, 65.0% and 60.0% using SSP, Chitosan and MSP, respectively, at 20 ppm of dose and 60 minutes flocculation time.

Generally, it can be concluded that lower doses of investigated natural coagulants were better than higher ones. This is very important not only for process economy but also for lower organic matter load in processed water because it is known that high organic load might cause microbial growth.

3.3. Effect of initial turbidity
Turbidity is caused by the presence of suspended solids in the water. The higher suspended solid in water, the higher the turbidity. Figure 2 shows the effect of initial turbidity on coagulation activity. The experiment run at pH 7 and coagulant dose of 30 ppm.
Figure 3. Effect of initial condition on turbidity removal

Turbidity removal up to 92.48% and 85.02% were recorded for water sample with initial turbidity 300 NTU (high turbidity) and 50 NTU (low turbidity), respectively. The higher initial turbidity of the water, the higher coagulation activity (turbidity removal) will be obtained. High initial turbidity indicates a large number of colloidal particles inside. The more colloidal particles, the more bonds between colloids and coagulant particles will be occured, vice versa. As a result, produced water will be clear because the more flocs are formed.

4. Conclusion
The purpose of this study was to investigate the ability of natural coagulant derived from extract *Lemna perpusilla*tor turbid water clarification. The various parameters like pH, coagulant dose and initial turbidity were investigated in this study. The process optimization of these mentioned parameters was also intended and highest percentage removal of turbidity was achieved using it. Sample water with high initial turbidity will produce high turbidity removal. Coagulation activity will run effectively in highly acidid or highly alkaline condition.

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