International Journal of Eco-Innovation in Science and Engineering Vol 3 (2), 2022 (15-20)
https://ijeise.upnjatim.ac.id/ E-ISSN: 2721-8775

Article

The Effect of Velocity Gradient and Camp Number on Solids Removal using Bio-Coagulant from *Corbula faba* Hinds Shells

Ardika Nurmawati[1,a], Kindriari Nurma Wahyusi[1,b*], Retno Dewati[1], and Jauhar Hilmy[1]

1 Department of Chemical Engineering, Faculty of Engineering, Universitas Pembangunan Nasional (UPN) "Veteran" Jawa Timur, Gunung Anyar 60294 Surabaya, Indonesia
*Corresponding author: (kindrinurma@gmail.com) | Phone number: -

Received: 17th March 2022; Revised: 27th August 2022; Accepted: 24th October 2022;
Available online: 22 November 2022; Published regularly: May and November.

Abstract

The TSS and TDS values of water are required to meet the standard. Like coagulation, the pretreatment process in water helps reduce solid content in water. The coagulant destabilizes water pollutants and helps flocs formation with the coagulation process. This paper studies the performance of chitosan bio-coagulant produced from *Corbula faba* Hinds shells. The velocity gradient and the Camp number of solids removal were also evaluated. The velocity and period of rapid mixing varied from 110 to 150 rpm, and the velocity gradient (*G)* was 181.2 to 288.5 s^{-1}. The mixing period also ranged from 1 to 5 minutes. The highest TSS and TDS removal resulted in 140 rpm or 260.2 s^{-1} and 4 minutes of mixing. The residual TSS and TDS decreased with the increase of Camp Number until reaching a point and increased again afterward.

Keywords: Camp Number, Chitosan, Coagulation, Solids, Velocity gradient

1. Introduction

Water is crucial for every organism, with a quality standard in every use. One parameter that needs to be controlled is solids concentration, such as Total Suspended Solids (TSS) and Total Dissolved Solids (TDS). TSS contained solids with a size of more than 2 μm like clay minerals, plankton, and humic substance. In contrast, TDS particle size is less than 2 μm or ranges from 0.001 to 1 μm, like inorganic salts (Na^+, Mg^{2+}, Ca^{2+}, SO_4^{2-}, etc.) and dissolved organic matter [1,2]. A high concentration of TSS and TDS in the water results in decreased water quality. Their presence becomes contaminants and toxic sources affecting aquatic organisms, water colour, and taste [3].

Jagir River, located in Surabaya, East Java, Indonesia, is one of the raw water sources for tap water. The water quality of the Jagir River decreased due to various activities around the river, whether domestic or industrial. The water monitoring result from 2010 to 2013 showed that the water from PDAM Jagir intake condition did not meet tap water standard. The average BOD concentration was 5,715 mg/L, the COD was 22.86 mg/L, the TSS was 59.59 mg/L, and the pH was 7.05 [4]. According to Indonesian government regulation number 82:2001, the standard for water is divided into four classes. Several water standards for domestic and agricultural uses (class I and II) are TSS 1,000 mg/L, TSS 50 mg/L, BOD 2-3 mg/L, and COD 10-25 mg/L. Under those conditions, the water needs pretreatment to remove pollutants before use [5].

The coagulation process is part of the water pretreatment process. This process runs with the help of a coagulant and gets rid of solids and colloidal form components. The coagulation process mechanism may leaded by zeta potential from double-layer interaction, charge neutralization, bridge formation, and precipitation. The addition of coagulant caused unstable conditions affected by the Van der Waals force and Brownian movement of particles [6].

There are many types of commercial coagulants used in water treatment. Chitosan, as a bio-coagulant, became an alternative to metal coagulant uses like aluminum and iron. The advantages use of chitosan were non-hazardous material, non-corrosive, and biodegradable. The sludge production was also easy to handle and safe for the environment [7]. It not only works as a coagulant, but chitosan also act as a flocculant due to its high molecular weight, cationic charge density, and bridging the flocks and precipitation with their stability in any pH range condition [8].

Chitosan is a derivative product of chitin that can be found easily in the exoskeleton of crustaceans (crab, shrimp, prawn), mollusks (snail, oyster), fungi, and yeast [9,10]. *Corbula faba* Hinds, or white mussel, is a bivalve mollusk found easily in muddy or shallow water near the beach. In Sidoarjo, East Java, Indonesia, white mussel production is up to 8.6 million kg annually [11]. This high mussel production also generates a high quantity of shell waste. Mussel shell compositions comprised 51.62% mineral content and 21.32% chitin [12]. With the potential content of chitin, mussel shells likely be processed to become chitosan. According to previous research, chitosan from these shells had a 65.08% on deacetylation degree [13].

The coagulation process took several steps. First is rapid or flash mixing, when the coagulant is added to sample water and stirred at high speed. Then the rate is reduced (slow mixing) to allow particles to form larger flocs that be easier to settle down. And the last step, the sediment developed and separated from the water [14]. In the coagulation process, many factors affected the performance of solids removal. The water characteristics, coagulant used, and operation conditions influenced the result. T. R. Camp (1995) evaluated the degree of mixing measured by velocity gradient (G) related to the shear force in the water. Another property that plays a role in the coagulation is Gt or Camp Number. This value showed the sum of particle collisions that equal velocity gradient and detention time [15].

This study investigated the correlation of velocity gradient and Camp number in the coagulation process of river water using chitosan from *Corbula faba* Hinds shells. Those two parameters correlated with the solids removal of the sample water, shown by TSS and TDS values.

2. Material and Method

2.1 Material

In this experiment, the water sample was from the Jagir River. The sampling port was in the sluice gates area during the rainy season. The bio-coagulant proceeds from white mussel shells waste. The shells were collected from Kenjeran beach, located at Sidoarjo, East Java, and processed to make chitosan.

2.2 Method

2.2.1 Bio-coagulant Production

Chitosan production was obtained in several steps. First, the collected white mussel shells were cleaned and dried under sunlight, followed by the oven. The dried shells were grounded and sieved with size 100 mesh to obtain a uniform powder. The powder shells were demineralized using chloric acid. After removing the mineral, the shell reacted with 3.5% NaOH solution to extract the chitin. To transform the chitin become chitosan, it reacted again with 60% of the NaOH solution under certain conditions. The detailed process was described in the previous work [13].

2.2.2 Coagulation Test

The coagulation was done using jar-test equipment that contains six beaker glasses for water testing with a volume of 1000 mL. Chitosan, as a coagulant, was dissolved in 100 mL of 1% acetic acid solution. The solution was stirred for 6 hours to ensure the chitosan dissolved. The chitosan solution was added to the sample water until the water pH was neutral. The mixture was stirred using two-speed levels, rapid and slow mixing. The rapid mixing varied from 110 to 150 rpm, with the period also differing for 1 to 5 minutes. The slow mixing was done after the rapid mixing at 40 rpm for 10 minutes. The precipitation process was done for 1 hour to allow the flocs to settle down. After that, the mixture was filtered to separate the sediments. The coagulant performance was evaluated by the decrease of the TSS and TDS that showed the solids removal.

DOI:10.4186/ijeise.upnjatim.ac.id/E-ISSN: 2721-8775

2.2.3 Velocity gradient and Camp Number Calculation

The velocity gradient is one of the essential factors in the coagulation and flocculation process. It measured the degree of mixing based on the power inserted into the water [15]. The value of the velocity gradient is depended on the power entered into the water, the water viscosity, and the flocculator capacity [16]. The velocity gradient can be calculated using Eq. 1.

$$G = \sqrt{P/_{\mu V}} \quad (1)$$

where G is velocity gradient (1/s), P is power imparted to the water (watt or N.m/s), μ is absolute viscosity of the water (N.s/m^2), and V is basin volume (m^3).

The power applied in the basin is related to the water flow types, turbulent or laminar, where the Reynold Number can be calculated as shown in Eq.2.

$$N_{Re} = {D_a^2 n\rho}/_{\mu} \quad (2)$$

where D_a is the diameter of the impeller, n is rotational speed (rad/s), and ϱ is water density (kg/m^3). The value of Reynold Number indicated the flow of the water, whether laminar (less than 10) or turbulent (more than 10^4). The power was calculated using Eq.3 for laminar flow and Eq.4 for turbulent flow [15].

$$P = k_L n^2 D^3 \mu \quad (3)$$

$$P = k_T n^3 D^5 \rho \quad (4)$$

where k_L is impeller constant for laminar flow and k_T is impeller constant for turbulent flow.

Multiplication between the detention time and the velocity gradient will result in Camp Number (Gt). The value of Gt was more critical than the separated value of G and t. This parameter can be calculated using Eq.5.

$$Gt = t\sqrt{P/_{\mu V}} = 1/_Q \sqrt{PV/_{\mu}} \quad (5)$$

where t is rapid mixing period (s) and Q is flowrate (m^3/s) [16,17].

3. Results and Discussion

In this experiment, the velocity gradient value differed based on the rapid mixing speed. Based on the coagulation results, the residual of TSS in the water sample decreased with the increase of velocity gradient up to the minimum condition. Then the TSS residue increased again with a higher velocity gradient applied (Fig.1). The lowest residual TSS resulted in 260.2 s^{-1}. The velocity gradient was related to the shear force applied in the sample water. The increased power shaft increased the velocity gradient and impacted the shear force. A higher velocity gradient maximized the flocs formation process, but when the velocity gradient exceeded its limit, it broke the floc and reduced its size [18,19]. The same condition also appears in TDS analysis (Fig.2). The minimum TDS residue was reached when 260.2 s^{-1} of velocity gradient was applied.

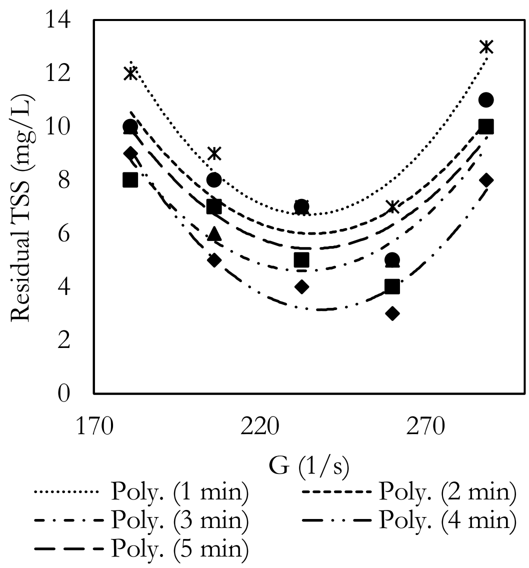

Fig. 1. The effect of velocity gradient in coagulation process to residual TSS

Another factor that affected the floc formation in the coagulation and flocculation process was detention time. Fig. 1 and Fig. 2 show that the lowest residual TSS and TDS resulted in 4 minutes of rapid mixing. These conditions appeared due to the interaction between ions from the chitosan and water pollutants. A higher period of mixing gave the contact time to the particles. But on the contrary, it also affected the stability of the flocs if the mixing time took longer. It caused flocs breakage and size reduction [20,21].

DOI:10.4186/ijeise.upnjatim.ac.id/E-ISSN: 2721-8775

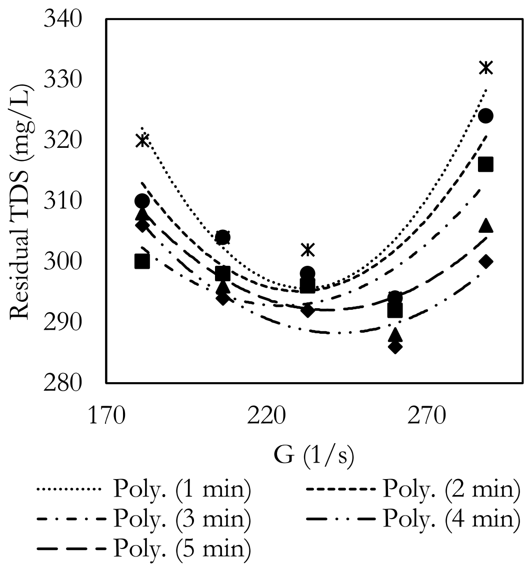

Fig. 2. The effect of velocity gradient in coagulation process to residual TDS

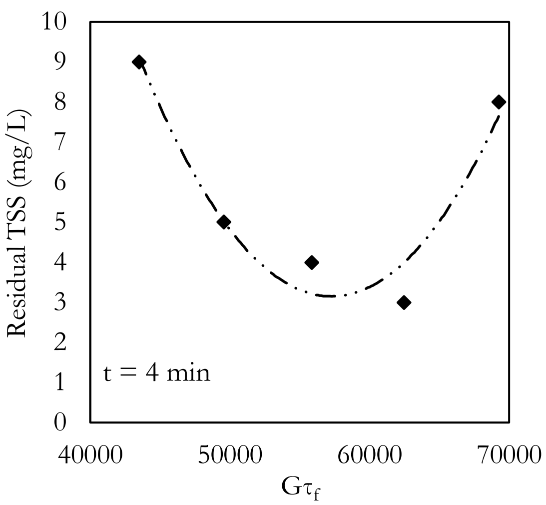

Fig. 3. The effect of Camp number to residual TSS in 4 minutes mixing

The effect of Camp Number on residual TSS and TDS showed in Fig.3 and Fig. 4 at 4 minutes of rapid mixing time. The residual TSS and TDS decreased until the minimum Camp Number value at 62,443.46 and afterward increased again with the increase of Camp Number. With those Camp Number values, the final TSS and TDS values in the water sample were 3 mg/L and 286 mg/L, respectively.

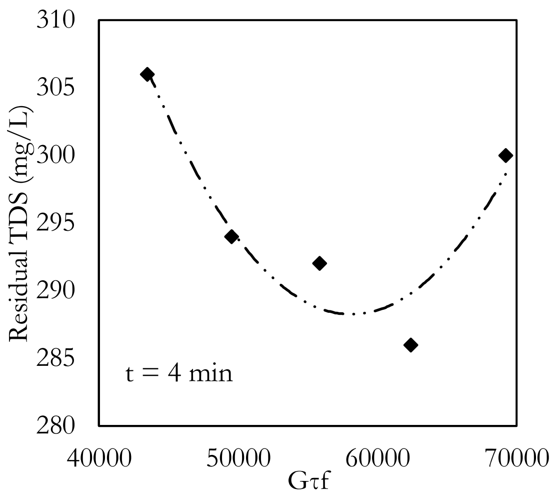

Fig. 4. The effect of Camp number to residual TDS in 4 minutes mixing

4. Conclusions

In the coagulation process, the velocity gradient and the Camp number affected the solids removal in the water. With the act of chitosan from *Corbula faba* Hinds shells as bio-coagulant, the floc formation was more convenient. A higher velocity gradient up to 260.2 s^{-1} removed more TSS and TDS. The velocity gradient limitation due to the water shear rate broke the formed flocs. The same condition also appeared in the Camp number evaluation. The maximum rapid mixing time applied in the mixtures was 4 minutes. More than that limitation, the residual TSS and TDS were higher.

References

[1] G. Tchobanoglous, F.L. Burton, H.D. Stensel, Wastewater Engineering: Treatment and Reuse, 2003.

[2] M. Jamei, I. Ahmadianfar, X. Chu, Z.M. Yaseen, Prediction of surface water total dissolved solids using hybridized wavelet-multigene genetic programming: New approach, J. Hydrol. 589 (2020) 125335. https://doi.org/10.1016/j.jhydrol.2020.125335.

[3] C. Zhang, W. Zhang, Y. Huang, X. Gao, Analysing the correlations of long-term seasonal water quality parameters, suspended solids and total dissolved solids in a shallow reservoir with meteorological factors, Environ. Sci. Pollut. Res. 24 (2017) 6746–6756. https://doi.org/10.1007/s11356-017-

DOI:10.4186/ijeise.upnjatim.ac.id/E-ISSN: 2721-8775

8402-1.
[4] S. Yudo, N.I. Said, Kondisi Kualitas Air Sungai Surabaya Studi Kasus: Peningkatan Kualitas Air Baku PDAM Surabaya, J. Teknol. Lingkung. 20 (2019) 19. https://doi.org/10.29122/jtl.v20i1.2547.
[5] PSPDL, Pengkajian Kriteria Mutu Air Lampiran PP no. 82 Tahun 2001 tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air, 2011.
[6] C.C. Lee, S.D. Lin, Handbook of Environmental Engineering Calculations, second, McGraw-Hill Companies, 2007.
[7] A.K. Verma, R.R. Dash, P. Bhunia, A review on chemical coagulation/flocculation technologies for removal of colour from textile wastewaters, J. Environ. Manage. 93 (2012) 154–168. https://doi.org/10.1016/j.jenvman.2011.09.012.
[8] F. Renault, B. Sancey, P.M. Badot, G. Crini, Chitosan for coagulation/flocculation processes - An eco-friendly approach, Eur. Polym. J. 45 (2009) 1337–1348. https://doi.org/10.1016/j.eurpolymj.2008.12.027.
[9] C.K.S. Pillai, W. Paul, C.P. Sharma, Chitin and chitosan polymers: Chemistry, solubility and fiber formation, Prog. Polym. Sci. 34 (2009) 641–678. https://doi.org/10.1016/j.progpolymsci.2009.04.001.
[10] E. Alabaraoye, M. Achilonu, R. Hester, Biopolymer (Chitin) from Various Marine Seashell Wastes: Isolation and Characterization, J. Polym. Environ. 26 (2017) 2207–2218. https://doi.org/10.1007/s10924-017-1118-y.
[11] K.T. Pursetyo, W. Tjahjaningsih, H. Pramono, Perbandingan Morfologi Kerang Darah di Perairan Kenjeran dan Perairan Sedati, J. Ilm. Perikan. Dan Kelaut. 7 (2015) 31–33.
[12] A. Abdulkarim, M.T. Isa, S. Abdulsalam, A.J. Muhammad, A.O. Ameh, Extraction and characterization of chitin and chitosan from mussel shell, Civ. Envi. 3 (2013) 108–114.
[13] K. Nurma Wahyusi, A. Nurmawati, L. Indrati Utami, Application of Chitosan from Corbula Faba Hinds shells as a Bio-Coagulant for River Water Treatment , E3S Web Conf. 328 (2021) 01009. https://doi.org/10.1051/e3sconf/202132801009.
[14] J.M. Ebeling, P.L. Sibrell, S.R. Ogden, S.T. Summerfelt, Evaluation of chemical coagulation-flocculation aids for the removal of suspended solids and phosphorus from intensive recirculating aquaculture effluent discharge, Aquac. Eng. 29 (2003) 23–42. https://doi.org/10.1016/S0144-8609(03)00029-3.
[15] T.D. Reynolds, P.A. Richards, Unit operation and process in environmental engineering, Wadsorth, CA. (1982) 798. http://books.google.ca/books/about/Unit_Operations_and_Processes_in_Environ.html?id=9oViQgAACAAJ&pgis=1.
[16] T.J. Mohammed, E. Shakir, Effect of settling time, velocity gradient, and camp number on turbidity removal for oilfield produced water, Egypt. J. Pet. 27 (2018) 31–36. https://doi.org/10.1016/j.ejpe.2016.12.006.
[17] O.S. Amuda, A. Alade, Coagulation/flocculation process in the treatment of abattoir wastewater, Desalination. 196 (2006) 22–31. https://doi.org/10.1016/j.desal.2005.10.039.
[18] S.R. Ramphal, M.S. Sibiya, Optimization of coagulation-flocculation parameters using a photometric dispersion analyser, Drink. Water Eng. Sci. 7 (2014) 73–82. https://doi.org/10.5194/dwes-7-73-2014.
[19] P. Polášek, Influence of velocity gradient on optimisation of the aggregation process and properties of formed aggregates: Part 2. Quantification of the influence of agitation intensity and time on the properties of formed aggregates, J. Hydrol. Hydromechanics. 59 (2011) 196–205. https://doi.org/10.2478/v10098-011-0016-6.
[20] W. zheng Yu, J. Gregory, L. Campos, G. Li, The role of mixing conditions on floc growth, breakage and re-growth, Chem. Eng. J. 171 (2011) 425–430. https://doi.org/10.1016/j.cej.2011.03.098.
[21] T.S. Aktas, M. Fujibayashi, C. Maruo, M. Nomura, O. Nishimura, Influence of velocity gradient and rapid mixing time on flocs formed by polysilica iron (PSI)

and polyaluminum chloride (PACl), Desalin. Water Treat. 51 (2013) 4729–4735. https://doi.org/10.1080/19443994.2012.751883.

DOI:10.4186/ijeise.upnjatim.ac.id/E-ISSN: 2721-8775