International Journal of Engineering & Technology, 7 (4.35) (2018) 739-742

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Alternative Approach to Conventional River Water Treatment Using Natural Coagulant

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Abstract

Extensive studies have been conducted to discover natural, efficient and cost-saving coagulants for water treatment. Meanwhile, chemical coagulants are being used conventionally in drinking water treatment. This study investigates the efficacy of diatomite as a natural coagulant in river water treatment. First, synthetic turbid water was used to validate the coagulant efficiency. Then, coagulation and flocculation behaviors were studied by using the river water samples from Langat River and Semenyih River. Turbidity removal efficiency of synthetic turbid water revealed that a low dosage of 3.5 mg/L could reach turbidity reduction of 83.46%. The turbidity reduction for Semenyih River water with initial turbidity of 31.8 NTU was achieved at 91.7% with 18 mg/L dosage at pH of 7.4 whereby, for Langat River water with an initial turbidity of 43.3 NTU, the turbidity reduction was achieved at 94.5% with a dosage of 26 mg/L at pH of 8.0. These results showed that water turbidity removal was influenced by both high and low natural organic material. This is because the best dosage of coagulant is indirectly proportional to the molar mass of natural organic material. In conclusion, diatomite is a promising material to be used as a natural coagulant in water treatment applications.

Keywords: *Coagulation; Diatomite; River Water; Turbidity; Water Treatment.*

1. Introduction

It has been predicted that global demand for water will increase by approximately 50% by the year 2030. In addition to that, it has been estimated that by 2050, an increment of 2.3 billion people is expected to be suffering from serious water stress [1]. Therefore, researches on water quality are conducted by many scientists around the world as well as in Malaysia [2-8]. In Malaysia, water treatment plant generally starts with aeration process followed by coagulation, flocculation, and sedimentation, as stated by Azzouz and Ballesteros (2013), is effective for removing dissolved organic contaminants present in surface water [9]. Coagulation and flocculation are the key steps for clean water production in a generic water treatment processes. Coagulation is defined as a process of aggregating all the smaller particles into larger flocs which are then removed through subsequent sedimentation process [10]. Flocculation is a process of forming larger particles to assist the sedimentation process of the suspended particles [11]. In this context, many scientists have done studies in investigating the potential of diatomite as a coagulant. Diatomite is a naturally occurring sedimentary rock formed by fossilization of phytoplankton. It is a biodegradable material found abundantly around the world in both fresh and seawater. It is available at a low cost as well. It consists of approximately 87–91% silicon oxide (SiO_2), and an estimable amount of alumina (Al_2O_3) and iron oxide (Fe_2O_3) [12]. The major component of silica found in diatomite derives from an external cell wall (frustules) formed surrounding the diatoms [13]. This material has driven the interests of scientists for its remarkable physicochemical properties such as high porosity, surface area, and thermal resistance [14-15]. Traditionally, chemical coagulants used in water treatment are aluminum sulfate, ferric and ferrous sulfate [16]. These coagulants are added during coagulation and flocculation process. The previous study has reported on the effectiveness of diatomite in reducing turbidity. As mentioned by Meesuk, Benjamas and Utha-aroon (2008) the natural diatomite from Thailand can be used to remove sugarcane juice color and turbidity in an industrial process [17]. Another studies Turbidity indicates the presence of fine organic and inorganic matter, colored compounds, algae and other microorganisms. It is measured by the relative clarity of a liquid where the intensity of light scattering is directly proportional to turbidity in Nephelometric Turbidity Units (NTU) using turbidimeter [18]. The national drinking water quality standard as implemented by the Ministry of Health, Malaysia (2010) [19]. Thus the objective of this study was to investigate the efficiency of diatomite as a coagulant in coagulation and flocculation process in treating raw water. The optimum dosage of diatomite is also discussed in this paper.

2. Methodology

This study was conducted in two phase. The first phase involves the preparation of synthetic turbid water. Synthetic turbid water was used as a preliminary test to validate the coagulant efficiency. In the second phase, the best dosage of coagulant was determined to study the coagulation and flocculation behavior. For the second phase, river water from Sungai Langat and Sungai Semenyih were used as river water with low turbidity (less than 50 NTU).

2.1. Coagulant

The diatomite coagulant was washed with distilled water and air-dried. It was then stored in a desiccator to prevent moisture prior to use.

2.2. Preparation of Synthetic Turbid Water

The overall methodology of the first phase is as illustrated in Fig. 1. Level of turbidity used in this study was 50 NTU (low turbidity).

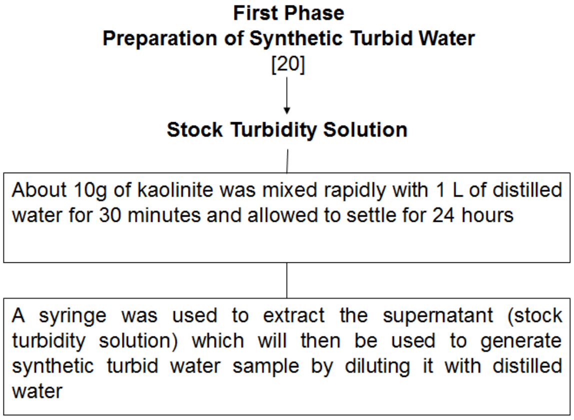

Fig. 1: Flowchart of overall methodology for preparation of synthetic turbid water at an initial turbidity of 50 NTU

2.3. Coagulation/Flocculation Test

The methods used for jar test and turbidity measurement are conforming to the Standard Practice for Coagulation-Flocculation Jar Test of Water published by ASTM (2003) [23]. The Jar test method is as illustrated below in Fig. 2.

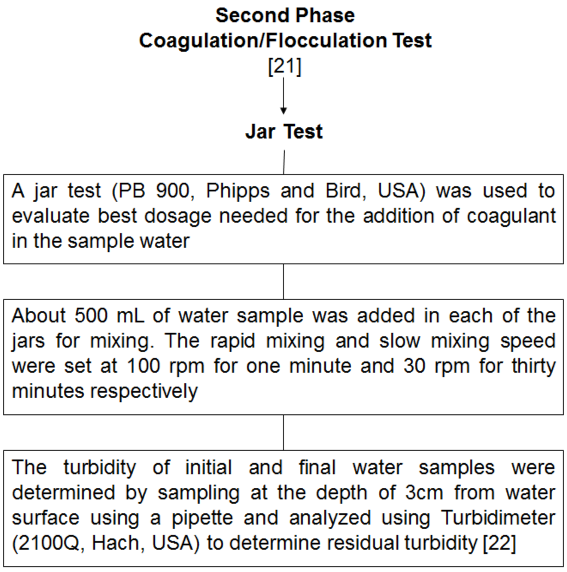

Fig. 2: Flowchart of Jar test procedure to determine the best dosage of coagulant for both synthetic turbid water and river water samples

3. Results and Discussion

In this study, the initial phase which is the preliminary test was conducted to study the efficiency of diatomite as a coagulant in treating synthetic turbid water. It was analyzed based on lowest residual turbidity at the best dose. Few parameters were kept constant using jar test likewise (i) simultaneous rapid and slow mixing throughout the test, (ii) clockwise rotation of the paddles, size and speed of each paddle, and also (iii) size of the beakers used.

The varying parameter is the dosage of coagulant used. Fig. 3 showed results of coagulant activity of diatomite at 50 NTU of synthetic turbid water. The lowest peak in the graph shows that a low amount of diatomite dosage of 3.5 mg/L could reach the turbidity reduction of 83.46%. The coagulant activities were further illustrated by the formation of flocs throughout the settling process lasting approximately 60 mins after the slow mixing process.

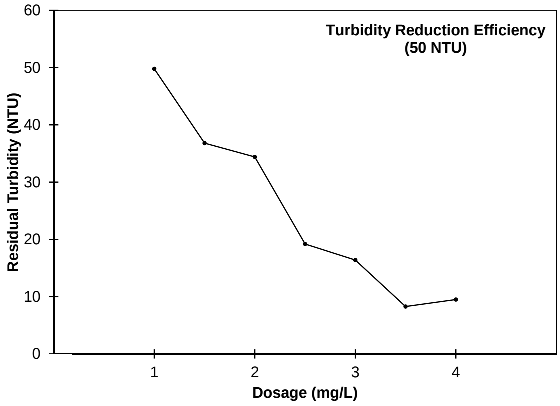

Fig. 3: Turbidity removal efficiency of synthetic turbid water at an initial turbidity of 50 NTU

The graph is shown in Fig. 3 revealed that the increment in residual turbidity of synthetic turbid water at a dosage of 4mg/L suggests that dosing high amount of coagulant above the best dosage has led to the increase of turbidity. This scenario could be due to charge neutralization mechanism, where dosing of coagulant should be proportional to the removal of organic matter in order to avoid destabilization [24]. The charge neutralization at the best dose allows the positively charged diatomite particles to collide with the negatively charged kaolinite particles thus forming flocs and sediment.

However, overdosing may disrupt the mechanism as it causes charge reversal and destabilization of colloids. The colloids will be positively charged and repulsion of the particles occurs thus increases the turbidity. Furthermore, this destabilization process is rapid that the colloids change from positive to negatively charge and vice versa [25]. Lastly, insufficient dosing and overdosing result in poor performance of diatomite in the flocculation process.

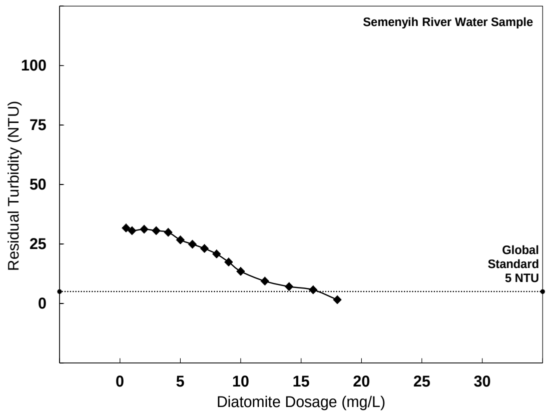

Fig. 4: Turbidity removal efficiency of Semenyih River water at an initial turbidity of 43.3 NTU

Moving on to the second phase graph as shown in Fig. 4 and Fig. 5 for the Semenyih River water and Langat River water respectively. The turbidity reduction achieved for Semenyih River water was 91.7% with the best dosage of 18 mg/L of diatomite at pH of

7.4 whereby, for Langat River water the turbidity reduction achieved was 94.5% with the best dosage of 26 mg/L of diatomite at pH of 8.0.

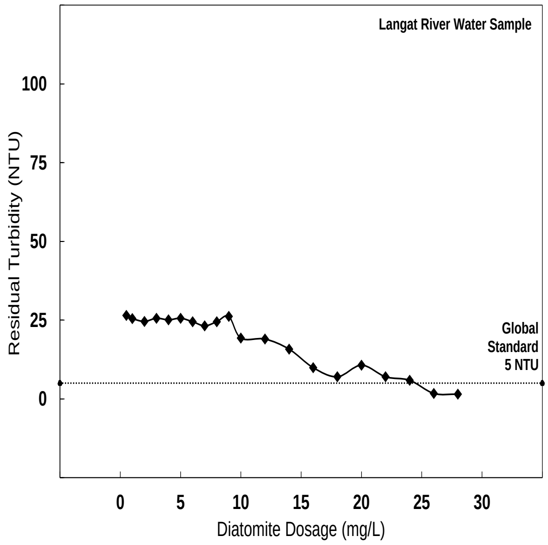

Fig. 5: Turbidity removal efficiency of Semenyih River water at an initial turbidity of 31.8 NTU

In terms of turbidity, Semenyih River water has higher turbidity however the dosage of diatomite required is comparatively lower than the dosage used to treat Langat River water. This phenomenon might be due to the presence of natural organic matter (NOM) where the range of organic components may vary at different origins or same location but seasonally thus affecting the dosage. This is because the best dosage of coagulant may be low for water with high molar mass (HMM) NOM in contrary to NOM with low molar mass (LMM) which requires high dosage. This was supported by Matilainen, Vepsäläinen, and Sillanpää (2010), where the hydrophobic part of NOM is removed effectively than the hydrophilic part [26]. Therefore, HMM components are removed easily than LMM compounds as HMM is hydrophobic in nature, consisting more of aromatic compounds as compared to LMM.

In this case, enhanced coagulation in which excess dosing might be required for the removal of organic matter. This scenario was not applicable to river water as it may contain a high amount of organic matter as compared to synthetic turbid water which contains less organic matter. The organic material particles either resist aggregation or form flocs that have a lower fraction than particle flocculated in the absence of organic matter.

4. Conclusion

The synthetic turbid water and river water samples from Semenyih River and Langat River provide sufficient data to study the efficiency of diatomite as a coagulant. The turbidity reduction in synthetic turbid water demonstrated the adsorptive coagulation mechanism, where dosing of coagulant should be proportional to the removal of organic matter in order to avoid destabilization. Whereas, the organic material found in river water sample consists of both high natural organic material and low natural organic material which influence the dosage of diatomite. Since diatomite is an effective coagulant as discussed earlier, therefore, further research should be conducted to review coagulation activity in detail.

Acknowledgement

The authors would like to express sincere gratitude to Ministry of Higher Education (MOHE) and Universiti Teknologi Malaysia (UTM) for providing Flagship grant (Vote No. 03G24), Malaysia and Japan International Institute of Technology (MJIIT) and Universiti Tenaga Nasional (UNITEN) for supporting the research.

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