

Study on the Effectiveness of Banana Peel Coagulant in Turbidity Reduction of Synthetic Wastewater

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Abstract- Coagulation is an effective, simple and widely practiced water treatment method. However, the usage of chemical coagulant pose detrimental effect on living organism and human health as well as producing large amount of toxic sludge. This study describes the utilization of banana peel as a natural coagulant for the treatment of household wastewater. The natural coagulant extracted from banana peel was prepared by using simple extraction method. Synthetic wastewater was used in this study to imitate the medium strength household wastewater. The parameters investigated in this study were pH of wastewater, coagulant dosage, and solvent of extraction. The effectiveness of the natural coagulant was evaluated based on the reduction of turbidity during the treatment process. The treatment of synthetic wastewater using banana peel coagulant was found to be the most effective at pH 1 and dosage of 100 mg/l whereas the most effective solvent to extract this type of fruit waste is sodium hydroxide (NaOH). In present work, it can be concluded that the banana peel coagulant was highly feasible in removing turbidity of the synthetic wastewater with removal efficiency of 88% under optimum condition.

Keywords- Household wastewater; plant-based coagulant; banana; turbidity; extraction.

I. INTRODUCTION

Water is one of the key factors for economic development worldwide as it is widely used in different productive sectors including industry, agricultural production, livestock and urban supply. The fast-paced industrialization, economic growth and population growth in developing countries has implicated in unpredicted water requirement in cities. In the last few decades, the water used capacity and wastewater production in domestic sectors has increased remarkably [1]. Wastewater treatment is a crucial process in sanitation system. Effective municipal wastewater resource treatment and contamination control are necessary to ensure compliance to environment compliance and reutilization of resources.

Amongst the wide range of existing methods accessible for wastewater treatment, coagulation and flocculation process is the most preferable. This treatment is commonly being practiced as it is cost effective, reliable, simple and best regarded as low-energy consuming process [2]. This established physical-chemical process removes colloidal, suspended and soluble particles efficiently by prompting aggregation of macro and micro particles into larger size proceeded by sedimentation [2]. In conventional treatment processes, various types of coagulants are often used depending on chemical traits of the contaminants present in the wastewater. The inorganic and synthetic organic polymer coagulants include alum, ferric chloride, calcium carbonate as well as polyaluminium chloride were generally used in the wastewater treatment [3]. Despite that, such treatment leads to disposal problems as the sludge obtained after the treatment using aluminium salts risks accumulation in the environment [4]. At the same time, synthetic organic polymers like acrylamide possess carcinogenic and neurotoxic

effects [5]. The alternative solution to these problems is replacement of metal and synthetic coagulants with natural coagulants which are more environmental friendly.

Plant extracts derived from seeds, leaves, root, barks and fruits have been used in water purification process ever since ancient times [6]. Natural coagulants exhibit various benefits which include reduction in production of sludge, lower cost, restrain variations in the pH of treated water, innocuity and provide greater biodegradability [7-10]. Researchers on biological originated coagulants that have been studied include okra [11], nirmali plant [12], Moringa Oleifera [13] and chitosan [14]. In addition, Jahn (2001) has also conducted experimental study on the performance of apricot, peach kernel and beans in clarifying water [15]. In the current study, banana peel is developed into a source of natural coagulant. Banana plants belong to the family of Musaceae and species of Musa which includes *M. Acuminata*, *M. Sapientum*, *M. Paradisiaca*, and *M. Cavendishii* are grown worldwide [16]. Banana tree can bear fruit almost 3 to 20 hands in a cluster once in a lifetime which leads to huge amount of biomass waste generated from the tree [17]. The Southeast Asian countries including Malaysia, India and Japan has initially cultivated banana plant. Nevertheless, some species are regarded to be genetically connected with species of banana from Africa [18].

There are different parts of banana that can be utilized like banana fruit peels, piths, trunks, leaves and pseudo-stems. These wastes from banana plants have been analysed extensively as solid adsorbent to remove various pollutants [18-21]. One of the important wastes generated in large quantities is banana peel as this fruit is highly consumed and constitutes almost 40% of total weight of the fresh fruit [19]. Banana peel is rich in organic compounds such as pectin substances, chlorophyll pigments cellulose, hemicellulose, and other compounds of low molecular weight [22]. Mohapatra et al. (2010) has experimentally verified that banana peels are good source of galacturonic acid, pectin (10-21 %), lignin (6-12 %), cellulose (7.6-9.6 %) and hemicelluloses (6.4-9.4 %) [16]. The aim of this research is to investigate the effectiveness of banana peel as a potential coagulant to reduce turbidity of synthetic wastewater by varying different pH of wastewater, dosage of coagulant and types of solvents for extraction. The standard jar test was carried out to determine the performance of extracted banana peel with respect to its coagulation activity. Synthetic sewage used in this work was prepared by using commercial cat food to imitate the original composition of domestic wastewater and the details comparison with the literature is shown in Table 1. Normally, it is common to use the cat food as the Complex Organic Particulate Artificial Sewage (COPAS) material for representing the actual domestic wastewater. This type of COPAS is easily prepared, cheap and commercially available. Prior to the synthetic wastewater preparation, no special procedure is needed as the desired particle size can be obtained just by grinding process. In addition, the dried granular cat food for COPAS did not requires any specific preservation method as the chemical composition can be maintained under ambient condition in the room temperature throughout prolonged storage [23].

II. MATERIALS AND METHODS

2.1 Materials

Banana (*Musa Acuminata* species) peels were collected from Kuantan, Pahang market. Analytical-grade hydrochloric acid (HCl), sodium hydroxide (NaOH) and sodium chloride (NaCl) were purchased from Fisher Scientific Malaysia. The cat food used for this study was a commercial brand, Whiskas® (Ocean Fish Flavor) obtained from Gambang, Pahang grocery store.

2.2 Preparation of synthetic wastewater

The synthetic sewage was prepared by dissolving 10 grams of ground cat food into 1 litre of tap water as described by Kutty et al. to imitate the medium strength of domestic wastewater [24]. The nutritional composition of this cat food comprised of 30% crude protein, 10% crude fat, 5% crude fibre and 12% moisture. The characteristics of the synthetic sewage were characterized based on parameters tabulated

in Table 1. The analysis on Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Ammonia Nitrogen (NH₃-N), Nitrate Nitrogen (NO₃-N) and phosphorus (P) of the synthetic wastewater were conducted based on standard APHA method.

Table 1: Characteristics of 10 gram/liter of dissolved cat food

| Parameter | Value (mg/L) | Value of domestic wastewater (mg/L) [26] |
|-------------------------|--------------|--|
| BOD | 300 | 190 |
| COD | 1500 | 430 |
| TSS | 216 | 210 |
| NH₃-N | 15 | 25 |
| NO₃-N | 27 | 40 |
| P | 42 | 7 |

2.3 Preparation of natural coagulant from banana peel

The coagulant preparation method was done by following the procedure described by Zurina et al. [27]. The banana peels were washed thoroughly with distilled water to remove any impurities and cut into small pieces of size range of 0.5 - 0.6 cm. The peels were then dried in the oven (Memmert Model 30, German) for 48 hours at 60°C. After that, the dried fruit peels were ground into fine powder and sieved to a particle size of 0.5 mm. Then, 0.5 g of the dried raw materials was soaked in 100 ml distilled water at room temperature of 24°C and stirred at 120 rpm for 1 hour period. Before using in the jar test experiments, the mixture was filtered with muslin cloth to get the finalised filtered extract.

2.4 Coagulation Jar Test Experiments

Coagulation test experiments were performed by jar flocculation test method with JLT6 Velp Scientifica six-paddle rotor jar test equipment. 500mL of synthetic household wastewater was filled into six beakers respectively. The desired amount of coagulant was then added for coagulation test. The jar test was conducted at room temperature of 24 °C. In this experiment, different pH of wastewater was tested in the range of pH 1 to pH 12. The pH of wastewater was adjusted by adding 1.0 M HCl and 1.0 M NaOH to obtain range of tested pH. The analyses were done triplicated in order to obtain the average results. The dosage of the coagulant used in this experiment was set at constant concentration of 100 mg/L. The suspension was stirred at 100 rpm for 4 minutes of rapid mixing and followed by 25 minutes of slow mixing at 40 rpm. This is to keep flocs particles to suspend uniformly. The mixture was left for one hour to allow settling and the sample was filtered with muslin cloth [27]. Turbidity test was conducted by using portable turbidimeter (LaMotte, USA) measured in nephelometric turbidity unit (NTU). The turbidity reduction was calculated for each sample by using formula as in Eq. 1:

$$\text{reduction of turbidity (NTU)} = \text{initial turbidity (NTU)} - \text{final turbidity (NTU)} \quad (1)$$

The best pH of wastewater obtained was then applied to evaluate different dosages of coagulant within range of 10 mg/L to 120 mg/L. After completing these experiments with distilled water extracted coagulant, the active compounds from banana peel were extracted using NaCl of concentrations 1 M, 0.5 M, 0.1 M, and 0.05 M as well as NaOH of concentrations 0.1 M, 0.05 M, 0.01 M and 0.005 M. The concentration of solvent that were used similar as to rambutan seeds extraction done by Zurina et al [27]. This is to determine whether the same concentration works well for banana peel. These suspension of different concentration were used as coagulant respectively with the most effective pH of wastewater and dosage of coagulant based on earlier experiment results [27, 31].

III. RESULTS AND DISCUSSION

3.1 Effect of pH of wastewater to the effectiveness of banana peel coagulant

As for this experiment, the pH of the synthetic wastewater was varied according to the range proposed in this study. The coagulation test was performed with banana peel extracted using distilled water. The results obtained from the coagulation test by using banana peel extract are shown in Figure 1. The error bars in the figure indicates the standard deviation of triplicate experiments. From this experiment, it can be seen that the pH of wastewater mainly affects the surface charge of coagulants as well as the suspension stabilization. The coagulation performance of banana peel in reducing turbidity favoured the acidic condition. It was observed that the banana peel extract works best at pH 1. Highest turbidity reduction can be obtained at this particular pH which recorded result of 73% reduction. The result obtained were compared with the study conducted by Kakoi et al. in which the extracted banana pith coagulant worked best under acidic condition [21]. In their work, they managed to obtain turbidity reduction of 98% at pH 4 where the water appeared to be clearer and more flocs were observed. The effectiveness starts declining gradually when the pH is increased from 2 to 12. It was observed that the water turns cloudier and less flocs was found after the settling process due to the incremental pH from 2 to 12. The lowest turbidity reduction was found at pH 12 when the wastewater condition is most alkaline. The turbidity reduction was only 21% which indicates the least effective pH for banana peel to perform as natural coagulant. The coagulative behaviour of banana peel decreases when the alkalinity of the wastewater increases as within the range of pH 8 to pH 12. Thus, it is clearly shows that banana peel can perform very well in acidic condition. It can be assumed that the active agent that contribute to the effectiveness of the banana peel coagulant is mainly comes from the composition of proteins present in the fruit waste. This is because the larger the molecular weight of these polymers, the longer a polymeric chain can be. It would encourage the coagulation process as higher active sites are freely available for the particles to exhibit the adsorption mechanism [27]. As reported by Lestari et al. the acidic condition of wastewater promotes the attraction towards the positive charges on the amino acids in the molecules of protein. his might enhance and influence the performance of the molecules to perform efficiently as coagulant agent [28]. The charge on the protein itself depends on the values of pH which resulted in different turbidity reduction especially when the pH is increased. It is believed that the net cationic potential of the coagulant for coagulation process decreases when the positive and negative charges of different amino acids in the protein increases. Thus, this phenomenon significantly affects the turbidity reduction of the synthetic wastewater.

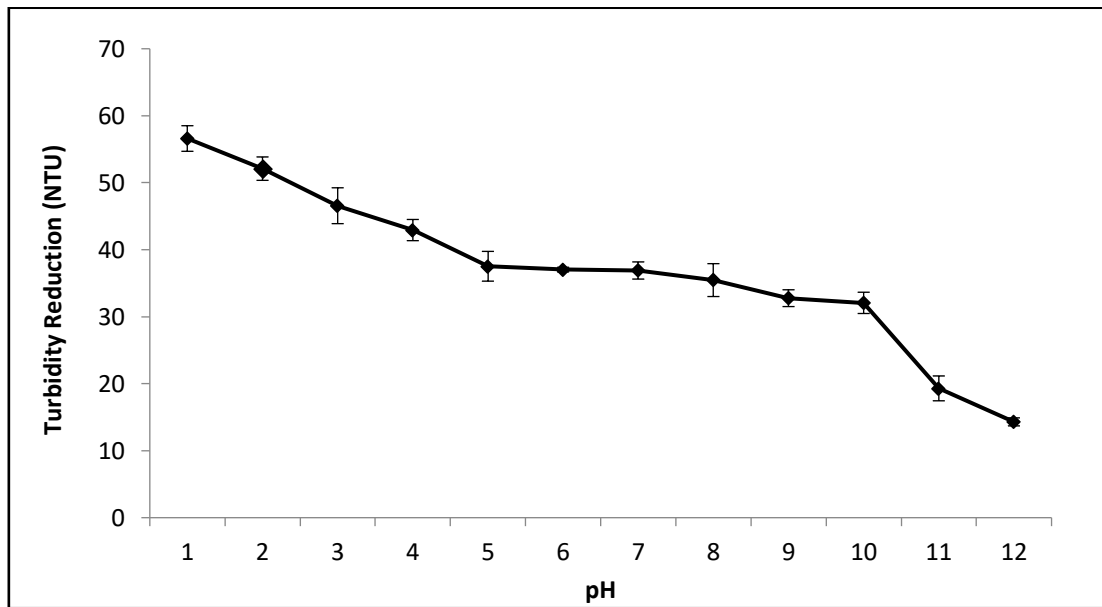


Figure 1: Turbidity reduction at different pH of wastewater

3.2 Effect of coagulant dosage to the effectiveness of banana peel coagulant

The coagulation performance of banana peel in reducing turbidity varied in terms of optimum dosage required. Therefore, it is significant to discover the optimum dosage of coagulant for minimization of cost of materials and sludge formation as well as to achieve optimum performance in the treatment process. It is perceived that the banana peel extract efficiently worked at dosage of 100 mg/l as the turbidity removal achieved was almost 79 %. Figure 2 displayed the trend of turbidity reduction at different dosage of the coagulant. The water appeared to be purer and more flocs were successfully formed. The effectiveness starts declining gradually when the dosage was increased to 110 mg/L and above. It was observed that lesser amount of particle removal from the synthetic wastewater. It can be interpreted that the dosage of coagulant is highly influence the process of coagulation. In summary, higher dosage of coagulant will directly contribute to the effectiveness of the natural coagulant in reducing turbidity of the wastewater. The highest removal of turbidity can be deduced at dosage of 100 mg/L. However, concentration of coagulant above the optimum value may hinder the reaction between the coagulant and particles in the wastewater. This reduction can be inferred that overdosing contributes to destabilization of colloidal particles and charge reversal. Hydrolyzation of coagulant in wastewater produces cationic species which can be absorbed by particle with negative charges and neutralize their charge. The mechanism of particles destabilization allows flocculation process to take place and coagulant overdosing may interfere this process [29].

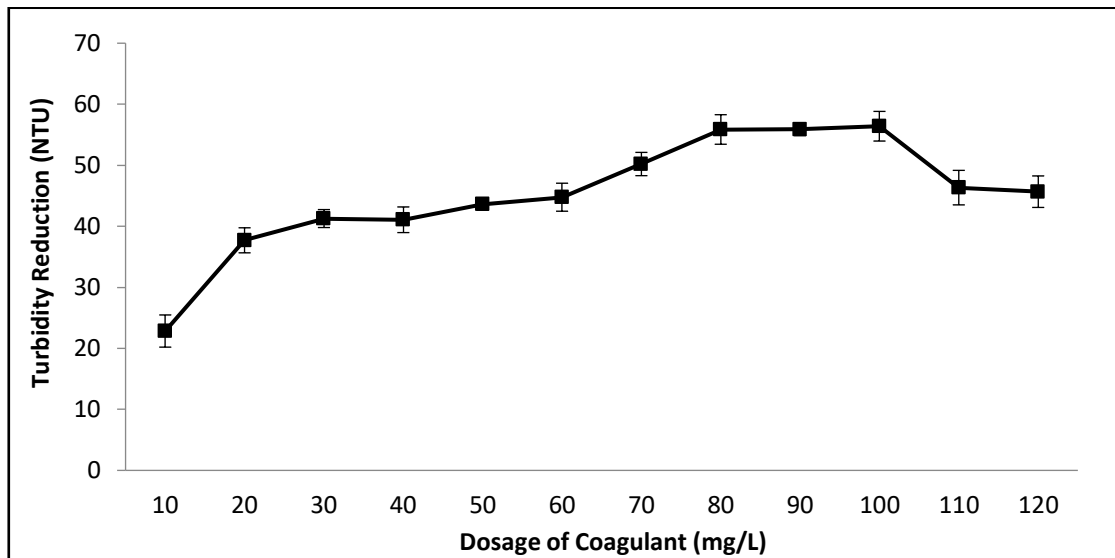


Figure 2: Turbidity reduction at different dosage of coagulant

3.3 Effective solvent for extraction

Apart of selecting the best pH of wastewater and the optimum dosage of coagulant, the extraction process was carried out in order to determine the most effective solvent that works well in reducing turbidity of wastewater. Previously, Zurina et al. was observed that NaCl was the effective solvent for extracting the coagulant agent from seed of rambutan [27]. Up to now, no study related to extraction of fruit peel by using different types of solvents has been carried out. To address that issue, this study was performed to compare the effectiveness of NaCl, NaOH and distilled water as solvents primarily to select the best type of solvent for extraction of banana peel. The pH and dosage used for this experiment were based on previous results in which the optimum condition was found to be at pH 1 and 100 mg/L, respectively. Figure 3 displayed that the highest turbidity removal recorded when NaOH was used as the solvent for extraction from banana peel. Meanwhile, distilled water extraction observed to be fairly effective as well. However, the usage of salt solution which is NaCl found to be the least effective solvent in contrast to the previous study for seed extraction. The percentage of turbidity removal for NaOH was almost 88% but the effectiveness decreases as the concentration decreases. As for NaCl, the turbidity removal was only 72% which is much lower compared to distilled water which achieved 79%. It has been described that protein extraction and solubility were closely related to protein-solvent interaction in respective solvents [30]. This interaction can be increased by adjustment of pH of the solvent. The net charge of protein increases when the pH of solvent is higher than the protein isoelectric point where the net charge is zero. This will lead to increase of charged residue hydration and electrostatic repulsion which consequently promote protein solubilization into the extracting solvent [31]. Thus, NaOH has the capability to increase pH of solvent extract which improved the protein-solvent interaction. It can be presumed that NaOH effectively functioned in extracting protein from banana peel that resulted in the highest turbidity removal of wastewater.

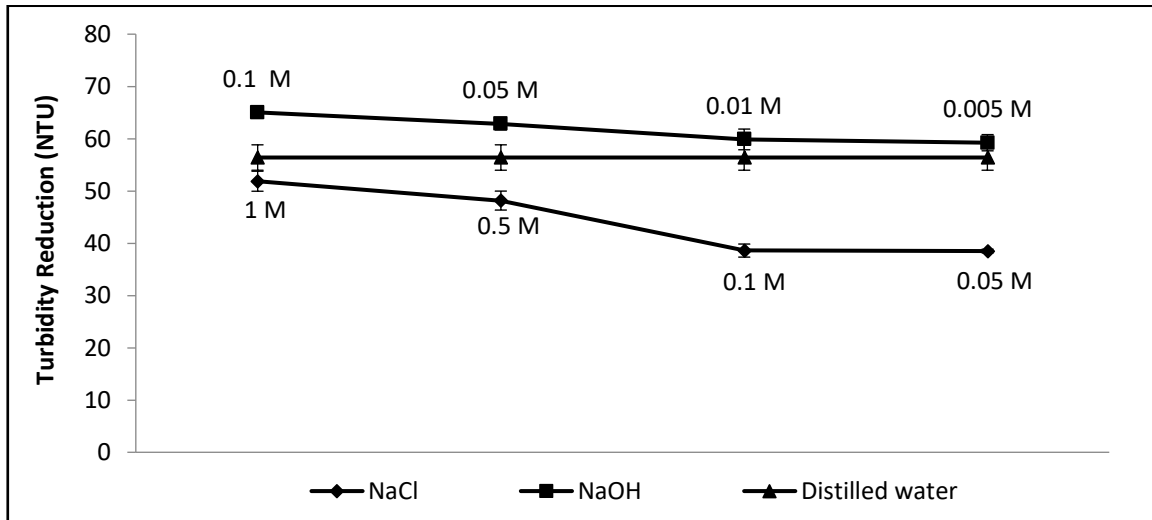


Figure 3: Turbidity reduction by coagulant extracted using different coagulant

IV. CONCLUSIONS

The results obtained from the present study show the feasibility of locally available banana peel as natural coagulant on the turbidity reduction of synthetic household wastewater. The optimum pH for effective coagulation process using banana peel extract was found to be at acidic pH which was less than pH 3. The optimum dosage that effectively reduced turbidity was determined to be 100 mg/L. In terms of solvent extraction, NaOH was found to be the suitable solvent to extract the active compound in banana peel. Hence, banana peel which that creates a generous amount of waste has the potential to function as natural coagulant. Further studies should be carried out to precisely identify the specific components in the banana peel that assist in the coagulation process as well as study the potential of this locally waste in reducing other water quality parameters to make it widely accepted as the new coagulant.

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