The Effectiveness of Raw and Dried Artocarpus Heterophyllus (Jackfruit) Seed as Natural Coagulant in Water Treatment

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Abstract. Coagulation is one of the process in water treatment that mainly reducing turbidity of water by adding the coagulant such chemical or natural coagulant. Chemical coagulant such as Alum is widely used as it is efficient in removing turbidity. However, there are some adverse impact of chemical as coagulant to human and environment specifically. In this study, the effectiveness of Artocarpus Heterophyllus seed as natural coagulant were measured. There are two types the natural coagulant from Artocarpus Heterophyllus were considered in this study such as raw and dried seed. Besides, two different extraction process of coagulant by using distilled water and Sodium Chloride (1M NaCl) were used to determine the efficiency. The result showed dried Artocarpus Heterophyllus seed (1M NaCl) at 20mg/L achieved the optimum dosage of coagulant compared to dried Artocarpus Heterophyllus seed (distilled water), raw Artocarpus Heterophyllus seed (distilled water) and raw Artocarpus Heterophyllus seed (1M NaCl) in removing turbidity. It reduced up to 50% turbidity, and 70% suspended solid after the treatment process. It also showed that salt Sodium Chloride (NaCl) can be used as additive in treating the water.

1. Introduction

Almost all types of productions in agriculture, industry, energy, transport need water as their source of life [1]. All organisms need water as essential element for survival in maintaining their life [2]. For millennia, it has been known that ecosystem conservation and human survival depend on the reliable availability of adequate quality of water.

Population growth and rapid industrial developments increase the issues that related to cleanliness and sanitized water globally. Many of fresh water supplies can be contaminated with inorganic, organic and biological matters that rise potential harm towards people [3]. Clean water is such an important thing in human life. It is because without clean water, people cannot continue with their daily life. Groundwater, surface water and rainwater are three sources of water. There are some processes on how people can obtain the clean and safe surface water to be drinking and use them by water treatment process that comprised of coagulation and flocculation, followed by settling, filtration and disinfection process [3].

According to [5], the objective of water treatment is to ensure effluent that contain clean water is discharged back to environment after removal of suspended solids to prevent the solid material uses up oxygen (O2) in the process of decay. Oxygen gas is needed for the aquatic life to survive.
The use of chemical coagulants can be reduced by the availability of the natural coagulants. Usually alum is widely used as chemical coagulant because it promised turbidity reduction but it also causes health problem to human and voluminous sludge production [3]. Water quality guidelines can be reached by monitor of raw water. It can be done by measure colloidal and suspended matters which affects cloudiness of water that call as turbidity [3]. Level of sulphate is high in treated water when the alum is used as chemical coagulant. It is because alum is an inorganic coagulant which increases concentration of Total Dissolve Solid (TDS) in finished water [6].

Jar test is a process of mimics of full scale operation that give a great help to determine the relationship of coagulant and the water sample that being use in jar test. In addition, beakers or jar is use to hold water sample and then certain amount dosage of coagulant by varying the amount of dosage to obtain the optimum dosage amount of coagulant by added them into the beaker. After that, the water sample is stirred so that the floc formation, development, and settlement can be happen like in a real water full scale treatment plant. When the materials in sample of water react with coagulant, the floc will be form and clump together [7].

Clean water production cause many coagulants are widely used in conventional water treatment processes. These coagulants can be inorganic coagulants such as aluminum sulfate and polyaluminum chloride or synthetic organic polymers such as polyacrylamide de-rivatives and polyethylene imine. Lastly, natural coagulants such as chitosan and microbial coagulants are also being used in the water treatment [8]. Chitosan helps to remove turbidity in the range of 50% up to 87.5% which more than half of turbidity in water sample. The study shows E.Coli can be reduced by using chitosan as naural coagulant [9]. As for bioflocculant produced by Aspergillus niger microbe, the optimum pH required to result in lowest turbidity was in the range 4-5 [10]. Coagulant is an agent to remove colour and turbidity in coagulation process of water treatment.

A study by [11], shows that aluminium can be obtain easily as it is natural abundance, mammal species like human being can be harm by aluminum. People who diagnose with Alzheimer’s disease show the presence of aluminum in their neuron. Alzheimer’s dis-ease makes its patients to loss their memory because the brain cells are dead. It happens when human drink the treated water that contain residue of aluminum and the water reach the gastrointestinal system following oral exposure and lastly small amount of alumini-um penetrate into nervous system tissues.

Actually, majority of natural coagulant is coming from the plant based coagulants such as cactus, cereals, fungus, nuts, shrubs and spice. Currently, natural coagulant is made up of fruit waste that surprisingly become a great help in treating the water [4]. Furthermore, by using natural coagulants such as the Moringa Oleifera tree instead of aluminium salts might give a lot of advantages such as smaller costs of water production, less sludge production and can be obtain easily [5].

Nowadays, there a lot demand to change the chemical coagulant to the natural coagulant in the coagulation process. It is because natural coagulant does not give negative effect towards human health and natural coagulant also can remove turbidity of water successfully. Aluminum Sulfate (alum) and ferric chloride that has been used in water treatment process may have high potencies to remain some metal residual in treated water which is not good for people use.

This study related to Artocarpus Heterophyllus (Jackfruit) seed that act as natural coagulant to replace chemical coagulant such as alum in this study. The weight of Artocarpus Heterophyllus seed is 8%-15% of the total fruit weight. Its seeds comprised of 67% of carbo-hydrates and 20% of protein contents [12]. The coagulant is more effective when the concentration of protein in the coagulant is higher [13]. Besides, Artocarpus Heterophyllus seed also has jacalin and artocarpin which both of them are lectin. These lectins are antibacterial, antifungal and ant carcinogetic properties [14].

2. Materials and Methods

2.1. Sampling Procedure

The water samples were taken from Sungai Klang at Kampung Padang Jawa, Shah Alam. The colour of water sample is green-brownish and turbid. The plastic container must be clean from any impurities.
to ensure the water sample is not affected by the impurities as it will change the quality of water sample. The plastic containers were then be labelled to differentiate them with others container. This research involved laboratory work where the jar test experiment is carried out (ASTM D2035). Twenty litres (20) of water sample is taken to undergo the Jar Test process. In this study, 500 mL of water sample were filled in each beaker for six (6) numbers of beakers. The apparatus for this study are spectrophotometer, turbidity meter, jar test apparatus, weighing balance, spatula, magnetic stirrer, magnetic stir bar, beaker of 500 mL and 1 L, pipets, oven and blender. Alum, Artocarpus Heterophyllus seed, distilled water and 1M NaCl are material that is needed in this laboratory work. Figure 1 shows summary of methodology.

![Figure 1. Summary of methodology [15]](image)

2.2. Preparation of raw and dried Artocarpus Heterophyllus seed in powder form

The Artocarpus Heterophyllus was obtained from Masjid Tanah, Melaka. Figure 2 shows raw Artocarpus Heterophyllus seeds and dried Artocarpus Heterophyllus seeds. The seeds were dried in oven for 24 hours at 50°C. After that, the dried and raw Artocarpus Heterophyllus was blended by using domestic blender to obtain the powder form [15].
2.3. Extraction method of Aluminum Sulphate (Alum)

Use 10000 mg of Alum powder to be dissolved in one (1) liter of distilled water by using a magnetic stirrer mixer to obtained 10000 mg/L concentration of Alum as chemical coagulant.

2.4. Extraction method of dried Artocarpus Heterophyllus

Dried Artocarpus Heterophyllus coagulant was obtained by dis-solved 5000 mg of powder of dried Artocarpus Heterophyllus in 500 mL of distilled water or Sodium Chloride (1M NaCl) by using magnetic stirrer mixer for 30 minutes to get 10000 mg/L in concentration. Lastly, filter it with muslin cloth to remove larger particle of seeds [15]. 1 M NaCl is used in this study because of the previous research shows that the coagulant solutions extracted with 1 M salt solution is more effective in reducing colour and turbidity of water sample compared to the solution extracted with water [14]

2.5. Extraction method of raw Artocarpus Heterophyllus

The 10000 mg/L concentration of raw Artocarpus Heterophyllus coagulant was produced by mix 500 mL of distilled water or Sodium Chloride (1M NaCl) with 5000 mg of raw Artocarpus Hetero-phyllus powder by using magnetic stirrer mixer for 30 minutes as shown in. Lastly, remove large particle of seeds from the solution by using muslin cloth [15].

2.6. Jar test experiment

Coagulation, flocculation and sedimentation test (ASTM D2035) was conducted by using Jar Test apparatus. 500 mL of water sample were poured into six (6) beakers. After that, 0 mg/L, 20 mg/L, 40 mg/L, 60 mg/L, 80 mg/L and 100 mg/L coagulants were added into each beaker. Start the jar test with rapid mixing process for one (1) minute at 80 rpm followed by slow mixing process for 30 minutes at 20 rpm. Lastly, allowed the water sample to undergo sedimentation process for 30 minutes at 0 rpm. The experiment was repeated for each type of coagulants (Alum, dried and raw Artocarpus Heterophyllus).

HACHDR-2800 Spectrophotometer was required to determine colour (Method 8025), COD (Method 8000) and suspended solid (Method 8006) of water sample. The river water sample in each beaker need to be checked with colour, COD and suspended solid because there is different amount of them in each of beaker even though it was from the same water sample. Turbidimeter (HACH 2100P) was used to evaluate the turbidity in water sample in unit of NTU. Before evaluation of COD value by
spectrophotometer, the water sample was filled into the vial that contained oxidizing agents that called as silver sulphate, mercury, potassium dichromate and sulphuric acid and need to be digested in DRB 200 COD Reactor.

3. Results

The purpose of this research is to identify the water quality parameter such as turbidity, suspended solid and colour and COD before and after the process, to determine the optimum dosage concentration of natural coagulant of raw and dried Artocarpus Heterophyl-lus seed to be compared with Alum in surface water treatment process, to determine the effectiveness of raw and dried Artocarpus Heterophyllus seed in improving water quality and lastly, to determine the effect of salt Sodium Chloride, NaCl as additive in treat-ing the water. Table 1, Table 2, Table 3, Table 4 and Table 5 show the quality of water sample and result of Alum and Artocarpus Heterophyllus seeds.

Table 1. The quality of water sample and result of Alum for distilled water as solvent in extraction process of coagulant.

| Water sample | Turbidity (NTU) | Turbidity removal (%) | Suspended solid (mg/L) | Suspended solid removal (%) | Colour (PtCo) | Colour removal (%) | COD (mg/L) |
|--------------|-----------------|-----------------------|------------------------|-----------------------------|--------------|--------------------|------------|
| Raw          | 26.70           | -                     | 37                     | -                           | 238          | -                  | 62         |
| 0 mg/L       | 14.00           | 47.57                 | 14                     | 62.16                       | 129          | 45.8               | -          |
| 20 mg/L      | 8.25            | 69.10                 | 7                      | 81.08                       | 83           | 65.13              | -          |
| 40 mg/L      | 5.98            | 77.60                 | 5                      | 86.49                       | 66           | 72.27              | -          |
| 60 mg/L      | 3.99            | 85.06                 | 3                      | 91.89                       | 45           | 81.09              | -          |
| 80 mg/L      | 2.76            | 89.66                 | 2                      | 94.59                       | 28           | 88.24              | 36         |
| 100 mg/L     | 3.03            | 88.65                 | 3                      | 91.89                       | 30           | 87.39              | -          |

Table 2. The quality of water sample and result of dried Arto-crpus Heterohyyllus seed for distilled water as solvent in extraction process of coagulant.

| Water sample | Turbidity (NTU) | Turbidity removal (%) | Suspended solid (mg/L) | Suspended solid removal (%) | Colour (PtCo) | Colour removal (%) | COD (mg/L) |
|--------------|-----------------|-----------------------|------------------------|-----------------------------|--------------|--------------------|------------|
| Raw          | 26.7            | -                     | 37                     | -                           | 238          | -                  | 62         |
| 0 mg/L       | 21.60           | 19.10                 | 30                     | 26.83                       | 171          | 29.92              | -          |
| 20 mg/L      | 14.19           | 46.85                 | 12                     | 70.73                       | 128          | 47.54              | 39         |
| 40 mg/L      | 15.13           | 43.33                 | 14                     | 65.85                       | 137          | 43.85              | -          |
| 60 mg/L      | 16.67           | 37.57                 | 15                     | 63.41                       | 146          | 40.16              | -          |
| 80 mg/L      | 17.19           | 35.62                 | 17                     | 58.54                       | 147          | 39.75              | -          |
| 100 mg/L     | 18.08           | 32.28                 | 20                     | 51.22                       | 152          | 37.7               | -          |
Table 3. The quality of water sample and result of raw Artocrpus Heterohyllus seed for distilled water as solvent in extraction process of coagulant.

| Water sample | Turbidity sample (NTU) | Turbidity removal (%) | Suspended solid (mg/L) | Suspended solid removal (%) | Colour (PtCo) removal (%) | COD (mg/L) |
|--------------|------------------------|-----------------------|------------------------|----------------------------|---------------------------|------------|
| Raw          | 47.8                   | -                     | 47                     | -                          | 308                       | -          |
| 0 mg/L       | 43.10                  | 9.83                  | 44.5                   | 5.32                       | 294                       | 4.55       |
| 20 mg/L      | 27.70                  | 42.05                 | 24                     | 48.94                      | 203                       | 34.09      |
| 40 mg/L      | 24.20                  | 49.37                 | 23                     | 51.06                      | 193                       | 37.34      |
| 60 mg/L      | 25.10                  | 47.49                 | 23                     | 51.06                      | 196                       | 36.36      |
| 80 mg/L      | 29.40                  | 38.49                 | 30                     | 36.17                      | 226                       | 26.62      |
| 100 mg/L     | 25.80                  | 46.03                 | 27                     | 42.55                      | 194                       | 37.01      |

Table 4: The quality of water sample and result of dried Artocrpus Heterohyllus seed for Sodium Chloride (1M NaCl) as solvent in extraction process of coagulant.

| Water sample | Turbidity sample (NTU) | Turbidity removal (%) | Suspended solid (mg/L) | Suspended solid removal (%) | Colour (PtCo) removal (%) | COD (mg/L) |
|--------------|------------------------|-----------------------|------------------------|----------------------------|---------------------------|------------|
| Raw          | 8.12                   | -                     | 10                     | -                          | 50                        | -          |
| 0 mg/L       | 6.82                   | 16.01                 | 9                      | 10                         | 49                        | 2          |
| 20 mg/L      | 3.96                   | 51.23                 | 3                      | 70                         | 41                        | 18         |
| 40 mg/L      | 4.25                   | 47.66                 | 5                      | 50                         | 43                        | 14         |
| 60 mg/L      | 4.31                   | 46.92                 | 6                      | 40                         | 45                        | 10         |
| 80 mg/L      | 4.34                   | 46.55                 | 6                      | 40                         | 46                        | 8          |
| 100 mg/L     | 5.84                   | 28.08                 | 8                      | 20                         | 48                        | 4          |
Table 5: The quality of water sample and result of raw Artocarpus Heterophyllus seed for Sodium Chloride (1M NaCl) as solvent in extraction process of coagulant.

| Water sample | Turbidity (NTU) | Turbidity removal (%) | Suspended solid (mg/L) | Suspended solid removal (%) | Colour (PtCo) | Colour removal (%) | COD (mg/L) |
|--------------|-----------------|-----------------------|------------------------|-----------------------------|--------------|--------------------|------------|
| Raw          | 13.21           | -                     | 17                     | -                           | 104          | -                  | 18         |
| 0 mg/L       | 10.5            | 20.51                 | 16                     | 5.88                        | 102          | 1.92               | -          |
| 20 mg/L      | 8.88            | 32.78                 | 12                     | 29.41                       | 89           | 14.42              | -          |
| 40 mg/L      | 7.26            | 45.04                 | 9                      | 47.06                       | 93           | 10.58              | 9          |
| 60 mg/L      | 10.3            | 22.03                 | 14                     | 17.65                       | 96           | 7.69               | -          |
| 80 mg/L      | 11.53           | 12.72                 | 15                     | 11.76                       | 101          | 2.88               | -          |
| 100 mg/L     | 12.3            | 6.89                  | 16                     | 5.88                        | 102          | 1.92               | -          |

4. Discussion

4.1. Colour
The water sample after treatment should be colourless. From the Table 1 until Table 5, Alum is the most efficient coagulant to remove the colour from water sample at 80mg/L of dosage coagulant while the raw Artocarpus Heterophyllus seed (1M NaCl) at 100mg/L is the less efficient to remove the water sample colour. The most efficient natural coagulant in reducing the colour of water sample is dried Artocarpus Heterophyllus seed (distilled water) at 20mg/L with the colour removal of 47.54% compared to other natural coagulant. The raw Artocarpus Heterophyllus seed (distilled water), dried Artocarpus Heterophyllus seed (1M NaCl) and raw Artocarpus Heterophyllus seed (1M NaCl) are efficient to remove the colour at 40mg/L, 20mg/L and 20mg/L with the colour removal of 37.34%, 18 and 14.42% respectively. Previous research shows Moringa Oleifera seed removed 82% of colour by using 1 M KCl solution in the extraction of coagulant active component compared to water solution with 33% colour removal [14].

4.2. Suspended solid
Based on the results in tables provided, Alum, dried Artocarpus Heterophyllus seed (distilled water), dried Artocarpus Heterophyllus seed (1M NaCl) and raw Artocarpus Heterophyllus seed (1M NaCl) removed the suspended solid after the treatment at 80mg/L, 20mg/L, 20mg/L and 40mg/L. Raw Artocarpus Heterophyllus seed (distilled water) remove the most of suspended solid at 40mg/L and 60mg/L which is up to 70% removal. However, the percentage of reduction is slightly lower as compared to Moringa Oleifera seed after oil extraction (MOAE) with the removal of 95% suspended solids [16].

4.3. Turbidity
The result of turbidity removal is shown in Table 1 until Table 5 for five (5) sample of different coagulant that comprised of Alum, dried Artocarpus Heterophyllus seed (distilled water), raw Artocarpus Heterophyllus seed (distilled water), dried Artocarpus Heterophyllus seed (1M NaCl) and raw Artocarpus Heterophyllus seed (1M NaCl).

Water, organic compound, or salt solution can be used as different types of solvent for the seed extraction process but water is the most popular compared to the other because of its availability, good
polarity and cheap in the cost. Extraction protein also widely used by using the salt solution which gives a great turbidity removal [17].

The optimum dosage for Alum, dried Artocarpus Heterophyllus seed (distilled water), raw Artocarpus Heterophyllus seed (distilled water), and raw Artocarpus Heterophyllus seed (1M NaCl) are 80mg/L, 20mg/L, 40mg/L, 20mg/L and 40mg/L respectively.

When the coagulant reached the optimum dosage, the values of turbidity removal is slightly increase but still shows improvement compared to the raw water. The highest turbidity removal (50% removal) for natural coagulant is dried Artocarpus Heterophyllus seed (1M NaCl). However the result is not effective as rambutan seed at dosage of 50 mg/l gave a maximum turbidity removal of 92% for distilled water solvent while 99% turbidity removal for 1M NaCl solution. The use of salt solution to extract protein is also widely used. Previous study has also reported that better turbidity removal can be achieved by using salt solution to extract the coagulant agent (protein) from the seed [16]

4.4. COD

The reading of COD value is taken by using spectrophotometer before the water sample was treated by the coagulants. After finish each of the jar test, the water sample that has reached the optimum coagulant dosage for each test must be taken to test the COD. From the result in Table 1, Table 2, Table 3, Table 4 and Table 5 shows that Alum, dried Artocarpus Heterophyllus seed (distilled water), raw Artocarpus Heterophyllus seed (distilled water), dried Artocarpus Heterophyllus seed (1M NaCl) and raw Artocarpus Heterophyllus seed (1M NaCl) are very effective in reducing the COD value in water sample especially raw Artocarpus Heterophyllus seed (distilled water). Previous study shows that when cactus was used with Aluminum Chloride Hexahydrate (AlCl36H2O) synchronously to treat water sample, the removal efficiency of turbidity and COD were higher than that of cactus or AlCl36H2O was used solely [17]

5. Conclusion

Based on this study it can be concluded that raw Artocarpus Heterophyllus seed and dried Artocarpus Heterophyllus seeds have potential to be used as an alternatives natural coagulant for the water treatment purposes whether by using distilled water or Sodium Chloride (NaCl) as coagulant solution.

From Table 4, it shows that dried Artocarpus Heterophyllus seed (1M NaCl) at 20mg/L which removes turbidity up to 51.34% as the optimum dosage coagulant in this research is the most effective of natural coagulant compared to dried Artocarpus Heterophyllus seed (distilled water), raw Artocarpus Heterophyllus seed (distilled water) and raw Artocarpus Heterophyllus seed (1M NaCl) to remove turbidity. It reduced turbidity, suspended solid and colour and COD in water sample after the treatment process. It shows that salt Sodium Chloride (NaCl) can be used as addictive in treating the water. From the results, Artocarpus Heterophyllus seed can remove the turbidity in the low turbidity of water sample. As the results show, it can be said that the result of Alum is better than dried Artocarpus Heterophyllus seeds as it can remove large amount of colour, suspended solid and turbidity from water sample compared to Artocarpus Heterophyllus seed. Table 1 exhibits that Alum at optimum coagulant dosage 80mg/L is more effective in the water treatment compared to the natural coagulant but Alum is not suitable to be consumed by the human body while Artocarpus Heterophyllus seed as natural coagulant is more environmental friendly and more safe to be use by human.

This study investigated Artocarpus Heterophyllus seed and found its potency for water treatment comparable to Alum. The Artocarpus Heterophyllus seed demonstrated turbidity removal comparable to the conventional water treatment coagulant alum, making community water safe for use. Artocarpus Heterophyllus seed should be investigated further individually and in combination with other natural coagulants for community water treatment because of its being eco-friendly (Green) and having demonstrated great potentials as water treatment. Artocarpus Heterophyllus is easy to be finds in Malaysia at all season. By using the Artocarpus Heterophyllus seed as natural coagulant, it helps to reduce the waste generation as the seeds cannot be eat by people. Natural coagulants also prove that it
gradually reducing the reliance on chemical coagulants and still can maintain the efficiency of water treatment.

6. References

[1] Grey, D., & Sadoff, C. W. 2007. Sink or Swim? Water security for growth and development. Water Policy. 9 545–571
[2] A. Azlan, H.E. Khoo, M.A. Idris, I. A. and M. R. R. 2012 Consumption Patterns and Perception on Intake of Drinking Water in Klang Valley, Malaysia. Pakistan Journal of Nutrition 11 584-590
[3] Choy, Y. S., Prasad, K., Wu, T. Y., & Raghunandan, M. (014. Utilization of Pant-based natural coagulants as future alternative towards sustainable water clarification. Journal of Environmental Sciences 26 2179–2181.
[4] Arnoldsson, E., Bergman, M., Matsimhe, N., & Persson, K. M. 2008. Assessment of drinking water treatment using Moringa oleifera natural coagulant. VATTEN 64 137–150.
[5] United States Geological Survey 2015. Wastewater treatment: Water use. The USGS Water Science School Retrieved from http://water.usgs.gov/edu/ww.html
[6] Gebbie, P. (2006). An operator’s guide to water treatment coagulants Earth Tech Engineering 31st Annual Qld Water Industry Workshop – Operations Skills an operator’s guide to water treatment 14 pp 14–20.
[7] Satterfield, Z. 2005 Jar Testing Tech Brief (The Environmental Service Centre) 5 pp 1–4.
[8] Okuda, T., Baes, A. U., Nishijima, W., & Okada, M. 1999. Research Note Improvement of Extraction Method of Coagulation Active Components From Moringa Oleifera Seed. Water Resources 15 3373–3378.
[9] Bina, B., Mehdinejad, M. H., Nikaen, M., & Attar, H. M. 2009 Effectiveness of chitosan as natural coagulant aid in treating turbid waters Iran. J. Environ. Health. Sci. Eng 6 247–252.
[10] Fatin Nabilah Murad, Md. Zahangir Alam, M. N. S., & Al-Mamun, A. A. 2017 Optimization of flocculation process by microbial coagulant for removal of turbidity in river water. IJUM Engineering Journal 18 63–70.
[11] Perl, D. P. 1985 Relationship of aluminum to Alzheimer's disease. Environmental Health 63 149–153
[12] Resendiz-Vazquez, J. A., Ulloa, J. A., Urias-Silvas, J. E., Bautista-Rosales, P. U., Ramirez, J. C., Rosas-Ulloa, P., & Gonzalez-Torres, L. 2017 Effect of high-intensity ultrasound on the technofunctional properties and structure of jackfruit (Artocarpus heterophyllus) seed protein isolate. Ultrasonics Sonochemistry, 37, 436–444.
[13] Madrona, G. S., & Serpelloni, G. B. 2010 Study of the effect of saline solution on the extraction of the moringa oleifera seed’s active component for water treatment Water Air and Soil Pollution 211 409–415.
[14] Bhatia, S., Othman, Z., & Ahmad, A. L. 2007 Pretreatment of palm oil mill effluent (POME) using Moringa oleifera seeds as natural coagulant Journal of Hazardous Materials 145 120–126.
[15] Natumanya R., & Okot-okumu J. 2015 Evaluating coagulant activity of locally available Syzygium cumini , Artocarpus heterophyllus and Moringa oleifera for treatment of community drinking water International Journal of Biological and Chemical Sciences 2535–2554.
[16] Abidin, Z. Z., Mohamed, M. F., Ghani, A., & Abdullah, L. 2014 Preliminary Study of Rambutan ( Nephelium Lappaceum ) Seed as Potential Biocoagulant for Turbidity Removal Advanced Materials Research 917 96–105
[17] Zhang, J., Zhang, F., Luo, Y., & Yang, H. 2006 A preliminary study on cactus as coagulant in wastewater Process Biochemistry 41 730–733
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