Potential of *Psidium guajava* Shoots Extract as Coagulant for Drinking Water Treatment

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ABSTRACT

The usage of alum-based coagulant in drinking water treatment process caused residues in completed drinking water treatment, which eventually supplied to consumers. This poses possible risk to their health. Furthermore, alum-based coagulant is expensive. Due to the risk and cost of using alum-based coagulant, natural coagulants which are environmental friendly, safe and cost effective, are needed. A plant-derived coagulant was successfully extracted from *Psidium guajava* by using physical extraction method. This study was intended to explore the effectiveness and optimum dosages of *P. guajava* needed for turbidity and heavy metals removal in surface water sources. Flavonoids and tannin are coagulating agent which are naturally present in *P. guajava* shoot and they are responsible for turbidity and heavy metals removal in water. Three types of heavy metals (Cuprum, Ferum and Manganese) and three level of turbidity were chosen for this study (500-700 NTU, 30-50 NTU and 5-20 NTU). The experiment was performed with crude extracts of *P. guajava* with different dosage (2.0 mg/L, 4.0 mg/L and 6.0 mg/L). Results demonstrated that the best and optimum turbidity removal is observed in low and moderate turbid water sample (5 – 50 NTU) up to 66.5 % at 2.0 mg/L of extract *P. guajava* shoot. However, there were no significant removal in Cuprum, Ferum and Manganese. It could be concluded that, *P. guajava* shoot extract has the ability to remove suspended solid in water, hence it has a great potential to replace chemical coagulant in drinking water treatment. Furthermore, *P. guajava* shoot extract is much cheaper and easy to prepare as compared to chemicals coagulant.

Key words: *Psidium guajava*, turbidity, ferum, cuprum, manganese, coagulant, alum

INTRODUCTION

Apparently, aluminium and ferrous or ferric salts are used in drinking water treatment as chemical coagulants to reduce the suspended solids and turbidity in raw water. According to the Malaysia Drinking Water Quality Standard, recommendations for aluminium levels in treated drinking water should not exceed 0.2 mg/L (Ministry of Health Malaysia, 2010) (**Table 1**). According to Driscoll and Letterman (1988), about 11% of the aluminium (Al) input during treatment process remains in the treated water as residual Al and distributed through piping system without any significant loss. From there, another problem has attributed to increase alum concentration where the products of alum hydrolysis are deposited on pipe walls, which decreases its capacity. Recent studies have shown that the dose of Al contained in drinking water is high, which is 0.5 mg/L and proven that high dosage of Al in drinking water could pose health risk in some cases, whereas in some worse cases, evidence points out that Al could increase the risk of Alzheimer's disease (McLachlan *et al.*,1996). Crapper and Boni (1980) made an observation on the relationship between Al and both Alzheimer's disease and dialysis encephalopathy in humans and it was proven that kidney dialysis patients are suffering from dementia due to Al concentration of 80 microgram per litre contained in their dialysis fluid (Srinivasan *et al.*, 1999).

The level of Al intake from drinking water varies with Al level in raw water and dose of Al coagulants used in water treatment process. Various physicochemical and mineralogical factors can also significantly affect the concentration of Al in natural water. Intake of Al via food and water is unavoidable yet 5% of the total intake is from drinking water and the major part (5mg/day) of total intake comes from food and its additives (Tomperi *et al.*, 2013). Hence, it is important to minimize the amount of residual aluminium in drinking water to ensure safe drinking water for locals. Thus, the urge to replace Al salts with sources from natural products have been raised in order to minimize the effect of the A1 residual in the treated water which results in high accumulation of turbidity and some health effects on consumers. In order to facilitate this problem, this study was proposed to determine the potential of *Psidium guajava* shoots (**Figure 1**) extracts to be used as coagulant to remove suspended solids and some heavy metals in drinking water treatment. *P. guajava* is a tropical and semitropical plant and it is well known for its edible fruits, which is commonly found in backyards. **Figure 1.0** belong to Myrtaceae family and it has numerous common names especially in Malaysia which are known as "Jambu burung", "Jambu padang", "Jambu batu" , "Jambu biji" etc. The presence of Manganese is detected in the plant resulting from combination with phosphoric, oxalic and malic acids, which are naturally found in guava fruits. The extracts of roots, bark and leaves are used or consumed to treat gastroenteritis, vomiting, diarrhoea, dysentery, wounds, ulcers, toothache, coughs, sore throat and inflamed gums. The leaves of guava contain an essential oil rich in cineol, triterpenic acids and flavonoids besides resin, fat, cellulose, tannin, volatile oil, chlorophyll and mineral salts. On the other hand, its bark contains 12-30% of tannin, resin and crystals of calcium oxalate whereas the roots are also rich in tannin, and contained high proportions of carbohydrates and salts. Tannin seems to be common in root, stem, bark, and leaves in large percentage. Apart from that, the extracts of the leaf has the capability to stimulate vasoconstriction and platelet aggregation therefore inhibit blood coagulation (Dweck, 1987). Concerning these practices, the extract of this plant as coagulant is believed to have high potential in drinking water treatment to replace the current conventional coagulants due to its ability in absorb excess water during diarrhea. Moreover, this method seems to be inexpensive, environmental friendly as well as an effective agent in drinking water treatment, especially in removing heavy metal and suspended solids (Yap, 2013).

Table 1.0: Drinking Water Quality Standard by Ministry of Health Malaysia, 2010

Parameter	Raw water (mg/L)		Treated Water (mg/L)	
	Min	Max	Min	Max
Turbidity	0	1000	0	5
Ferum/Iron	0.00000	1.00000	0.00000	0.30000
Manganese	0.00000	0.20000	0.00000	0.10000
Cuprum/ Copper	0.00000	1.00000	0.00000	1.00000

Figure 1.0: *Psidium guajava*

The use of natural plants as natural coagulants in clarifying turbidity of water has been a common practice since ancient times. Some of the common phytochemical compounds found in plants, for instance tannins, flavonoids; oil and protein are responsible for coagulation mechanism involved in water clarification. Direct coagulation of *P. guajava* as a coagulant appeared to be effective in clarifying turbidity, coagulating suspended solids and removing heavy metals. Flavonoids are an important group of polyphenols, widely distributed among the plant floras, which has benzene ring in its structure. These compounds function as antioxidants or free radicle scavenger. The common types of flavonoid present in nearly 70% of plants are quercetin, kaempferol, and quercitrin. There might be other group of flavonoids appear to be plants phytochemical compound such that flavones, dihydroflavons, flavans, flavanols, anthocyanidins, proanthocyanidins, calchones and catechin and leucoanthocyanidins (Doughari, 2009). Other than that, tannins also play a major role in coagulation mechanism because they have feature to turn or to convert substances into leather. The properties of tannins are such as good solubility in water and alcohol, phenolic compounds of high molecular weight and found abundantly in the root, bark, stem, and outer layers of plant tissue. They are acidic in reaction and this acidic reaction is attributed to the presence of carboxylic group. They do form complexes with proteins, carbohydrates, gelatin and alkaloids, which are associated to formation of agglomeration, resulting in coagulation.

MATERIALS AND METHODS

Good quality shoots of *P. guajava* were collected randomly from Tanah Merah, Kelantan, Malaysia. The collected shoots of *P. guajava* were thoroughly washed using distilled water before drying. After drying in oven for two days at temperature of 50 ºC, the leaves were grounded using grinder in the laboratory. The grounded material was sieved through 0.4 mm size sieve and the particles smaller than 0.4 mm size sieve was used for crude extraction process. For the preparation of crude extract, 1.0 g of *P. guajava* was added into 1000 ml of distilled water and then stirred by using magnetic stirrer for 60 minutes and the mixture was left for 20 minutes to settle down and after that 0.95 mm filter paper was used to filter the mixture so as to remove solid particles.

Jar-test was performed in four (4) cleaned Biological Oxygen Demand (BOD) bottles. Each bottle was added with 300mL water sample and then different concentrations of *P. guajava* crude extract; 0.0mL, 2.0mL, 4.0mL and 6.0mL were added. The standard procedure implies 3 minutes of rapid mixing (200 rpm) in the incubator shaker at 21^{o}C temperature followed by 30 minutes of slow mixing (50 rpm) for flocculation. The treated water was allowed to settle for 20 minutes and 100 ml of the sample was taken from the top of each BOD bottle to be measured and analysed for turbidity, iron, manganese and cuprum. Jar test was conducted by adding different dosage of crude plant extract to the 250ml of prepared water samples. The test was done to determine optimum dosage and proportion needed to prepare the efficient coagulant in removing Fe, Mn, Cu, and turbidity. The water sample with certain concentration of heavy metals and turbidity was analysed before and after jar test. Atomic Absorption Spectrophotometer (AAS) was used to identify the concentration of heavy metals, whereas, Turbidimeter Hanna Model 2100P was used to identify the turbidity.

The difference in concentration of turbidity, iron, manganese and cuprum before and after treatment was used to indicate the effectiveness of *P. guajava* in reducing these parameters in raw water. Turbidity and heavy metals reduction were presented in percentage (%), according to Yap (2013):

Biosorbent removal (%) = [(Ci-Ca) / (Ci)] × 100

Where: Ci – initial concentration of turbidity and heavy metals before treatment (mg/L)

Ca- concentration of turbidity and heavy metals after treatment (mg/L)

RESULTS AND DISCUSSION

Turbidity Removal

Table 2.0 and Figure 2.0 show the reduction of turbidity with initial turbidity of 691.5 NTU and after treated with *P. guajava* crude extract with 2.0 mg/L, 4.0 mg/L and 6.0 mg/L respectively. The highest reduction was recorded at 2.0 mg/L concentrations of *P. guajava* with 0.29 % reduction. It could be concluded that 2 mg/L, 4 mg/L and 6 mg/L of *P. guajava* have no significant difference in removal of turbidity in highest turbidity water (P>0.05).

Table 2.0 : Turbidity concentration after treated with *P.guajava* shoots for 500-700 NTU water sample

Initial turbidity (Before treatment)	Dosage of crude extracts (mg/L)	Residual turbidity (NTU) (After treatment)
691.5 NTU	0.0	691.5
	2.0	689.5
	4.0	690.3
	6.0	691.2

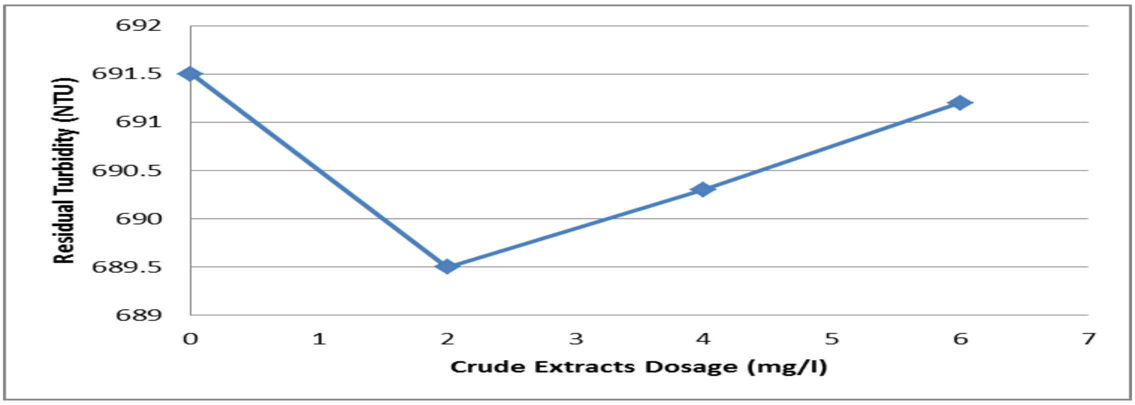

Figure 2.0. Concentration of turbidity with initial turbidity 691.5 NTU treated with different dosage of *P.guajava* crude extracts

Table 2.1 and Figure 2.1 show the results of coagulation mechanism study on moderate turbidity water with initial turbidity of 48.8 NTU, using *P. guajava* crude extract to test the effectiveness of the coagulant in turbidity removal. Based on the results obtained, rapid reduction in turbidity to 19.80 NTU at 2.0 mg/L crude extract with 59.4% reduction ($P < 0.05$) and after that slowly decreased to 18.57 NTU at 6.0 mg/L with the maximum rate of removal up to 61.9 %.

Table 2.1: Turbidity concentration after treated with *P.guajava* shoots for 30-50 NTU water sample

Initial Turbidity (Before treatment)	Dosage of crude extracts (mg/L)	Residual Turbidity (NTU) (After treatment)
48.8 NTU	0.0	48.20
	2.0	19.80
	4.0	20.00
	6.0	18.57

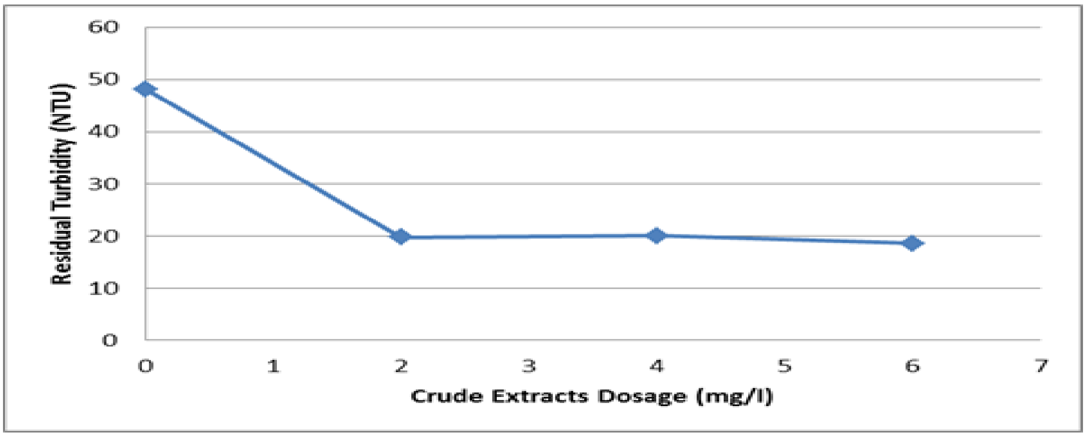

Figure 2.1: Concentration of turbidity with initial turbidity 48.8 NTU treated with different dosage of *P.guajava* crude extracts

Table 2.2 and Figure 2.2 show the reduction rate of turbidity with initial concentration of 14.7 NTU and after treated with *P. guajava* crude extract, it was seen that, significant reduction of turbidity was recorded ($P<0.05$) with the reduction rate of 66.5% at 2.0 mg/L crude extract. The turbidity concentrations slowly decreased from 2.0 mg/L to 6.0 mg/L crude extract dosage and the maximum reduction rate of 73.8% was recorded at 6.0 mg/L crude extract. However, the decrease were found to be not significant ($p>0.05$).

Table 2.2: Turbidity concentration after treated with *P.guajava* shoots for 5.0 – 20.0 NTU water sample

Initial Turbidity (Before Treatment)	Dosage of crude extracts (mg/L)	Residual turbidity (NTU) (After Treatment)
14.7 NTU	0.0	14.7
	2.0	4.93
	4.0	4.33
	6.0	3.85

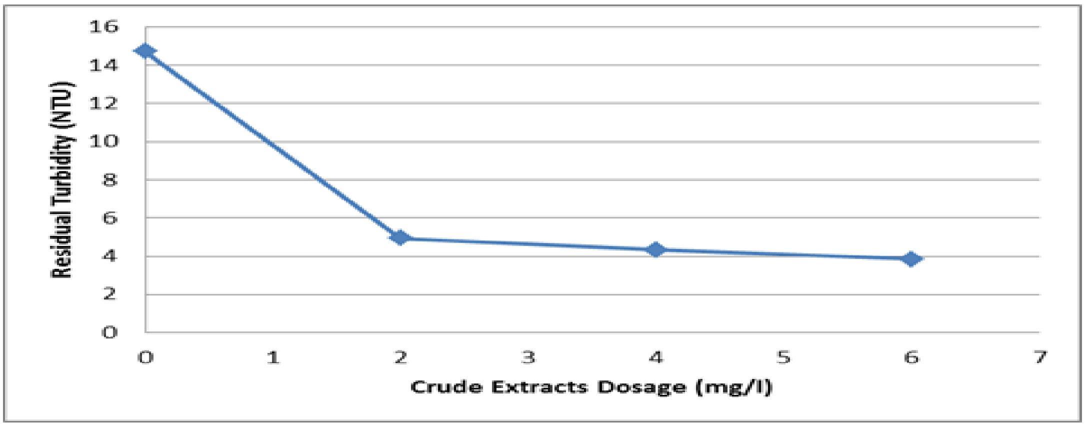

Figure 2.2: Concentration of turbidity with initial turbidity 14.7 NTU treated with different dosage of *P.guajava* crude extracts

Heavy Metals Removal

Mn and Fe are natural constituents of soil and rock, also present in insoluble forms but brought into water bodies by anaerobic conditions or in the presence of carbon dioxide. Problem have been found to occur when the concentration of iron and manganese exceeds 0.3 mg/L and 0.1 mg/L respectively (Vigneswaran *et al*., n.d.). This study focus on the effectiveness of *P. guajava* crude extract used as coagulant in removing the Mn and Fe from water samples, which was synthesized in the laboratory.

Table 3.0 and Figure 3.0 show the iron removal efficiency through coagulation mechanism using *P. guajava* plants crude extract. It was observed that, the iron concentration decreased as the dose of coagulant increased and the elimination of iron were stabilized from 4 mg/L to 6.0 mg/L of coagulant applied. The removal rate of iron was 35.5 % after treated with 6.0 mg/L crude extract.

Table 3.0 : Fe Removal

Initial concentration of Fe (mg/L) (Before treatment)	Dosage of crude extracts (mg/L)	Final concentrations of Fe (mg/L) (After treatment)
2.0 ± 0.09	0.0	1.909
	2.0	1.705
	4.0	1.458
	6.0	1.348

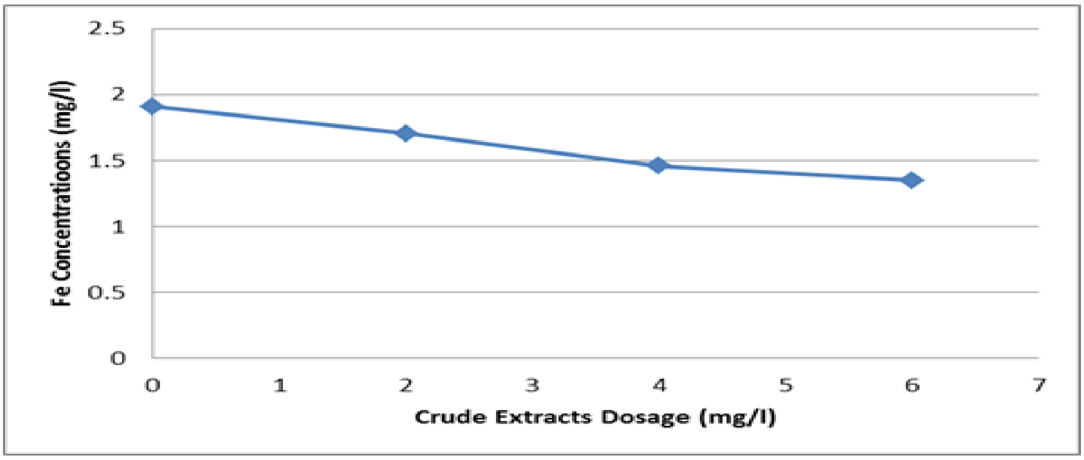

Figure 3.0 Fe Removal Efficiency through Coagulation process using *P.guajava* Crude Extracts

Table 3.1 and Figure 3.1 show the residual of Mn after treated with *P. guajava* crude extract. There was a reduction of Mn concentrations after treated with *P. guajava* crude extract but the reduction rate was small (36.3%).

Although Fe and Mn showed reduction in their concentration after treatment, the values of Fe and Mn after treatment still exceeded the standard value set in the National Drinking Water for Fe and Mn which are 0.3 mg/L and 0.1 mg/L respectively.

Table 3.1: Mn Removal

Initial concentration of Mn (mg/L) (Before treatment)	Dosage of crude extracts (mg/L)	Final concentrations of Mn (mg/L) (After treatment)
0.5±0.07	0.0	0.573
	2.0	0.528
	4.0	0.429
	6.0	0.363

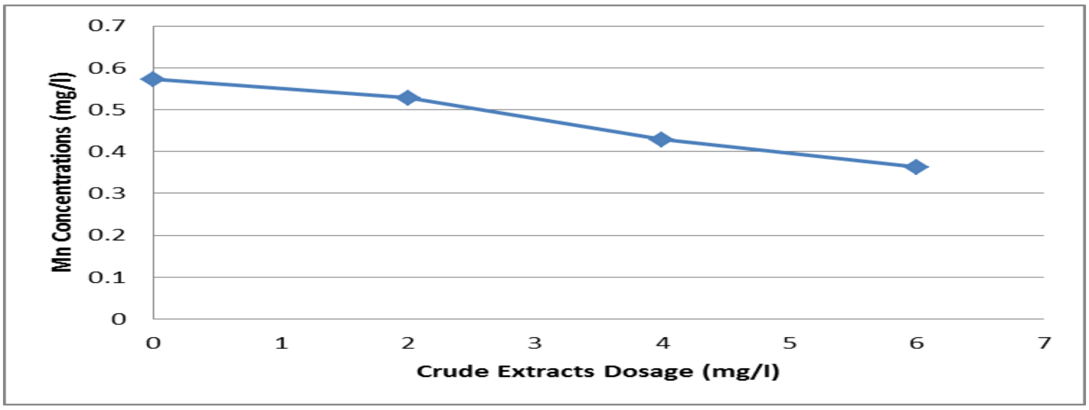

Figure 3.1: Mn Removal Efficiency through Coagulation process using *P.guajava* Crude Extract

Based on the test performed for the Cu, Mn and Fe contents in crude *P. guajava* extract, Cu recorded the highest content as compared to Mn and Fe with the concentrations 0.115 mg/L. This was believed to cause the concentration of Cu in treated water increase as the dosage of crude extract used increases instead of decreasing (**Table 3.2** and **Figure 3.2**). Hence, the *P. guajava* crude extract is not suitable to be used as coagulant in removing Cu in water samples as it has high Cu concentrations in the plant. The high concentrations of Cu might be due to the site which contains high Cu in the soil and substantial amount of Cu was taken in by the plant root since Cu is an essential micronutrient required in the growth of both plants and animals. In plants, Cu is an essential element for seed production, disease resistance, and regulation of water. In the soil, Cu strongly form complexes with organic compound, implying that only a small fraction of copper will be found as ionic copper, Cu(II). The high solubility of Cu will increase the pH value to 5.5. The connection between soil and water contamination and metal uptake by plants are determined by many chemical and physical soil factors as well as the physiological properties of the crops. Soils contaminated with trace metals may pose both direct and indirect threats through negative effects of metals on crop growth and yield (Wuana *et al*., 2011).

Table 3.2: Cu Removal

Initial concentration of Cu (mg/L) (Before Treatment)	Dosage of crude extracts (mg/L)	Final concentration of Cu (mg/L) (After treatment)
1.0 ± 0.01	0.0	0.987
	2.0	1.548
	4.0	1.549
	6.0	1.547

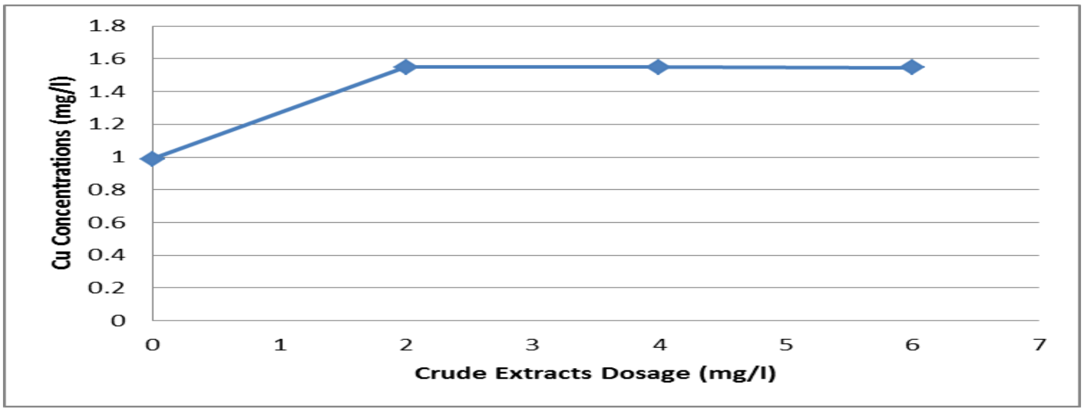

Figure 3.2: Cu Removal Efficiency through Coagulation process using *P.guajava* Crude Extracts

The results show that, *P. guajava* shoot extract can remove turbidity up to 73.8% at the dosage of 6 mg/L but the optimum concentrations would be 2 mg/L with the removal rate of 66.5%. The percentage of reduction of *P. guajava* was slightly lower as compared to *Cassia alata* leaves (Aweng *et al*. 2012) and Opuntia spp. (Miller *et al*. 2008), where the percentage of reduction is 93.33% and 95% respectively. On the other hand, *P. guajava* shoot extract has a weak Cu, Mn and Fe removal capacity with the rate of removal ranged between 0.0 to 36.3%.

CONCLUSION

It could be concluded that the *P. guajava* shoot extract has a good potential to be used as natural coagulant to replace chemical coagulant in removing suspended solids in water. However it is ineffective in eliminating heavy metals.

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