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Original Research Article

The used of dragon fruit peels as eco-friendly wastewater coagulants

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Abstract

Background: Coagulation and flocculation has been widely adopted as one of the most effective methods to remove colloidal particles in water or wastewater.
Objectives: To explore the potential of dragon fruit peels as coagulants through removal level of turbidity, total dissolved solids (TDS) and total suspended solids (TSS) from wastewater.
Methodology: Dragon fruit purple pink fleshed (DFPP) and dragon fruit white fleshed (DFPW) were applied to the leachate at several dosages (10 to 90 mg/l) using standard jar test method and sedimentation times were recorded. Turbidity, TDS and TSS were measured using meter.
Results and Discussion: DFPW removed 67% of turbidity, 69% of TDS and 36% of TSS at optimum dosage of 90 mg/L. DFPP removed 60% of turbidity and 23% of TSS at an optimum dosage of 50 mg/L and 65% TDS at optimum dosage of 90 mg/L. The percentage of removal increased with the sedimentation time but not significant difference between DFPs.
Conclusion: DFPs is potential to be used as eco-friendly wastewater coagulant.

Keywords: Wastewater, turbidity, TDS, TSS, coagulation-flocculation, dragon fruit peel

Introduction

Coagulation and flocculation methods are effectively removed the colloidal particles in water or wastewater. These methods are widely adopted in wastewater treatment. It is the components that promote aggregation and sedimentation of suspended particles in a solution (Nharingo et al., 2015). Introduced high charged cations into the water, will destabilize the colloidal particles and large aggregates will be formed, effectively separate the flocs by subsequent sedimentation, flotation or filtration units (Mounir et al., 2014). There are two types of coagulants which are the natural based such as using plants and the chemical-based such as alum, ferric chloride and polyaluminium chloride (PAC) (Vishali & Karthikeyan, 2014). The plant that mainly used as natural coagulants are *Moringa oleifera* seeds, Nirmali seeds, tannin and *Opuntia ficus indica* cactus (Vijayaraghavan, et al., 2011; Yin, 2010). Natural coagulants are biodegradable and safe for human health. It is also made from abundance material, cost effective, highly biodegradable and toxic-free (Yin, 2010; Asrafuzzaman et al., 2011; Bratby, 2006). In contrast, chemical based coagulants are characterized as poisoning and related to some disease such encephalopathy. A strong evidence has linked the chemical based coagulants made of aluminium with neurodegenerative illnesses such as senile dementia (Okuda et al., 1999) and alzheimer’s (Rondeau et al., 2001; Flaten, 2001). This has becoming the interest of researcher to explore the potential of natural plant to be used as coagulants to replace the chemical based coagulants that are safe to the environment and human (Muralimohan et al., 2014).

Dragon fruit is belongs to the Cactaceae family known as pitaya or pitahaya with coagulant characteristic (Diaz et al., 1999; Shafad et al., 2013). For example, *Latifaria* and *Opuntia* cactus exhibits high turbidity removal for sewage and seawater treatment (Zhang et al., 2006; Diaz et al., 1999). The mucilage of these cactus contains polygalacturonic acid, a biopolymer with coagulating-flocculating abilities (Torres, 2012). Dragon fruit is a native plant to Mexico, Central America and South America; but now widely cultivated as fruit crops in Southeast Asia such as in Vietnam, Taiwan, Philippines including Malaysia (Nerd & Mizrahi, 1997). The commercial production of dragon fruit in Malaysia is between 16,000–27,000 kg/ha per year (Mizrahi & Nerd, 1999; Pushpakumara et al., 2005). The mucilage of dragon fruit contain galacturonic acids, the predominant active coagulation agent (Choy et al., 2014) while the peels are rich in pectin, a heterogeneous structural polysaccharide contain α-1,4-linked D-galacturonic acid (D-GalA) residues (Ridley et al., 2001).

Fruit waste is an example of a biomaterial that is suitable to be derived into plant-based natural coagulants. Fruit waste such as peels and seeds comprised a significant amount of up to 50% of the total fruit weight and are commonly non-edible (Choy et al., 2014). The prospective of dragon fruit as the natural coagulant agents is not much studied so far. A recent study indicates that *Opuntia ficus indica* (a cactus species) produces "mucilage" that contains polygalacturonic acid (biopolymer) with interesting coagulating-flocculating abilities. The mucilage at dose of 50 mg/l removed 65% of the initial chemical oxygen demand (COD) value at pH 10 (Torres, 2012). Another study showed that mucilage derived from the species *Opuntia ficus indica* demonstrated high efficiency to eliminate turbidity compared to aluminium sulfate ($Al_2(SO_4)_3$) (Pichler, Young, & Alcantar, 2012). The mucilage extracts increased particulate-settling rates to 330% compared to aluminium sulfate at dosage concentration of 3 mg/L, while its performance was equivalent at doses 0.3% of the required $Al_2(SO_4)_3$ concentration. Hence, the positive outcome of studies on cactus-based wastewater coagulation justifies further research on dragon fruits with a similar characteristic to cactus family as natural coagulants (Idris et al., 2013).

Therefore, this study was conducted to explore the potential of dragon fruit peels (DFP) as wastewater coagulants. Wastewater is generally known as high-strength water that is most difficult to deal with (Schoeman et al., 2003). This liquid has a dark colour and a foul odor and contains complex chemical and organic compounds (Galeano et al., 2011). This study would provide a new insight of the potential of DFP as an environmental friendly coagulant for wastewater treatment.

Materials and Method

Wastewater sampling

Wastewater sample was collected from a sanitary landfill in Kuala Langat district, Selangor. The sanitary landfill received 1,000 tonne of domestic, industrial and other type of waste per day. The pH measurement was taken *in-situ* with the aid of a portable pH meter (Model HACH). Turbidity, TDS and TSS were measured using HACH Turbid meter 2100N, portable TDS meter (Model HACH) and vacuum filter apparatus respectively (American Public Health Association, American Water Works Association, & Water Environment Federation, 1999).

Preparation of dragon fruit peel as coagulant

Two types of dragon fruit peels involved in this study. They are the white fleshed *Hylocerus undatus* (DFPW) and the purple pink fleshed *Hylocerus polyrhizus* (DFPP). The peels were washed with tap water and subsequently cut into small pieces to facilitate the drying. It was dried in the oven and blended through 250 µm sieved (Priyantha et al., 2015). Then, 1.0 g dried powder was suspended in 100 mL distilled water and filtered using Whatman 42 filter paper (Prasad, 2009; Vega-rodriguez & Perez-casas, 2003; Shafad et al., 2013). The extract was collected to be used as coagulant.

Coagulation test

Coagulation tests were conducted using jar floc test unit. The pH was fixed at neutral pH for every experiment (Idris et al., 2013) as it is the optimum pH of river water (Shafad et al., 2013). The coagulant was added into beakers at different dosage (i.e. 10 mg/L, 30 mg/L, 50 mg/L, 70 mg/L and 90 mg/L) to observe the optimization of dragon fruit peels in a larger range (Shafad et al., 2013). The speed and duration of the jar floc test used were rapid mixing at 100 rpm for 4 minutes and slow mixing at 40 rpm for 25 minutes followed by sedimentation for 30 minutes (Muhyibi et al, 2002). After sedimentation, the residual turbidity of the clarified water collected from the middle of the beaker was measured using Hach Turbidimeter, TDS using portable TDS meter (Model HACH), and TSS using vacuum filter apparatus (American Public Health Association et al., 1999).

Data and Statistical analysis

Descriptive statistics were used to elaborate the data in terms of the mean, standard deviation, t-test, and p-value. The results were statistically analyzed using Paired t-test and Independent t-test. Paired t-test was used to compare the removal percentage of all parameters before and after addition of coagulants.
Independent t-test was used to compare the removal percentage of parameters from leachate between DFPP and DFPW coagulants.

Quality Control & Quality Assurance

Measurements were taken in duplicate (Shafad et al., 2013). Instruments calibration was done prior to measurement. Instruments maintenance were done according to the manual instructions. Instrument manufacturer's recommendations for calibration were used in accordance to the type of instrument used. As a minimum, one reagent blank was included with each sample set (American Public Health Association et al., 1999).

Results

Figure 1 shows the removal percentage of turbidity, TDS and TSS by DFPP and DFPW at different dosage (mg/L). The optimum dosage of DFPW was obtained at 90 mg/L. At this dosage, DFPW removed 67% of the turbidity, 69% of TDS and 36% of TSS. The optimum dosage for DFPP was obtained at 50 mg/l with the removal percentage of 60% turbidity and 23% TSS. The highest removal of TDS by DFPP was obtained at 90 mg/l with 65% removal. The removal percentage for all parameters was increased with the sedimentation time. For instance, the level of turbidity removal by DFPW increased from 38% (in 5 min) to 68% in 60 min. Similar trend was observed for DFPP where gradual increase of turbidity removal from 35% in 5 min to 63% in 60 min.
There is no significant difference on the removal percentage between DFPP and DFPW. In average, both peels removed 48.8% (DFPP) and 45.2% (DFPW) of turbidity (t = -0.420, *p* = 0.686). Similar results were observed for TDS where the average removal was 46.2% for DFPP and 45.8% for DFPW (t = -0.40, *p* = 0.969). The average removal of TSS was 14.6% for DFPP and 22.6% for DFPW (t = 1.678, *p* = 0.132).

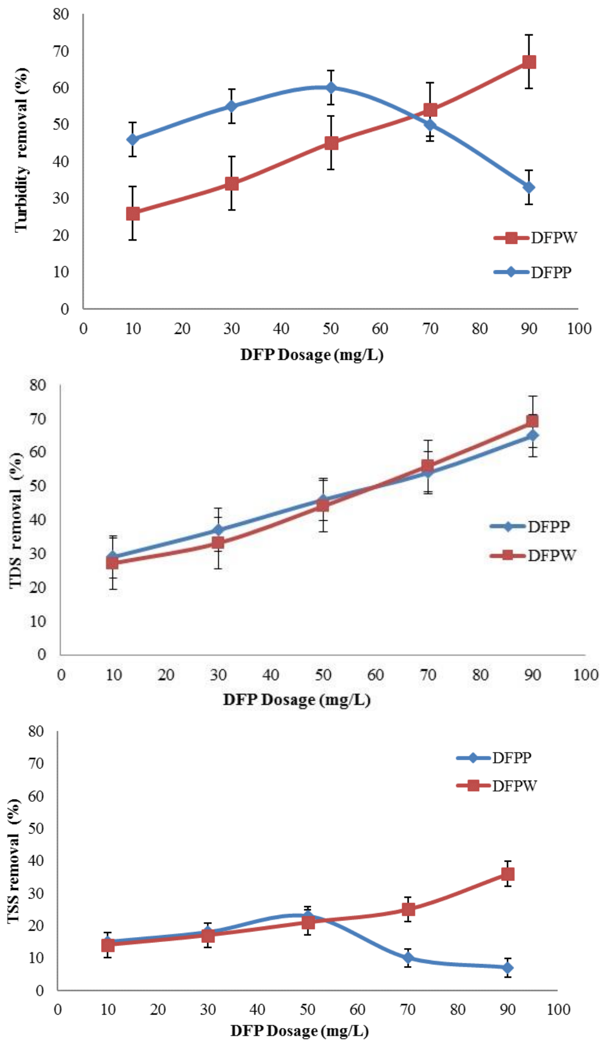

Figure 1: Removal percentage of turbidity, TDS and TSS by DFPP and DFPW dosage (mg/L)

DISCUSSION

Results of this study highlights that both DFP's have significantly removed the turbidity and TDS by half of its initial concentration and TSS by one third. A study done by Idris et al., (2013) have recorded higher turbidity removal level (95%) compared to what we have obtained in this study at a higher DFPs dosage between 200-800 mg/L. The level of TSS removal was obtained at 60% with the dosage of 500 mg/L DFPs. The mucilage extract increased particulate-settling rates to 330% compared to aluminium sulfate, at dosage concentration of 3 mg/L, while its performance was equivalent at doses 0.3% of the $Al_2(SO_4)_3$ concentration. Another research on *Moringa oleifera* (commonly known as horseradish or drumstick tree) has reported 94% of turbidity removal was obtained at the dosage of 400 mg/L (Sarpong & Richardson, 2010). *Molinga oleifera* is a plant of the Moringaceae family, a native to the sub-Himalayan region of northwest India, Sudan and other parts of Africa.

Dragon fruit peels (DFPs) are in the same family as cactus and they are rich in pectin, such as heterogeneous structural polysaccharide contain α-1,4-linked D-galacturonic acid (D-GalA) residues (Ridley et al., 2001). The mucilage of DFPs contains galacturonic acids which generally the predominant active coagulation agent regardless of the species (Choy et al., 2014). High natural polymers such as polysaccharides (i.e. galacturonic acid) and proteins in DFPs provide active sites at polymeric chain for particle adsorption and encourage coagulation process (Ridley et al., 2001; Choy et al., 2014).

Coagulation is the process of decreasing or neutralizing the electric charge on suspended particles (Idris et al., 2013). The coagulation process occurs in the colloidal particles of wastewater where it carries the negative electrical charges on their surface. This stable system of colloid should be un-stabilized by the application of coagulants with the opposite charge (Mahvi & Razavi, 2005). Meanwhile the colloids in foliage of DFPs were identified to be cationic. Thus, adsorption and charge neutralization have been proposed as the possible coagulation mechanism leading to formation of flocs (Choy et al., 2014; Idris et al., 2013). Similar electric charges on small particles in water cause the particles to naturally repel each other and hold the small colloidal particles apart and keep them in suspension. Thus, the coagulation/flocculation process neutralizes or reduces the negative charge on the particles (Ebeling et al., 2003) and allow initial aggregation of colloidal and fine suspended materials to form micro floc through van der Waals force. Flocculation is the process of bringing together the micro floc particles to form large agglomerations by physically mixing or through the binding action of flocculants, such as long chain polymers (Ebeling et al., 2003). The adsorption and charge neutralization are the coagulation mechanism leading to formation of flocs (Choy et al., 2014; Idris et al., 2013). Charge neutralization occurs by direct reduction of net charge to zero upon addition of a coagulant or flocculants of opposite charge and can result in charge reversal if an overdose occurs (Mahvi & Razavi, 2005).

The whole treatment process of coagulation-flocculation can be divided into two distinct procedures, which should be applied consecutively. The first one termed coagulation, is the process whereby destabilization of a given colloidal suspension or solution is taking place. The function of coagulation is to overcome the factors that promote the stability of a given system. It is achieved with the use of appropriate chemicals, usually aluminium or iron salts, the so-called coagulant agents. The second sub-process, termed flocculation, refers to the induction of destabilized particles in order to come together, to make contact and thereby, to form large agglomerates, which can be separated easier usually through gravity settling (Bratby, 2006). Material in wastewater carries negative charge and the electrostatic repulsive forces prevent the particles to get together and thus the solution is stable and need longer time to sediment. To reduce the sedimentation time, destabilization is required and this is the main role of coagulants through mechanism such as adsorption and charge neutralization, subsequently then flocculation promotes the aggregation and flocs formation (Tzoupanos & Zouboulis, 2008).

Our study also has observed decreased of removal percentage (except for TDS) with a further increase of DFPP dosage above the optimum level. This possibly due to overdosing where it has reversed the coagulation process and increases the charge of the suspended solids and destabilized (López-maldonado et al., 2014). The overdosing has resulted in the saturation of the polymer bridge sites and cause destabilization of the particles due to insufficient number of particles to form more inter-particle bridges (Muyibi & Evison, 1995).

Studies have been reported on the examination of coagulation–flocculation for the treatment of landfill leachates, aiming at process optimization such as selection of the most appropriate coagulant. Despite the superiority of chemical coagulants in treating turbid water, they are still lacking in terms of green chemistry (Choy et al., 2014). Residual aluminium in alum treated water has been the center of debate as it is linked to serious health issues such as the development of Alzheimer's disease (AD) (Flaten, 2001) and senile dementia (Rondeau et al., 2001). As for iron salts, careful process controls are necessary as excessive iron residual in the treated water will lead to highly visible rust or blood colored stains caused by the hydrolysis of iron salts. In contrast to chemical coagulants, plant-based natural coagulants are eco-friendly and generally toxic free (Bratby, 2006).

Apart from the outcome that has been achieved through this research, it also has some limitations that can be improved in future. For example, the exact composition of coagulant agent in both DFPs was not studied. As mentioned throughout the article, the possible of coagulant agent in this fruit peel is possibly from pectin, a heterogeneous structural polysaccharide contain α-1,4-linked D-galacturonic acid (D-GalA) residues and natural polymers such as polysaccharides (i.e. galacturonic acid) and proteins (Ridley et al., 2001). Future study is recommended to identify these coagulant agents to understand the mechanism. This study has not considered pH variability in the removal efficiency. The pH manipulation and optimization is recommended in future study to determine the relationship these parameters along with the removal efficiency. Only turbidity, TDS and TSS were assessed in this study while there are many other constituents need to be tested in the wastewater. Future study can evaluate the efficiency of DFPs in the removal of other constituents such as oil and grease.

Conclusion

In conclusion, the DFPW has removed 67% of turbidity, 69% of TDS and 36% of TSS at the optimum dosage of 90 mg/L. DFPP removed 60% of the turbidity and 23% of TSS at the optimum dosage of 50 mg/l and 65% of turbidity at the optimum dosage of 90 mg/l. The removal percentage increased significantly with the sedimentation time from 5 to 60 minutes. The removal level for both DFPs was similar.

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