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Cicer arietinum as coagulant for water clarification

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Abstract

This work aims to investigate the application of *Cicer arietinum* as an innovative coagulant for water clarification. Its coagulation ability for water clarification was demonstrated by treating lake water at average NTU of 146. *Cicer arietinum* was dried and ground to obtain uniform size of 500 µm. To achieve high turbidity removal from the polluted water, several parameters were studied including coagulant dosage, stirring speed and rapid mixing time. The turbidity removal, T(%), was determined using turbidity meter to track the suspended solids that have been coagulated with *Cicer arietinum* protein. Maximum turbidity removal (52.74%) was recorded by using 12 mg/L of coagulant at speed of 120 rpm for 4 mins. Additionally, the usage of *Cicer arietinum* as coagulant has hardly change the wastewater pH.

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1.0 Introduction

Wastewater is an effluent discharged by domestic, industrial, and agricultural sector alike, containing colloidal particles, suspended solids, impurities, pathogens, and bacteria (Kazi et al., 2013). Numerous methods were used to ensure the water is safe for the consumer. The methods vary according to the characteristic of the raw water and one of the common problems is the turbidity variation of the raw water (McConnachie et al., 1999). In conventional water treatment process, aluminium sulphate (alum) and synthetic organic polymer such as polyaluminium chloride (PACl), are commonly used in treating wastewater in the tertiary treatment facility as coagulant (Muthuraman et al., 2014). However, these chemicals are costly and require relatively high dosage. In fact, there are also reports associated chemical based coagulants with human health related issues, mainly Alzheimer's disease (Ghochikyan et al., 2006) and pre senile dementia (Basra et al., 2014). This is due to the presence of Al^{3+} ions in the coagulants that tends to bind with the phosphate groups of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), influencing the expression of various genes essential for brain function (Kawahara et al., 2011).

Recently, numerous studies on variety of plant-based coagulant have been reported to treat wastewater, for instance, drumstick (*Moringa oleifera*) seeds, common bean (*Phaseolus vulgaris*) and Nirmali seed (*Strychnos potatorum*). The usage of natural organic polymers has been discovered 2000 years ago in India, Africa, and China as an effective natural coagulant for removing water turbidity long before the advent of synthetic chemical (Asrafuzzaman et al., 2011). The usage of these organic polymers is favourable because it does not cause any side effects to human health and their cost are cheaper compared to the conventional chemicals used in water treatment process. The reduction in turbidity of wastewater is affected by the presence of water soluble cationic coagulant protein of high molecular weight which destabilises the particles in the water (Muthuraman et al., 2013).

Chickpea (*Cicer arietinum)* as shown in Fig.1 is one of many important grains legumes which ranked third in the world after dry bean (*Phaseolus vulgaris L.*) and field pea (*Pisum sativum L.*) It is the most abundantly planted grain legume grown in 11.6 million hectares with annual worldwide production of 8.8 million metric tonnes (Naim et al., 2015).

There are two major types of *Cicer arietinum*, differentiated by its seed-size, shape, and colour. Desi-type is recognised by its smaller seed of angular shape and dark coating whereas kabuli-type is characterised by large owl/ram-head-shaped seeds with beige-coloured seed coat. Due to its higher market price, kabuli-type is considered as more favourable and economically important than desi-type. Generally, the nutrient contents of *Cicer arietinum* are 41% to 50% starch, 12.4% to 31% of crude protein, about 6% of fats and the rest is fibre (Hirdyani, 2014; Naim et al., 2015). This high crude protein present in *Cicer arietinum* provides a promising potential to be used as a coagulant.

Fig. 1: Cicer arietinum in original form.

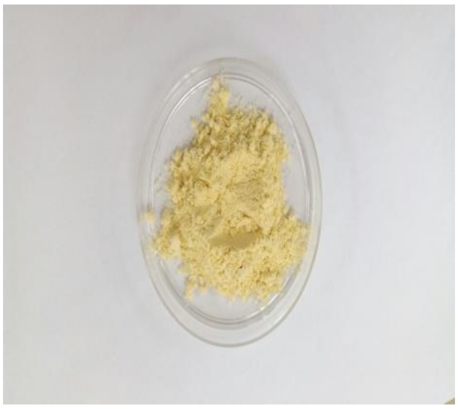

Fig. 2: *Cicer arietinum* powder at size of 500 µm.

Fig. 3: Jar test setup using *Cicer arietinum* as coagulant.

Recent study by Asrafuzzaman et al. (2011) who applied *Cicer arietinum* as substitution for present chemical based coagulant in treating a highly turbid wastewater reported a reduction up to 95.89% of turbidity. Hence, this research explores the potential of using *Cicer arietinum* as coagulant to treat wastewater at low turbidity and to find the most suitable *Cicer arietinum* dosage, stirring speed, and rapid mixing time to achieve high turbidity removal from the wastewater.

2.0 Methodology

2.1 Material

Cicer arietinum was purchased from a local market. It was dried and impurities were removed before it was ground to fine powder by using a kitchen blender. Fig. 2 shows the powdered *Cicer arietinum* sieved to uniform size of 500 µm.

On the other hand, samples of wastewater were obtained from a lake at Masai, Johor which receives wastewater from nearby house-holds. Fresh samples of water were collected each time before experiments started. The characteristics of the wastewater is presented in Table 1.

Table 1: Characteristic of the wastewater sample collected.

Parameters	Range	Average value
Turbidity (NTU)	129–163	146
pH	5.5–6.9	6.2

2.2 Methods

A conventional jar test apparatus (Fig. 3) was used in this experiment to perform coagulation process using *Cicer arietinum* as coagulant. The jar test accommodates a series of six beakers together with six-spindle steel paddles. 500 mL of wastewater was added in six units of 1 litre beakers, respectively. The dosage of *Cicer arietinum* was varied (8, 10, 12, 14, 16 and 18 mg/L). The content of the beaker was agitated at 100 rpm for 1 min (rapid mixing), otherwise mentioned. The agitation speed was then reduced to 30 rpm for 3 mins (slow mixing) before allowing the suspensions to settle for 20 mins (Kazi et al., 2013). Finally, 25 mL samples from each beaker ought to be measured for turbidity and pH.

The turbidity of the wastewater was measured by using a portable turbidity measurement meter, model

TB 210 IR whereas the pH value of the wastewater was measured by using a pH meter. Turbidity removal, T (%) is defined as follows:

$$\text{Turbidity Removal, T(\%)}=\frac{T_{io}-T_i}{T_{io}}\times 100 \quad (1)$$

where T_{io} is the initial turbidity reading of the wastewater sample while T_i is its turbidity after jar test. Performance of *Cicer arietinum* as coagulant will be evaluated based on its ability to reduce turbidity of the wastewater sample as calculated in Eq. (1).

3.0 Results and discussion

3.1 Effect of Cicer arietinum dosage

Fig. 4 shows the data of wastewater turbidity removal, T (%) as a function of the coagulant dosage. The dosage of *Cicer arietinum* was varied from 8 to 18 mg/L, where the agitation speed and time were fixed to 100 rpm and 1 min, respectively. The data suggested that the highest turbidity removal can be obtained at dosage of 12 mg/L. At this point, 44.07% of turbidity of the wastewater was reduced. Usage of low *Cicer arietinum* dosage (<12 mg/L) has resulted in poor T (%) as at minimal dosage (8 mg/L), only 40.54% of turbidity removal was achieved. This is due to the small amount of coagulant; hence the active ingredient is insufficient to coagulate the suspended solids in the wastewater as this process is aided by the electrostatic patch charge mechanism.

The positive charged of the proteins in the seed bind to the surface of the negatively charged particles or suspended solids (Bhatia et al., 2007). With sufficient agitation, the suspended solids collided and as result, flocs were formed (Gassenschmidt et al., 1995). This process allows the flocs to settle at the bottom of the container by act of gravity. However, increasing the *Cicer arietinum* dosage beyond 12 mg/L did not increase the turbidity reduction significantly. In fact, increasing the dosage to 18 mg/L turns out to be counterproductive. This is mainly due to the excessive amount of coagulant present in the water which contributed to the increment of the water's turbidity. Evidently, 12 mg/L of *Cicer arietinum* was selected as the optimum dosage.

3.2 Effect of stirring speed

Fig. 5 shows the data of turbidity removal, T (%) as a function of stirring speed. The speed for rapid mixing

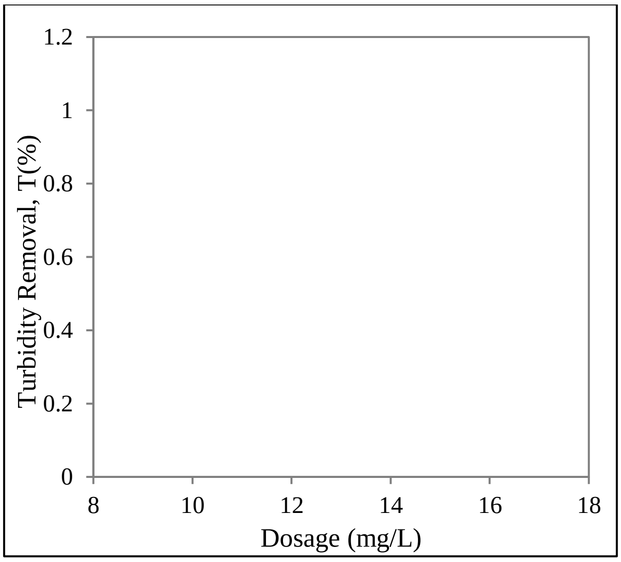

Fig. 4: Effect of *Cicer arietinum* dosage on turbidity removal, T (%).

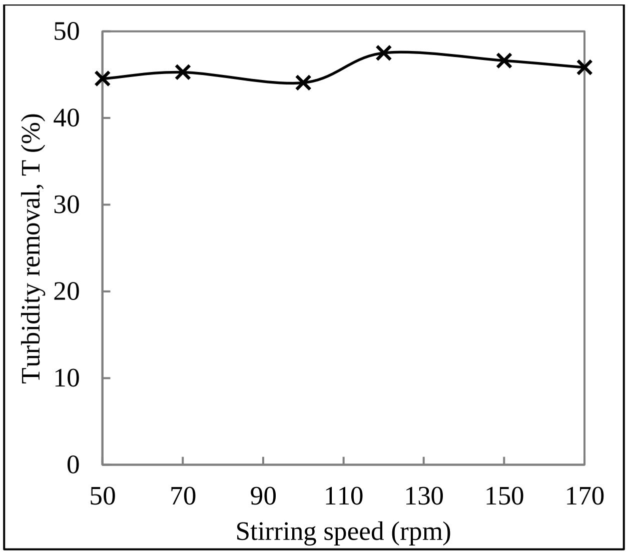

Fig. 5: Effect of stirring speed on turbidity removal, T (%).

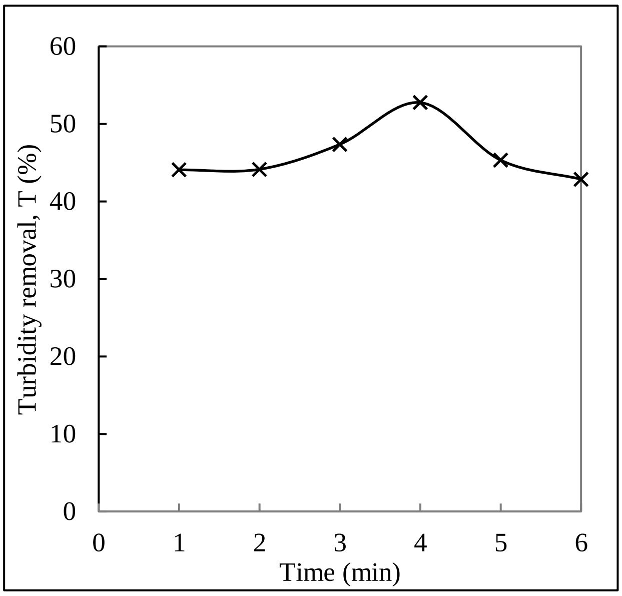

Fig. 6 : Effect of mixing time on turbidity removal, T (%).

was varied from 50 to 170 rpm at which the process took place for one minute. The process was followed by slow mixing at 30 rpm for 3 mins at *Cicer arietinum* dosage of 12 mg/L. The speed of slow mixing and its duration were fixed. Data from Fig. 5 suggested that the best rapid mixing speed is 120 rpm. At this optimal condition, 47.50% turbidity of wastewater was reduced. Setting at low rpm (<100 rpm) has resulted in poor turbidity removal. Ayoub et al. (2014) found that the mixing speed affects flocs size and strength. Sufficiently fast stirring would mix the wastewater and the coagulant well, hence providing high surface area for the coagulation process to take place. However, further increment of the speed has reduced turbidity removal mainly due to the chemical and physical factors of coagulant and different mixing regimes (Vrale et al., 1971). Thus, 120 rpm was selected as the appropriate speed of mixing.

3.3 Effect of rapid mixing time

Fig. 6 plots the data of turbidity removal, T (%) of wastewater as a function of rapid mixing time, using *Cicer arietinum* as coagulant. As shown in the figure, turbidity removal increases together with the duration of rapid mixing but decreases as the time was extended to 6 mins.

In this study, the dosage of Cicer arietinum and the agitation speed were fixed to 12 mg/L and 120 rpm, respectively. Based on the data in Fig. 6, the duration of rapid mixing of 4 mins yields maximum (52.74%) of turbidity removal, T (%). Longer mixing time (>4 mins) has resulted in significant reduction of turbidity removal, T (%) and it reached the lowest at 6 mins where only 42.86% of turbidity removal was recorded. This is probably due to longer mixing time that form much compact aggregates during rapid mixing. This situation resulted in smaller flocs and they were reported to be hard to be removed by sedimentation alone (Clark et al., 1991). On a contrary, shorter mixing time did not benefit the system either. This is because shorter period of rapid mixing provided slightly less probability of more compact aggregates to be formed. Instead, much more open and larger flocs can be found (Yukselen et al., 2004). This type of flocs tends to suspend in the water.

4.0 Conclusions

The recent study worked on the application of *Cicer arietinum* as a coagulant for water clarification. Results obtained showed promising results. Three parameters were looked at; *Cicer arietinum* dosage, stirring time and rapid mixing time. The experimental data shows 52.74% of turbidity was successfully removed coagulant dosage of 12 mg/L. Rapid mixing of 120 rpm for 4 mins was applied.

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