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# Removing Boron from an Aqueous Solution Using Turmeric Extract-Aided Coagulation-Flocculation

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**Abstract: Problem statement:** Boron exists in an environment naturally either through weathering of rocks or volcanic activity but due to anthropogenic activity, boron had been distributed widely into our surroundings. Boron was a problematic pollutant due to the difficulty to remove it from the water. Turmeric which had been widely used as a spice and traditional medicine, were investigated to determine its capabilities to aid in coagulation-flocculation process to remove boron. Optimizing coagulation-flocculation process might be effective to remove boron to a lower concentration. **Approach:** In this study, the optimum parameter for pH, dose of aluminium sulfate (alum) and a dose of turmeric extract were determined by conducting a set of jar test experiment. The coagulation-flocculation process was performed to study the effectiveness of the turmeric extract as a coagulant aid in boron removal. **Results:** The result demonstrated that coagulation-flocculation process with the aid of turmeric extract can remove boron effectively at optimum conditions rather than coagulation-flocculation process without the aid of turmeric extract. The optimum conditions for boron removal were achieved at pH 7, an alum dosage of 18, 367 mg $L^{-1}$ and turmeric extract dosage of 82 mg $L^{-1}$. **Conclusion/Recommendations:** Result showed that removal of boron depends on pH, alum dosage and turmeric extract dosage. The boron removal percentage of the aqueous solution using the coagulation-flocculation process aided by the addition of turmeric extract and without the addition of turmeric extract were 95 and 62%, respectively. In addition, there was a significance difference between both processes. Turmeric extract as a coagulant aid demonstrated promising performance in boron removal and can be used as an alternative treatment to treat boron-containing wastewater.

**Key words:** Turmeric extract, coagulation-flocculation, boron removal

## INTRODUCTION

Boron is widely distributed into our surroundings from various sources. The first element of the group IIIA on the periodic table of elements, boron is a metalloid, while the rest of the elements in group IIIA are metals. Boron does not form binary Ionic compounds and is unreactive toward both oxygen gas and water (Col and Col, 2003). Boron can be found in sedimentary rocks, coal, shale and some soils in the form of borates and it also exists in the environment through the rock weathering, volatilization of boric acid from seawater and volcanic eruption (Emiroglu *et al*., 2010). It also can enter the environment via the discharge of wastewater containing boron from anthropogenic sources and various industries (Coughlin, 1998; Howe, 1998). Boron had been used widely in various industries such as metal welding, pharmaceutical manufacture (Ozturk and Kavak, 2005), ceramic industry (Chong *et al*., 2009), burning wood fuel and glass products manufacture (Emiroglu *et al*., 2010). The concentration of boron in soil and irrigation water is normally low, however boron rapidly accumulates in soil irrigated with wastewater containing boron because of the difficulty of washing the residue out of the soil (Yilmaz *et al*., 2007).

Boron is an essential nutrient for plant growth but in relatively low concentration (Kabay *et al*., 2008). A boron deficiency in plants will result in reduced absorption of potassium, chloride and rubidium; alteration of the plasmalemma of root cells and

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cessation of root growth. Lack of boron also caused abnormalities of the apical meristem, which may be a secondary effect of damage to the plant's vascular tissue (Woods, 1994). As a plant nutrient, boron can form ester borates which are important for building the cell wall structure of certain plants (Camacho-Cristobal *et al*., 2008). However, the boron-poisoning will occur when the amount of boron absorbed exceeds the nutritional concentration that the plant needs; a yellowish spot will appear on the leaves and the fruit of boron-poisoned plant. Drinking water containing boron is suspected to be teratogenic to human health. The concentration of boron in the drinking water that recommended by the World Health Organization (WHO) should be below 0.3 mg boron /L (Cengeloglu *et al*., 2007; 2008). Later, this standard was amended to 0.5 mg/L due to the difficulty encountered in achieving the lower standard in regions with high natural levels of boron. Lately, boron had been classified as a pollutant by European Union (EU) and 1 mg boron/L had been adopted as a standard for drinking water. Therefore, it is inevitable to devise a suitable method to remove as much boron as possible from the water.

Physiochemical and biological treatments have been used widely to remove boron from wastewater. There are several physicochemical treatment, include using ion-exchange (Simonnot *et al*., 2000), adsorption (Alias *et al*., 2011), reverse osmosis (Nadav, 1999), membrane filtration (Mottez *et al*., 1998), electrodialysis (Kabay *et al*., 2008) and electrocoagulation (Yazicigil and Oztekin, 2006; Yilmaz *et al*., 2005; 2008). Biological treatment options include using aquatic plants such as *Caulerpa Racemosa var. Cylindracea* (CRC) (Bursali *et al*., 2009) and duckweed *Lemna gibba* (Marin and Oron, 2007).

Another method commonly used to treat wastewater is a coagulation-flocculation process that involves adding a coagulant such as aluminum sulfate (alum), ferric chloride or Poly-Aluminum-Chloride (PAC). This process has been found to be cost effective, less energy is needed and can be operated easily (Amuda and Alade, 2006). Coagulation acts by destabilizing the boron particle's charges. Coagulants are added to neutralize the negative charges on the colloid. Once the charge is neutralized, the small particles stick together and form microflocs which are not visible to the naked eyes. Meanwhile, flocculation will increase the size of the microflocs to form a visible floc that settles out at the end of the process. The problem with this process is that can be influenced by the nature of the water, temperature, pH, types and dose of the coagulant used, intensity and duration of the rapid mixed (Rossini *et al*., 1999).

Turmeric had been applied in traditional medicine to treat jaundice and liver problem, ulcers, skin problem, cold and flu symptoms. Turmeric also can act as an antimicrobial in food preservation. The effect of the presence of *Curcuma longa* powder in Tamarindus indica and Garcinia atroviridis solutions was indicated by the decreasing of aluminium solubility in food preparation was reported (Halim *et al*., 2011a). Adsorption studies of aluminium on *Curcuma longa* also was carried out by Halim *et al*. (2011b).

Turmeric was prepared from the rhizomes of the *Curcuma longa*, a plant that belongs to the *Zingiberaceae* family (Jayaprakasha *et al*., 2005). Curcumin (diferuloylmethane) is an active principle of the perennial *Curcuma longa* herb and is the major component in turmeric. The yellow pigment of the turmeric contains curcuminoids and consists of three major constituents: Curcumin I (curcumin), Curcumin II (demethoxycurcumin) and Curcumin III (bisdemethoxycurcumin) (Goel *et al*., 2008). Curcumin is an acid-base indicator where at pH 2.5-7.0, a brilliant yellow hue will appear while a red hue will appear at pH>7.0 (Goel *et al*., 2008). Rosocyanine which is a red-colored compound will form when curcumin reacts with boric acid (Akram *et al*., 2010). In acidic solutions, a 2:1 curcumin-acid boric complex will form. Curcumin also can be classified as a chelating agent due to the present of 1,3-diketone structure. The aim of this study is to investigate the feasibility of removing boron from an aqueous solution by the alum coagulation-flocculation process, aided by the addition of *curcuma longa* extract.

## MATERIALS AND METHODS

The boric acid solution (50 mg $L^{-1}$) and alum (100,000 mg $L^{-1}$) was prepared. The turmeric extract was prepared from fresh turmeric. Sodium hydroxide (NaOH) and hydrochloric acid (HCl) were added to the solution to adjust the pH. The Carmine method, adapted from the Standard Methods for the Examination of Water and Wastewater (Eaton and Franson, 2005) was used to determine the actual concentration of boron between the detection limits of 0.2-14.0 mg $L^{-1}$. Optimum parameters such as the pH of the mixture, the dose of alum and the dose of turmeric extract were determined in order to maximize the coagulation-flocculation process.

A jar test was performed with 1 min of the rapid mix at 80 rpm, 30 min of slow mix at 20 rpm and 30 min of settling period. The data were collected and the test was repeated three times.

**Optimum pH:** The range of pH that was chosen for this study ranged from 6.0 - 11.0. Six beakers (n = 6) with 400 mL of boron solution were prepared. 90 mL of alum solution was added to each beaker. In the coagulation-flocculation process aided by turmeric extract, 5 mL of turmeric extract was added to each beaker. After a 30 min settling period, the final concentration of boron from each beaker will be determined.

**The optimum dose of alum:** A jar test was performed by varying the dose of alum within a range from 50-100 mL. Six beakers (n = 6) with 400 mL of a pH 7 boron solution were prepared. In the coagulation-flocculation process with the aid of turmeric extract, 5 mL of turmeric extract was added in each beaker. After a 30 min settling period, the final concentration of boron from each beaker will be determined.

**The optimum dose of turmeric extract:** Six beakers (n = 6) with 400 mL of boron solution were prepared. The turmeric extract that was added to each beaker ranged from 2-12 mL. The pH of the boron solution was adjusted to achieve pH 7 and then 90 mL of alum was added to each beaker. After a 30 min settling period, the final concentration of boron from each beaker will be determined.

## RESULTS

The percentage of boron removed and the optimum parameters of coagulation-flocculation process with and without the aid of turmeric extract have been compared in this study.

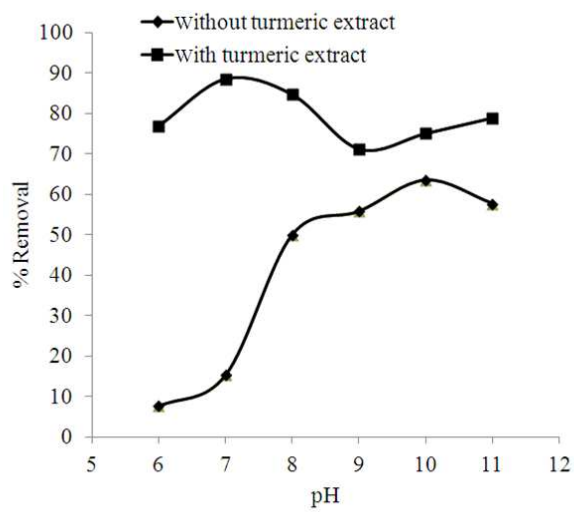


Fig. 1: Effect of pH on the effectiveness of removing boron

**The effect of the pH:** The optimum pH of the coagulation-flocculation process with and without the aid of the turmeric extract was pH 7 and pH 10, respectively. The result demonstrated that percentage of boron removed was 88% for pH 7 (with turmeric extract added) and 63% for pH 10 (without the addition of turmeric), as shown in Fig. 1.

**The effect of the dose of alum:** Optimum dose of alum to remove boron using the coagulation-flocculation process with and without the aid of turmeric extract was 18 367 mg $L^{-1}$; the percentage of boron removed was 76 and 73%, respectively, as shown in Fig. 2.

**The effect of the dose of turmeric extract:** The optimum dose of turmeric extract obtained from coagulation-flocculation process to remove boron was 82 mg $L^{-1}$, where the percentage of boron removed was 80%, as shown in Fig. 3.

**Comparison between the coagulation-flocculation process with and without the aids of turmeric extract:** By applying the optimum parameters that had been obtained in this studied (pH 7, 18,367 mg $L^{-1}$ dose of alum and 82 mg $L^{-1}$ dose of turmeric extract), we had compared the boron removal between coagulation-flocculation process with and without the addition of turmeric extract. The result had demonstrated as stated in the Table 1.

Table 1: The comparison between results from the coagulation-flocculation process with and without the assistance of turmeric extract

| | With the addition of turmeric extract | Without the addition of turmeric extract |
|---|---|---|
| Mean of percentage of boron removed | 95% | 62% |
| Optimum parameters: | | |
| pH | pH 7 | pH 7 |
| Dose of alum | 18,367 mg $L^{-1}$ | 18,367 mg$L^{-1}$ |
| Dose of turmeric extract | 82 mg $L^{-1}$ | - |

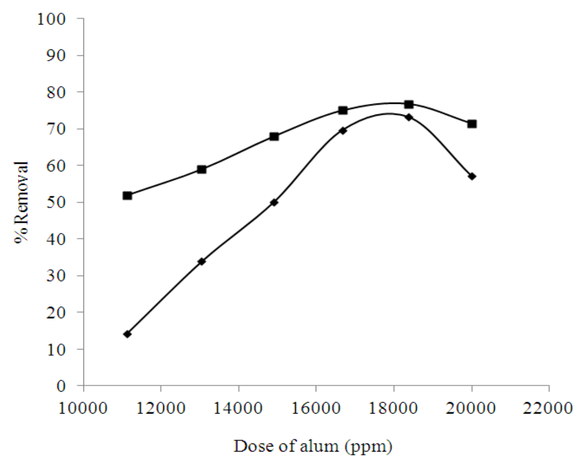


Fig. 2: Effect of the size of the dose of alum on the effectiveness of removing boron

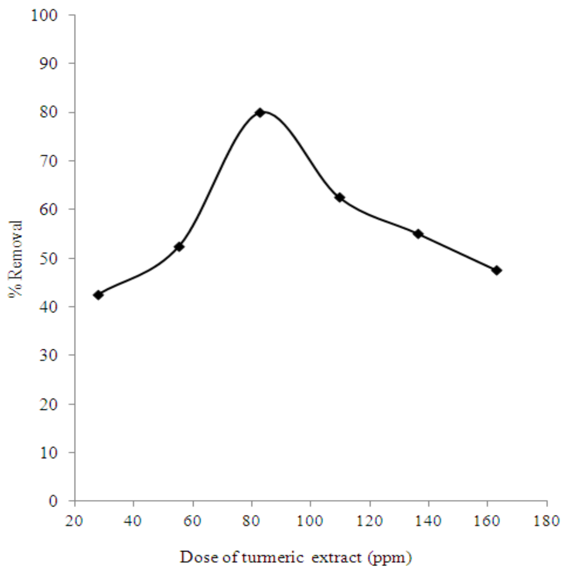


Fig. 3: Effect of the size of the dose of turmeric extract on the effectiveness of removing boron

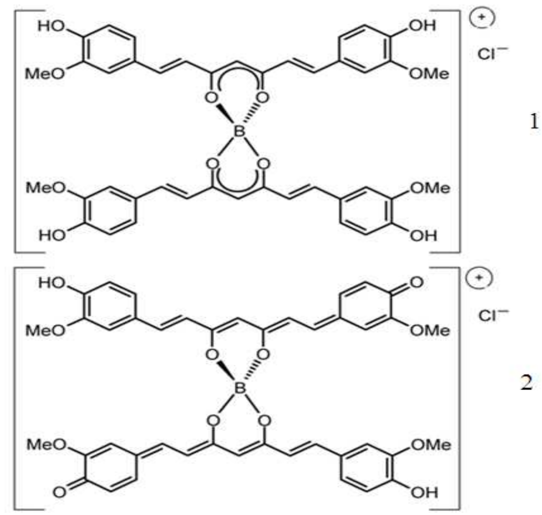


Fig. 4: Structure of the curcumin-boron complex (rosocyanine)

## DISCUSSION

The percentage of boron removed and the optimum parameters of coagulation-flocculation process with and without the aid of turmeric extract had been compared and discussed in this study.

**The effect of the pH:** The pH level is one of the important factors that affect the performance of the coagulation-flocculation process (Ayguna and Yilmaz, 2010) since it controls the hydrolysis species (Camacho-Cristobal *et al*., 2008). However, different coagulants will have different zones of pH where the coagulant will become more effective in removing the colloidal particle and producing a good coagulation-flocculation process. For an example, alum will become more effective when the solution falls within the pH range from 6.5-7.5.

**The effect of the dose of alum:** Aluminum-based and ferric-based hydrolyzing metal salts are widely used as coagulants in the treatment of water (Gregory and Duan, 2001). In this study, alum was added to the water and formed aluminum hydroxide floc, a gelatinous precipitate. By adding alum to the solution, positively charged aluminum hydroxide formed and neutralized the negative charges of the particles in the solution, thus reducing the electrostatic force between particles. When the electrostatic force was reduced, the particles agglomerated and formed a larger floc that was easily removed from water.

In this studied, there was a slightly different in the percentage of boron removal which might due to the addition of the turmeric extract in the process.

**Effect of the dose of turmeric extract:** In this study, turmeric extract was used as an aid to the coagulant. By enhancing the agglomeration of the particle to form a larger and heavier floc, the turmeric extract increased the percentage of boron removed. Curcumin, which is one of the constituents in turmeric, can react with the boron in the solution to form a curcumin-boron complex that is known as rosocyanine, as shown in the Fig. 4.

**Comparison between the coagulation-flocculation process with and without the aids of turmeric extract:** Comparison of the coagulation-flocculation process with and without the aid of turmeric extract had been studied and by using statistical analysis where an independent T-test had been applied, the result showed that the p value was less than 0.05 ($p<0.05$). Thus, there was a significant difference between the coagulation-flocculation process with and without the aid of turmeric extract, where the percentage of boron removed was 95 and 62%, respectively (as shown in Table 1). The coagulation-flocculation process with the aid of the turmeric extract removed the highest percentage of boron, due to the production of the curcumin-boron complex that known as rosocyanine, thus increasing the removal of boron.

## CONCLUSION

Optimum parameter determined in this study was pH 7, the dose of alum at 18,367 mg $L^{-1}$ and dose of turmeric extract at 82 mg $L^{-1}$. The coagulation-flocculation process, aided by the addition of turmeric extract, removed a higher percentage of boron than the coagulation-flocculation process without the addition of turmeric extract. The mean of the percentages of boron removed were 95 and 62%, respectively.

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