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TURBIDITY REMOVAL FROM SURFACE WATER USING *Tamarindus indica* CRUDE PULP EXTRACT

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ABSTRACT
Plant-based coagulants are potential alternatives to chemical coagulants used in drinking water treatment. This paper examined the turbidity removal efficiency of Tamarindus indica fruit crude pulp extract (CPE) towards evaluating a low-cost option for drinking-water treatment. Laboratory analysis was carried out on high turbidity raw water samples (i.e. 478 NTU) using T. indica CPE of concentrations ranging from 500 to 3000 mg/L as natural coagulant, using jar tests. Results obtained showed turbidity removal efficiency of the coagulant ranging from 64 to 99%. An optimum dose of 3000 mg/L resulted in highest turbidity removal efficiency of 99%. However, the treated water samples were observed to be of high acidity with pH values lower than 3.0, suggesting the need for pH adjustment. Nevertheless, this study demonstrated the potentials of T. indica CPE in coagulating high turbidity surface water.
Keywords: Coagulation; crude pulp extract, pH, turbidity removal, T. indica

INTRODUCTION

Conventional water treatment systems involve the use of synthetic chemicals. Such chemicals are mostly imported into developing countries (Barnes *et al.*, 1984; Peavey *et al.*, 1985; Rangwala, 2007) at relatively high cost (Muyibi, 2005). Considering the potential health risks associated with these chemicals (Muyibi, 2005; Peavey *et al.*, 1985), it is imperative to search for cheaper ways and substances that can alternatively be used in place of these chemicals while maintaining acceptable coagulation potential and/or microbiological quality, and consequently eliminating the risks involved in using synthetic chemicals (Diaz. *et al.*, 1999).

Natural materials from plants, animals and geological formations have been used in water treatment long before the advent of synthetic chemicals such as aluminum and iron salts (Ndabigengesere and Narasiah, 1998). However, lack of knowledge on the exact nature and mechanism by which these natural materials work has hindered their wide spread application, due to lack of clear information on socio-economic acceptability of such natural materials (Kalibbala, 2007; Marobhe 2008).

In the last three decades, there has been a renaissance of interest in the subject of using natural materials for water treatment to provide safe drinking-water to rural and peri-urban communities in developing countries. Recently, many natural substances have been studied and found to be promising in water purification, apparently because they are safe, locally available, relatively cheap, biodegradable (Shiong, 2007), and can serve different purposes. For instance, *Moringa oleifera* seeds have been used by the rural people of Sudan and Malawi to clarify turbid water (Jahn and Dirar, 1979). Since that time, intensive researches have been conducted to evaluate the use of extract of *M. oleifera* as natural coagulant in water treatment (Muyibi and Okuofu, 1995; Ndabigengesere *et al.*, 1995; Ghebremichael *et al.*, 2005). Other natural materials were also appraised by many researchers to evaluate their potentials in water treatment.

These include chitosan (Bina *et al.*, 2009), wood ash (Jahn and Dirar, 1979; Jahn, 1988), nirmali and okra (Al-Samawi and Shokralla, 1996), *Azadirachta indica* (neem) and *Luffa cylindarica* (Bhattarai *et al.*, 2009), neem oil (Templeton *et al.*, 2009), *Cactus latifera* (Alcantar *et al.*, 2012), powdered roasted grains of maize (Rao, 2005), etc. The potentials of these natural materials in water purification were evaluated and documented, and found to be good coagulants, coagulant aids and/or disinfectants; some were even found to be very useful in hard water softening like *M. oleifera* (Muyibi and Okuofu, 1996). Nonetheless, so many natural materials that are used by people in rural communities to purify water are yet to be discovered and studied, and among these natural materials is *Tamarindus indica*. Based on personal experience, crude concentration of tamarind pulp was traditionally used to clarify high turbid water in some areas of north-western Nigeria between late 1970 and early 1980. Bhole (1995) also reported the discovery of the use of *T. indica* in water purification by the rural people of north-eastern Nigeria, but the performance of *T. indica* has not been fully examined to discover its potentials in water treatment. Therefore, this paper evaluated the turbidity removal efficiency of *T. indica* CPE from surface water.

MATERIALS AND METHODS

Tamarind Pulp Extract

Fully matured and ripe Tamarind fruits were collected from country side Tamarind tree in Kano, Nigeria. Tamarind pulp powder was prepared by manually decorticating and pulverizing, drying and milling the fruit pulp to the possible finest size of the creamy pulp powder. Crude pulp extracts (CPEs) were then prepared from the powder between 0.5 to 5% solution (w/v) by dissolving the powder in distilled water and filtering the solution through muslin cloth and Whatman type A glass fiber filter paper to obtain CPEs and more refined CPEs, respectively (Ali *et al.*, 2009).

Water Samples Collection

High turbidity water samples (i.e. 478 NTU) used for the experiments were collected under turbulent condition from the side of the embankment of Kubanni Reservoir, Ahmadu Bello University (ABU) Zaria, Nigeria. The samples were manually collected in the morning between 09:30 – 10:30 in a 5 L plastic container, using grab sampling technique.

Jar Test

The effect of varying physical parameters on coagulation of the high turbidity water with the *T. indica* CPEs was evaluated using a jar test with the aid of a Flocculator (Paterson Candy, London, UK). Six 800 mL capacity Pyrex glass beakers were filled each with 500 mL of raw water, with another beaker serving as a control. The experimental beakers were dosed each with *T. indica* CPEs, with concentrations of 0.5, 1.0, 1.5, 2.0, 3.0 and 5.0% w/v, respectively. All measurements were conducted in duplicates.

The water samples in the beakers were mixed with the aid of the jar test flocculator at a high speed of 100 rpm for 60 s, to ensure complete dispersion of the coagulant added. Subsequent gentle and prolonged mixing at 10 rpm for another 15 min was employed to aid flocs formation. The solution was then allowed to stand for 30 min to allow the flocs to settle to the bottom. The residual turbidity of the supernatant was then measured using 2100N Turbidimeter. The jar test was conducted according to *Standard Methods* (i.e. APHA, 1999).

Turbidity Measurement

Initial and residual turbidity values of the water samples before and after coagulation were measured in nephelometric turbidity units (NTU) using 2100N Turbidimeter (HACH, Colorado, USA) in duplicates. The initial turbidity of the raw water was measured after thorough agitation of the collected water samples while residual turbidity measurements were carried out on the supernatant of the coagulated water after allowing it to settle in a near quiescent condition, after the jar test (APHA, 1999).

pH Measurements

The pH of the raw water and coagulated water samples was measured in duplicates using a pHS-25 pH Meter (Shanghai Jingke Rex, China) using electrometric method (APHA, 1999).

RESULTS AND DISCUSSION

Residual turbidity values of the raw water coagulated with *T. indica* CPE are shown in Figure 1.

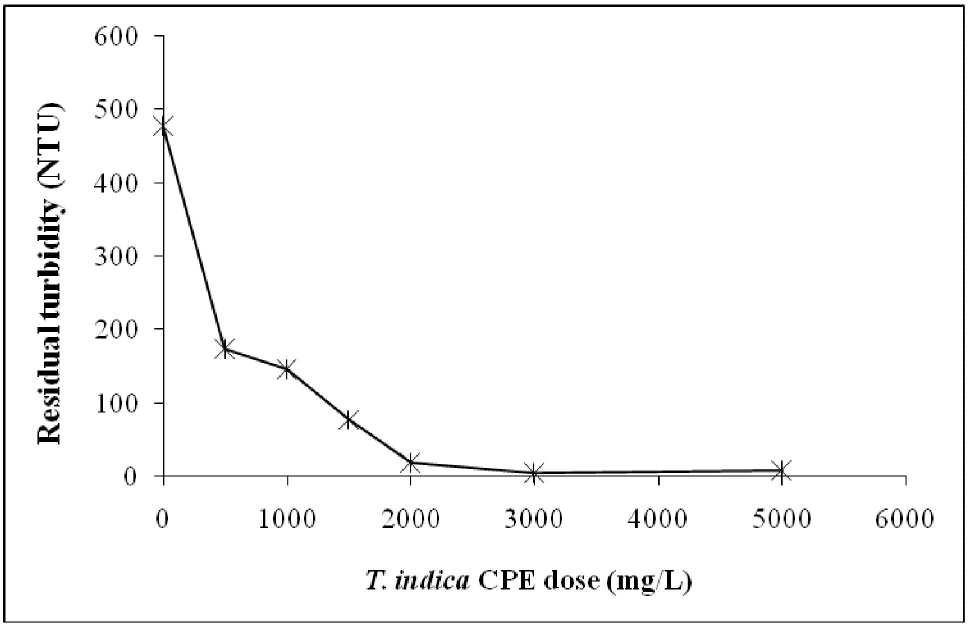

Figure 1: Variation of *T. indica* CPE dose with residual turbidity of the raw water

The residual turbidity of the raw water decreases with increase in the *T. indica* CPE concentration up to 3000 mg/L after which further increase in the CPE concentration resulted in no further decrease in the residual turbidity (Figure 1). The CPE dose of 3000 mg/L was achieved at a residual turbidity of about 5 NTU. This CPE dose appears to be the optimum for coagulating the raw water. In Figure 2, the *T. indica* CPE concentration increases with increase in turbidity removal efficiency up to a maximum of 99%. This value of 99% turbidity removal efficiency was achieved at *T. indica* CPE dose of 3000 mg/L (Figure 2). The turbidity removal efficiencies are significantly different at 5% level (p = 0.02). Interestingly, the residual turbidity at which this optimum dose was achieved is within the recommended value for drinking-water quality (i.e. 5 NTU; WHO, 2011). This implies that with appropriate disinfection, if need be, the treated water is suitable for human consumption.

Moreover, further increase in the coagulant dose above 3000 mg/L resulted in no additional turbidity removal from the raw water. Increasing the CPE dose above 3000 mg/L would have resulted in the wastage of the coagulant as no considerable effect would be recorded. As such, 3000 mg/L of *T. indica* CPE appears to be the optimum dose for removing turbidity from the raw water used in the current study. However, coagulant dose of up to 3000 mg/L seems high when compared to the dose of conventional coagulants such as aluminium sulphate (alum) with typical values lower than 100 mg/L reported in the literature (e.g. Baghvand *et al.* 2010). Consequently, the *T. indica* CPE dose obtained in the current study cannot be directly compared to those reported by previous studies on similar naturally occurring materials considered as potential coagulants in drinking-water treatment. Nevertheless, one possible reason for achieving the high value of *T. indica* CPE dose might be that the constituents active in the coagulation process in this coagulant are less soluble in water than those available in alum. In addition, the percentage composition of Al^{3+} in alum might be higher than the active ingredients in *T. indica*. As such, there is need for further optimization study on the use of *T. indica* for turbidity removal from surface water.

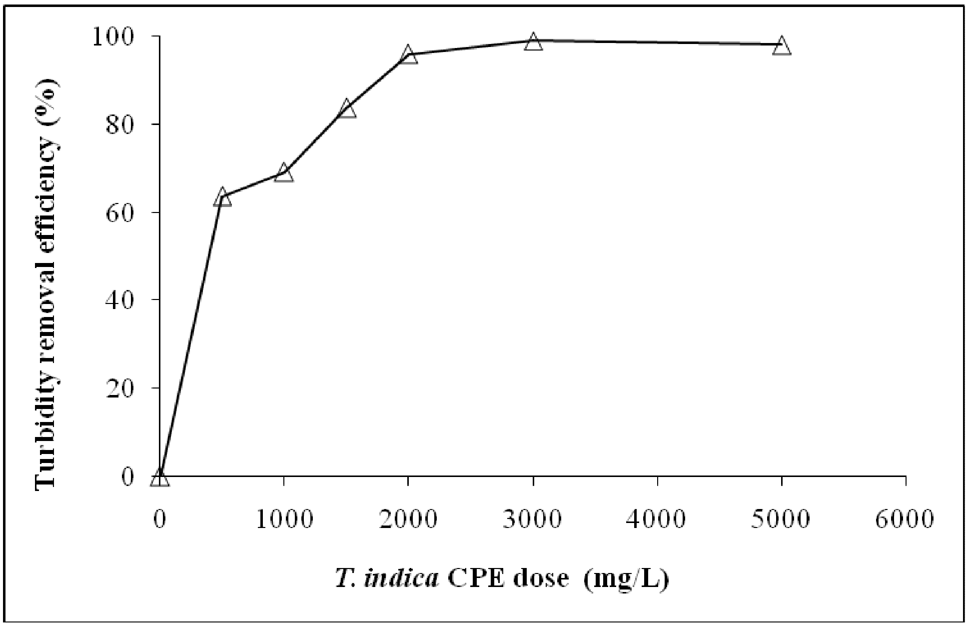

Figure 2 Variation of *T. indica* CPE dose with turbidity removal efficiency of the raw water

The pH values for the treated water samples are shown in Figure 3. It can be seen that the pH value observed at optimum dose is lower than 2.5 (Figure 3). For water to be suitable for human consumption, WHO (2007) reported a pH range of 6.5 to 8.5 as the optimum commonly found in drinking-water. Although WHO (2011) has not reported any health concerns with respect to pH in drinking-water, however, pH values lower than 2.5 can cause irreversible and extensive damage to epithelium in humans. Therefore, it is strongly recommended that water treated with *T. indica* CPE should be subjected to pH adjustment, preferably to within the optimum range reported by WHO (2007).

Noteworthy, Natrona, as a locally available naturally occurring material, could be used to achieve the recommended pH adjustment (Sa'id *et al.*, 2014). This will help in adjusting the pH of the treated water to near neutral and making it suitable for human consumption. With appropriate disinfection, where necessary, *T. indica* CPE has the potential of removing turbidity from surface water. Therefore, this material can be used to remove colloidal and dissolved solids from surface water at small scale such as household level, especially in developing countries.

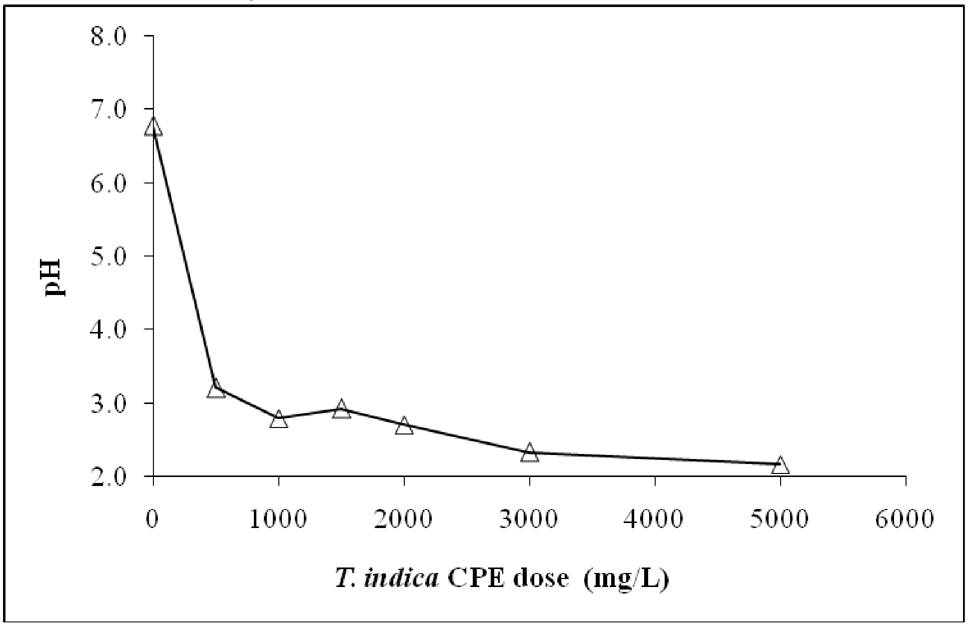

Figure 3: Variation of *T. indica* CPE dose with pH of the raw water

CONCLUSION

T. indica fruit pulp extract has been efficiently used as a natural coagulant in the treatment of high turbid water, and the extract can be prepared relatively easily at ambient temperature without distorting its coagulation potentials. Its use for turbidity removal achieved up to 99% efficiency, though the treated water needs to undergo pH adjustment and confirmatory tests for bacteriological analysis prior to human consumption. Therefore, the use of *T. indica* for turbidity removal in high turbid water can serve as a low-cost option for water purification, especially at household level.

Conflict of Interest

We confirm that there is no conflict of interest between the authors of this paper.

Contributions of Authors

Sa,id, S. designed and carried out the experimental work and drafted the manuscript. Mohammed, K. re-plotted some of the figures, conducted statistical analysis, and reviewed the manuscript; whereas Adie, D. B. and Okuofu, C. A. edited and reviewed the manuscript.

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