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Evaluating Moringa Oleifera, Papaya, and Pumpkin Seed as a Natural Coagulant

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Abstract: **There are increasing interests in utilizing natural coagulants in water purification due to the drawbacks associated with the use of chemical coagulant. This study evaluated three different natural seed materials (Moringa oleifera, Papaya, and Pumpkin) and alum for their coagulation efficacy in turbid water. A series of jar test was performed to determine optimal dose of individual coagulant and effect of settling time on the turbidity reduction. Two natural coagulants (moringa and papaya seeds) performed very well showing turbidity reduction up to 92-94 % compared to alum (92 %) when coagulating a canal water that has initial turbidity at 390 nephelometric turbidity units (NTU). The performance of pumpkin seed was relatively poor (< 79 % turbidity reduction). The optimal dose of all seed materials was found to be at 1 g L^{-1} while alum has the optimal dose at 40 mg L^{-1}. Our results suggested that moringa and papaya seeds could be effective natural coagulant for surface water and they would require further filtration step to separate seed material residues as well as nutrients and bacteria associated with them.**

Keywords: **Alum, coagulant, jar test, seed material, settling, turbidity.**

I. INTRODUCTION

Water covers 71 % of Earth's surface but freshwater contributes to only a minor fraction of 2.8 % (Hudson, 2016). Fresh water is critical to an array of global challenges from health, to malnutrition, poverty, and sustainable natural resources management. More than 60 billion m^3 of freshwater is needed every year to cope with the annual global population growth of 75 million people (Choy et al., 2014). According to the United Nations International Children's Emergency Fund (UNICEF), 783 million people worldwide do not have access to safe drinking water (Hutton, 2013). The lack of access to safe drinking water combined with poor personal hygiene causes massive health impact such as diarrhoeal disease, which was estimated to kill around 760,000 children under five every year worldwide (Pruss et al., 2002; Parashar et al., 2003).

Surface water drawn for human consumption can be highly turbid particularly during and after storm events. Sediment loss to the river by runoff and suspended solids from the bottom of river often contribute to the high level of turbidity in the water, which may contain colloidal particles, natural organic matter, pathogen and other soluble inorganic compounds in different concentrations (Zouboulis and Traskas, 2005). Therefore, when surface water is intended for human consumption, it is essential to remove suspended solids and reduce turbidity. Coagulation-flocculation followed by sedimentation, filtration and disinfection is commonly used in the water treatment industry before the distribution to consumers (AWWA, 1990).

Most of fine suspended solids in natural waters are negatively charged and they are stabilized due to mutual electrical repulsions (Duan and Gregory, 2003). Coagulation step involves adding cations that can neutralize the negative charges from colloidal materials. Colloids are small suspended particles that is very slow to be settled due to their light weight and stability (Baghvand et al., 2010). These particles pose some degree of stability and cause turbidity (cloudiness) in water.

Aluminum salts (alum) is by far the most widely used coagulant in water and wastewater treatment. However, alum may not be commonly available at considerable cost in many developing countries. Other concerns over the presence of residual aluminum in drinking water such as Alzheimer's disease and reduced water disinfection efficacy are found elsewhere (Driscoll and Letterman, 1995; McLachlan et al., 1996). An alternative is the use of natural coagulants that can be sourced locally at affordable price.

In this study, we selected three plant-based natural coagulants (Moringa oleifera seed, papaya seed, and pumpkin seed) based on previous review paper (Choy et al., 2014) and evaluated their coagulation efficacy under controlled conditions. The objectives of this study were to 1) determine optimal dose of natural coagulants in reducing turbidity in natural surface water, 2) compare their coagulation efficacy relative to a chemical coagulant (alum), and 3) to determine turbidity reduction affected by settling time.

II. MATERIALS AND METHOD

A. Seed material and turbid water:

Seed materials in this study (Fig. 1) were obtained locally except Moringa oleifera seed (referred to Moringa seed hereafter), which was purchased from online vendor. All seed materials were washed thoroughly with tap water and oven-dried at 105° C for 24 h. Dried seed materials were pulverized into a powder form using a coffee grinder. Ground seed materials were stored in a closed plastic bottle before use.

Figure 1. Seed materials: (a) Moringa oleifera, (b) Papaya, and (c) Pumpkin

B. Coagulation jar test:

Water sample in this study was collected from irrigation canal at Mission, Texas, USA. Collected water (Table 1) was measured for pH and electrical conductivity (EC) using a pH/EC meter (ExStik II, Extech Instruments Corp., Nashhua, NH, USA), and analyzed for total alkalinity, calcium hardness, and total hardness using a water testing kit (K-1741 Professional Complete kit, Taylor Technologies, Inc., Sparks, MD, US A). For turbidity measurement, NEP 260 turbidity probe (McVan Instruments, Melbourne, Australia) was used throughout this study and its initial turbidity was 390 nephelometric turbidity units (NTU).

Table 1. Physicochemical parameters for the turbid water

Parameter	Value
Total alkalinity	130 ppm
Calcium hardness	160 ppm
Total hardness	370 ppm
pH	7.1
Turbidity	390 NTU

Coagulation jar test began with determining optimal dose (concentration) of individual seed materials prepared. The powder form of seed materials was added to 500 mL of the canal water in a 1-L beaker at 0 (control), 1, 2.5, and 10 g L^{-1} (*w/v*). In each batch, four beakers for each of the seed materials were placed in a floc tester (ET 370 flocculator, Tintometer GmbH, Dortmund, Germany). For the mixing, we employed a fast agitation at 200 rpm for 2 minute followed by a slow mixing at 40 rpm for 10 minutes. After the mixing, the samples were left stagnant for 10 min and the turbidity and pH were measured at 1-min, 5-min and 10-min settling marks. Another batch was prepared for alum (Aluminum

Potassium Sulfate Dodecahydrate solution at 10 % (*w/v*) (Ricca Chemical Company, Arlington, TX, USA) and it was dosed at 0, 4, 10, 20, and 40 mg L^{-1}. Identical mixing and settling scheme were used for the alum coagulation.

III. RESULTS AND DISCUSSION

A. Turbidity affected by seed material:

Initial turbidity before flocculant addition (control) ranged from 318 ± 15 (mean ± std. error) to 487 ± 13 NTU depending the prepared samples (Fig. 2). At 10-min mark of settling followed by aforementioned fast and slow mixing, seed material dose at 1 g L^{-1} reduced turbidity the most (< 100 NTU) in all treatments. The lowest turbidity was observed with papaya (27 NTU) followed by moringa (36 NTU) 1 g L^{-1}. At higher dose (2.5 and 10 mg L^{-1}), turbidity increased with increasing dose with the highest turbidity increase up to 1600 NTU in Moringa seed. The turbidity of papaya showed the least fluctuation (99-233 NTU) from control.

Alum was very effective in reducing turbidity (Fig. 3). The final turbidity after 10-min settling ranged from 21 to 57 NTU, with decreasing turbidity with increasing dose. By comparing seed materials to alum, papaya seed (27 NTU) and moringa (36 NTU) at 1 g L^{-1} was comparable to the alum at 40 mg L^{-1}. Coagulation with alum reduced pH in the tested water substantially below 4.8. Alum solution are acidic and metal coagulants such as aluminum and ferric compounds require attention to pH conditions and consideration of alkalinity level in the raw and treated water (Ravina and Moramarco, 1993). Coagulation with seed materials did not substantially change the water pH (6.5 to 7.3, data not shown).

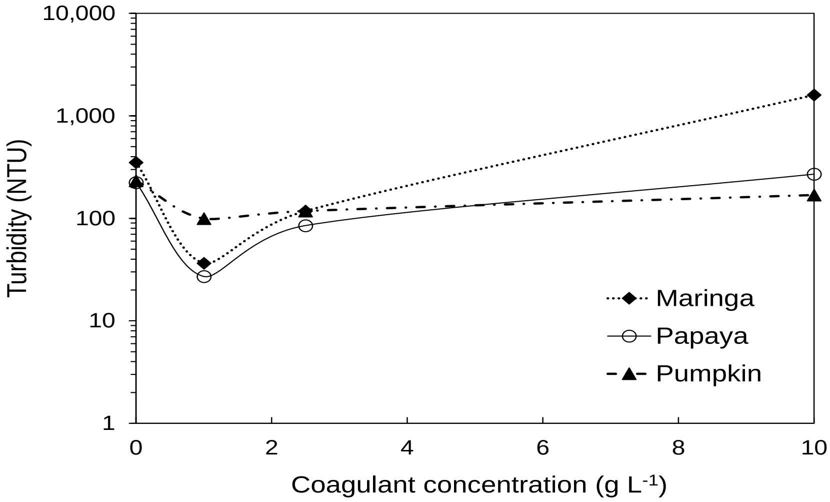

Figure 2. Turbidity affected by natural seed coagulant concentration. Note a logarithmic scale on Y-axis

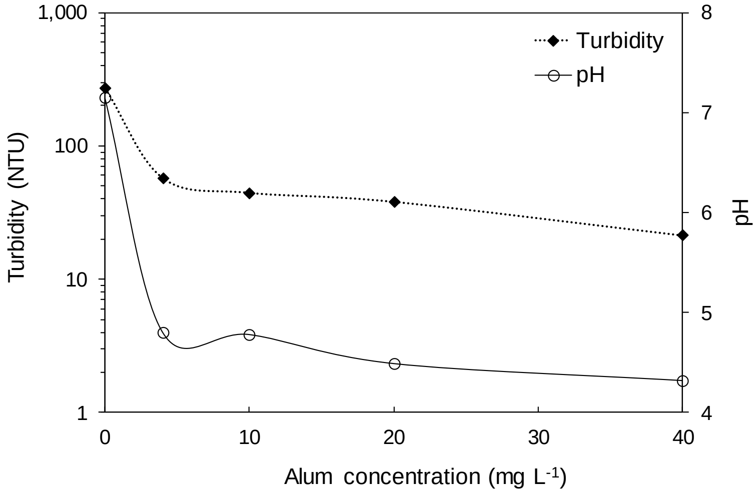

Figure 3. Turbidity and pH affected by alum concentration. Note a logarithmic scale on Y-axis

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B. Turbidity affected by settling time:

Based on the optimal doses of natural coagulant (1 g L^{-1}) and alum (40 mg L^{-1}), their turbidity reduction relative to control (390 ± 26 NTU) over time is presented in Fig. 4. At 1-min settling mark, alum reduced turbidity up to 80 % while seed coagulants showed 43-67 % of turbidity reduction. At 5-min settling mark, moringa and papaya showed turbidity reduction (82-85 %) comparable to alum (88 %) and their turbidity reduction was converged to 92-94 % at 10-min mark. These results suggested that alum resulted in the quickest turbidity reduction (within 1 min) but the turbidity reduction by moringa and papaya became equally effective when longer settling time was allowed (e.g., 10 min). Pumpkin seed appeared to perform well at 1-min mark (67 %) but there were not much turbidity reduction (74-79 %) afterward. It is important to note that the color of water samples was affected by the original color of seed materials (Fig. 5). For example, the water sample treated with moringa seed was showed much lighter color. Also, there were floating residue in all samples treated with seed materials, which necessitates filtering step to separate the residues.

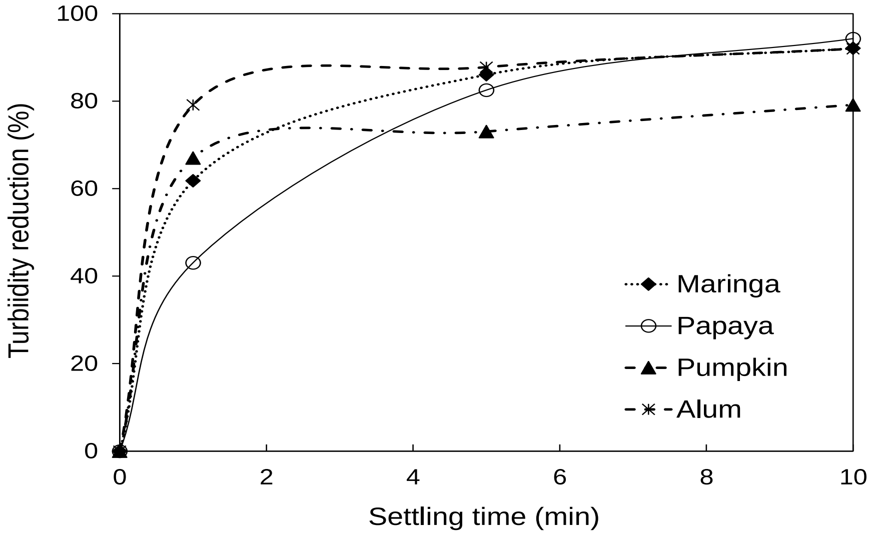

Figure 4. Turbidity reduction affected by settling time

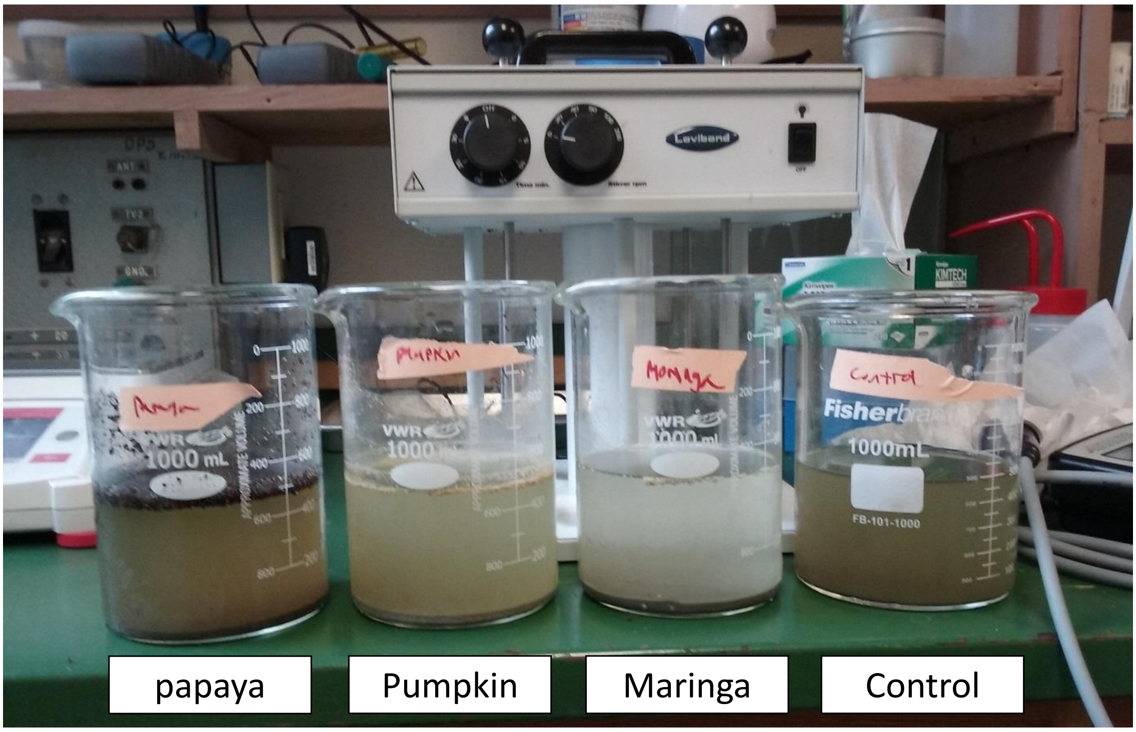

Figure 5. Water sample treated with natural seed materials after coagulation test

IV. CONCLUSION

The application of natural materials for clarifying turbid waters of rivers is an ancient and home-based practice in tropical developing countries where these natural materials act a primary coagulants. In this study, a powder form of moringa and papaya seeds showed a coagulating ability comparable to alum. *Moringa oleifera* is a tropical plant in which seeds contains an edible oil and a water soluble extract that has a coagulating property (Sutherland et al., 1994). Previous studies (Gassenschmidt et al., 1991; Ndabigengesere et al., 1995) reported that the active agents of coagulation in moringa are dimeric cationic proteins that has molecular weight of approximately 13 kilodaltons (kDa) having an isoelectric point between 10 and 11. Our study showed that a powder form of moringa seed dosed at 1 g L^{-1} showed up to 92 % turbidity reduction comparable to alum in a natural water that had initial turbidity of 390 NTU. However, it was notable that dose greater than 1 g L^{-1} increased its turbidity in the tested water, indicating a stabilization of colloidal solution.

In previous studies (Egila et al., 2011; Choy et al., 2014), papaya seed has been found to be effective in removing heavy metals such as lead and manganese with benefit in reducing turbidity. In our study, its coagulating ability was as effective as moringa and alum, resulting in 94 % of turbidity reduction dosed at 1 g L^{-1}. It was notable that papaya did not pose severe stabilization as much as moringa seed. Overall pumpkin seed showed some turbidity reduction (< 79 %) and it was not as effective as Moringa and pumpkin seed materials. Plant coagulant seeds are often rich in nutrients which may enter into the water and possibly serves as a substrate for bacterial growth. Thus, it is necessary to employ filtration step (e.g., sand filter) to retain nutrients and bacteria associated with the seed materials.

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