Asian Journal of Chemistry; Vol. 29, No. 6 (2017), 1235-1239

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2017.20442

Alternative Approach for Water Treatment by Using Natural Coagulants

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Received: 12 December 2016; *Accepted*: 7 March 2017; *Published online*: 10 April 2017; AJC-18332

The main purpose of this work is to determine the appropriateness of natural coagulants like *Moringa oleifera* (seed), *Solanum incanum* (seed), *Acacia catechu* (tannin) as an alternative and low-coist purification method in improving of water quality in terms of turbidity, total dissolve solid, pH and chemical oxygen demand. Residual turbidity was decreases up to 3.2 NTU with optimum dosage of 5 mL/L *Solanum incanum* extracts. Total dissolved solids (TDS) was reduced to 343 mg/L for optimum dose of 4 mL/L of tannin extract, it was observed that pH of pond water decreases with increases of coagulants dose except *Acacia catechu* (tannin extract). Chemical oxygen demand (COD) of raw water sample was reduced to 31.8 mg/L from initial turbidity 34 mg/L with optimum dose of *Moringa oleifera* extract. It was concluded that each coagulants has a potential to purify water and coagulant is biodegradable, eco-friendly and non-toxic.

Keywords: Natural coagulants, Tannin, Turbidity, Total dissolved solids, Chemical oxygen demand.

INTRODUCTION

Water is one of the most abundant and important gift of nature in this blue planet. It is essential for survival and maintenance of life. The rural population of India comprises more than 700 million people residing in about 1.42 Million habitations spread over 15 diverse ecological regions. It is an enormous challenge providing drinking water to such a large population. Our country is also identified by socio-economic development, non-uniformity in level of awareness, poverty, education, practices and rituals which add to the complexity of providing clean water [1].

The poor water quality adversely affects the human health. Reports suggest that about 37.7 million people of India affected by water borne disease and 1.5 million children are died alone due to diarrhea. In recent year's water pollution is found measure problem for poor nutritional standard and growth of children due prevalence increase in vector borne disease, dysentery, jaundice, diarrhea and cholera [2]. Therefore it is essential to treat polluted water before circulated to the consumers of local communities for domestic purposes including drinking. In drinking water treatment coagulation/ flocculation process is one the most important process to remove the impurities of water. Many plant based coagulants are known in conventional treatments process. These are classified in to inorganic coagulants *e.g.* aluminium sulphate, ferric chloride, polyaluminum chlorides and synthetic polymers *e.g.*, polyethylene imine, polyacryl amide derivatives [3,4]. All of these coagulants are capable to remove turbidities. Aluminium salts are widely used in conjunction synthetic polymers in water treatment process. It reduces the repulsion between the colloidal impurities, increases collision and resulting the precipitate formation. Proper coagulation is necessary for performance of good filtration and for disinfection by product. The aim of achieving desired level of water quality primarily depends upon availability and cost of chemical coagulants [5]. The chemical coagulants are often costly and needed in large quantities water treatment process. In many developing countries, they have to be imported and it puts burden on their economy. Reports related to the use of chemical coagulants indicate serious drawbacks of aluminium salts. The presence of high residual contents of aluminium in treated water causes Alzheimer disease and also affects the water quality due to reactions with the OH^- and alkalinity of water [6]. In addition, the sludge formed during flocculation-coagulation process in water treatment with synthetic polymers has a limited potential for recycling because of the non-biodegradability of monomers of synthetic polymers. Some synthetic organic polymers such as acrylamide have neurotoxicity and strong carcinogenic properties [7,8] and because of this, there has been considerable interest in the development of natural coagulants which are biodegradable and safe for human health. This has lead a growing research interest in the production of plant based and food grade natural coagulants which are renewable and relatively cost-effective precursors in water treatment. It can help to achieve sustainable water treatment technologies.

Natural coagulants may have bright future and are concerned by many researchers for water treatment in developing countries. *Moringa oleifera* is most widely known cultivated species in India commonly referred to as *Moringa*. The seeds powder of *Moringa oleifera* has been used for purification of water [9]. Among the various plants based materials seeds of *Moringa oleifera* have been discovered one of the most effective primary coagulants in water purification that can replace aluminium sulphate (alum) which is widely used for water treatment around the world [10]. Reports of various researchers [11] suggested that *Moringa oleifera* seed is non-toxic and good coagulant in water treatment. Encouraged results of these studies, many developing countries have turned to use this plant as a possible coagulant in water and wastewater treatment on a small scale. Muyibi and Evision [12] have reported *Moringa oleifera* powder has the potential of reducing low and high turbidity values in surface water. Various settle times for *Moringa oleifera* water treatment have been used for softening of hard water with *Moringa oleifera* seed powder used a settling time of 1 h. Dosage of *Moringa oleifera* at an 1800 mg/L the calcium hardness had reduced to almost zero. Doerr [13] reported steps for household water treatment and recommended a settling time of one to 2 h for all the particles and contaminants to settle to the bottom of the storage container. Lilliehook [14] showed that the use of sand filtration on river water flocculated with *Moringa oleifera* employed a settling period of 30 to 120 min for low, medium and high turbidity water. Hsu *et al.* [15] estimated that *Moringa oleifera* seed powder mixed with water should be kept for hours to obtain clean water. Khan *et al.* [16] attempted to decolourize dyes stuff of textile industries by using plant polyphenol oxidases *e.g.*, potato (*Solanumtu berosum*) and brinjal (*Solanum melongena*). It was found that potato polyphenol oxidase was more effective as compared to the enzyme obtained from brinjal polyphenol oxidase in decolorizing the dyes to higher extent. In this process, insoluble precipitate is formed which are easily removed by centrifugation.

Kihampa *et al.* [17] reported the performance of *Solanum incunum*as coagulant and disinfectant for water purification. Results suggested that coagulation depends on Fe(II) content and disinfectant on bioactivenatural product compounds from the plant.

Tannins are polyphenol compounds derived from plant materials such as organic extract of the bark and wood of trees such as *Acacia, Castanea* or *Schinopsis*. On the basis of their chemical structure tannins are classified into two main categories *i.e.*, hydrolyzable tannins and condensed tannins, presence of polyhydroxyphenyl multiple groups in their chemical structure possess a high affinity for proteins, metal ions and other macromolecules such as polysaccharides. The various studies that have been conducted on water treatment using the tannins as a coagulant have revealed that the effectiveness of tannins mainly depends on the source plant from which it extracted and the degree of tannin modification. An interesting study on application of commercial tannin containing both amine and phenolic groups for water treatment suggests that tannin is cationic in nature due to presence of a single tertiary amine group per monomer and also exhibits amphoteric nature since it have phenolic groups [18].

In this experiment, we have reported the three plants based materials namely *Moringa oleifera*, *Solanum incanum* and *Acacia catechu* (Tannin) in context to treat medium turbid pond water and attempted to compare coagulation efficiency to remove turbidity, TDS, pH, COD, *etc*.

EXPERIMENTAL

The coagulation-flocculation experiment was carried out using Tempstar-floculator, Jar testing or multiple spindle stirrers which consist of six beakers mixing paddle and a gauge for maximum 250 rpm. Six 1000 mL raw water filled beakers were used to study the effect of coagulant extracts dosage on coagulation, Six different amounts of the coagulant were added in each 1000 mL beaker, the first having 1 mL and the remaining five varying from 1-6 mL at 1 mL interval in order to determine the optimum dosage for coagulation and the jars were placed in the jar tester, agitated for 5 min at 150 rpm to achieve uniform mixtures. The mixing speed was then reduced to 30 rpm and maintained at slow mixing for 30 min. After this was accomplished the samples were allowed to settle and the flocs filtered using a filter paper and the following parameters turbidity, TDS, COD, DO, pH and conductivity *etc*. were measured after the completion of coagulation by the standard methods of the American Public Health Association.

From the results attained the dosage with the best results in turbidity, TDS *etc*. removal was taken as the optimum. Above procedure is repeated with all three plant coagulant extracts.

Collection of water sample: Water samples were collected from rural area of Raipur district includes Sunderkera (Temple pond), Nariara (Community pond). Water sample was categorized by their turbidity value in low turbid (< 50 NTU), medium turbid (< 150 NTU), high turbid (> 150 NTU) and kept in Teflon sealed plastic bottle and examine within 24 h.

RESULTS AND DISCUSSION

Nearly every part of the plant (leaves, flowers, seeds, roots and bark) can be utilized as food or with medicinal and therapeutic purposes, particularly in developing countries. These natural herbs can be used as primary coagulant in drinking water purification and waste water treatment due to the presence of a water-soluble cationic coagulant protein have a potential to reduce the turbidity, TDS, pH, COD, *etc.* of water to be treated.

The physico-chemical characteristics of pond water sample used in this study are compared presented in Table-1. It was observed that the pond water is not suitable for drinking or household purposes, in which rural community relies and it should use through treatment before use. The turbidity of raw water sample is in the range of 50-150 NTU which is classified as medium turbid water [13]. Coagulation occurs when coagulant diminish repulsive force of electrical double layers on colloids surface so as to it is function to drive among

TABLE-1
COMPARISON OF WATER QUALITY OF SUNDERKERA POND AND NARIARA POND

Parameter/locations	Sunderkera pond	Nariara pond
Colour	Faint brown	Faint brown
Odour	Specific	Specific
Temperature (°C)	28.17	27.25
Turbidity (NTU)	131	148
pH	8.9	8.5
TDS (mg/L)	323	845
Total hardness, $CaCO_3$ (mg/L)	197	219
Total alkalinity, $CaCO_3$ (mg/L)	248	369
Dissolved oxygen (mg/L)	6.21	2.35
COD (mg/L)	30.87	34.65
Electrical conductivity (µS/cm)	68	45

one and another [19]. Where interactions among the surface of the colloidal particles and coagulant are recognized by means of covalent bonds, hydrogen bonds, ionic bonds, coordinate bonds, intermolecular attraction forces or van der Waals forces. Consequently, with more sites adsorption existing in the coagulant, greater amounts of colloidal molecules is absorbed. Polymeric high molecular mass molecules can be chemically adsorbed on the colloidal particles and each branch of the polymer can be adsorbed by another colloid, given those molecular bridges, binding the particles and form a flock, destabilizing the colloidal particles and inducing deposition [20].

Determination of optimum dose of coagulant for removal of turbidity: In this study, coagulation efficiency of three plants based coagulants was compared in Table-2, to remove turbidity of pond water sample. It was observed that turbidity of water sample decreases with increase of coagulant dose, due to this there was an improvement in the flock size and flock settled quickly. After optimum doses of coagulant it increases, the overdosing resulted in the saturation of the polymer bridge sites and caused re-stabilization of the destabilized particles due to insufficient number of particles to form more inter-particle bridges.

TABLE-2
INITIAL TURBIDITY (148 NTU), VOLUME OF SAMPLE (1000 mL)

Dose of coagulant (mL/L)/Residual turbidity (NTU)	*Moringa oleifera*	*Solanum incanum*	*Acacia catechu* (Tannin)
1	123.00	102	69
2	102.00	69	43
3	63.00	34	8.8
4	26.30	21	16
5	11.84	3.2	17
6	17.86	3.2	19

It was clear from Fig. 1 that all the coagulants show good potential to remove turbidity of water sample. The residual turbidity decreases up to 11.84 NTU at 5 mL/L optimum dose of *Moringa oleifera*. It was reduced up to 3.2 NTU and 8.8 NTU with optimum doses of 5 mL/L and 3 mL/L of *Solanum incanum* and *Acacia catechu* (Tannin) extracts from initial turbidity from 148 NTU fall within WHO standard. Further increase in the coagulant dose above optimal value was disco-

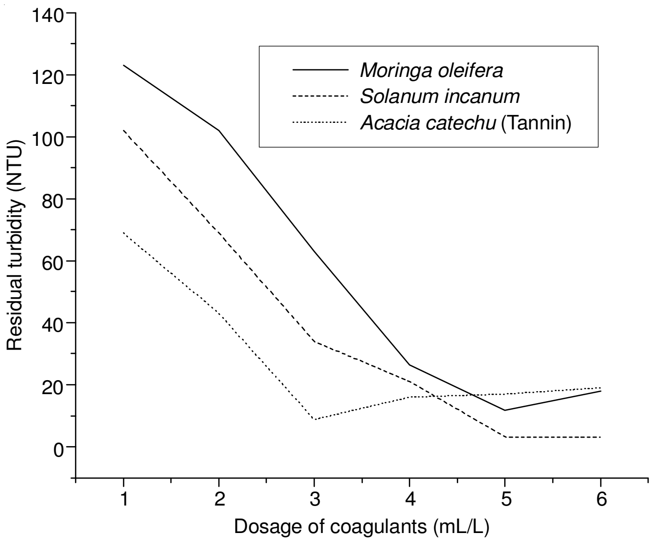

Fig. 1. Plot of residual turbidity *vs.* dosage of coagulant

vered to result in a re-increase in the turbidity of the sample shows agreement with findings of Marhobe *et al.* [17]. Residual turbidity reduces below 5 NTU, this was also reported by Madsen *et al.* [21] and established that 90-99 % of turbidity was removed by using *Moringa* seed Powder; similar results were also obtained by Bina *et al.* [22]. These studies a confirmed that these coagulants are highly effective in removing suspended and colloidal particles from water with medium to high levels of turbidity.

Determination of optimum dose of coagulant for removal of TDS: Coagulation efficiency of three natural coagulants to remove TDS of pond water was compared in Table-3. It was observed that amount of TDS decreases with increase the dose of coagulant extract after that increases due to destabilization of dissolve solids.

TABLE-3
INITIAL TOTAL DISSOLVED SOLIDS (845 mg/L), VOLUME OF SAMPLE (1000 mL)

Dose of coagulant (mL/L)	*Moringa oleifera*	*Solanum incanum*	*Acacia catechu* (Tannin)
1	723.0	762	737
2	658.0	738	648
3	598.0	639	456
4	532.2	548	343
5	563.0	537	369
6	593.0	539	377

It was clear from Fig. 2, that the extract of tannin shows maximum efficiency to reduce TDS and it was reduced to 343 mg/L from 845 mg/L of initial TDS content at 4 mL/L. Total dissolved solid was reduced to 532.2 mg/L, 537 mg/L for optimum dose of 4 mL/L and 5 mL/L, respectively for *Moringa* and *Solanum* extract. However, *Moringa oleifera* and *Solanum incanum* extract was not as effective to reduce TDS.

Determination of optimum dose of coagulant for reduction of pH: Water neutralization capacity of various natural coagulants was compared in Table-4. It was observed that the pH of pond water decreases with increases of coagulants dose. It was clear from Fig. 3, except tannin extract, *Moringa oleifera* and *Solanum incunum* showed good potential to reduce the

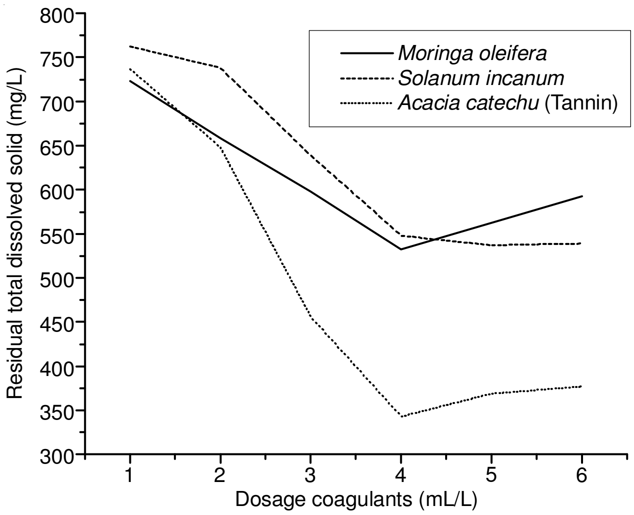

Fig. 2. Plot of residual total dissolve solids *vs*. dosage of coagulants

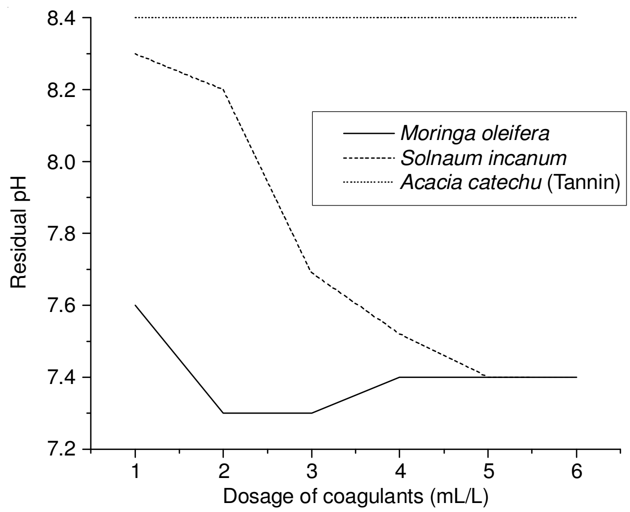

Fig. 3. Plot of residual pH *vs*. coagulants dosage

TABLE-4
INITIAL pH 8.5, VOLUME OF SAMPLE (1000 mL)

Dose of coagulant (mL/L)/residual pH	*Moringa oleifera*	*Solanum incanum*	*Acacia catechu* (Tannin)
1	7.6	8.30	8.4
2	7.3	8.20	8.4
3	7.3	7.69	8.4
4	7.4	7.52	8.4
5	7.4	7.40	8.4
6	7.4	7.40	8.4

pH of water sample. The pH of pond water sample was reduced to 7.3 and 7.4 with optimum dose 2 mL/L, 5 mL/L of *Moringa oleifera*, *Solanum inccunum* extract. The suggested suitable range of pH for drinking water specified by WHO is between 6.0 and 8.0. The treatments offer a pH range of 7 to 7.5 which falls within the reducing tendency as the concentrations of the dosing solutions were improved.

Determination of optimum dose of coagulant for reduction of COD: To study the COD reduction capacity of various natural coagulants was compared in Table-5 and it was observed that COD of raw water sample decreases with increases of coagulants dose.

TABLE-5
INITIAL COD-34.65, VOLUME OF SAMPLE (1000 mL)

Doses of coagulant (mL/L)	*Moringa oleifera*	*Solanum incanum*	*Acacia catechu* (Tannin)
1	33.8	33.8	33.4
2	33.3	33.7	33.3
3	30.6	32.7	33.4
4	31.7	33.8	33.4
5	32.8	33.8	33.5
6	33.0	33.8	33.6

It was clear from Fig. 4 that the COD of raw water sample was reduced to 30.6 mg/L from initial turbidity 34.65 mg/L with optimum dose of *Moringa oleifera* extract. Regarding the removal of COD, it appears that for Tanfloc SG coagulant, COD removal was 77.28 % and for Tanfloc SH was 44.14 %. Kazi & Virupakshi found that *M. oleifera* coagulants not only removed turbidity of 82.02 %, but also reduced COD up to 83.3 % of tannery wastewater. COD of dairy wastewater was significantly reduced from 1440 mg/L to 640 mg/L and 800 mg/L. for *Moringa* coagulant indicating a removal efficiency of 55.6 % and 44.4 % respectively. It was establish that 83 % of chemical oxygen demand (COD) and 90 % of colour decline was observed with chitosan.

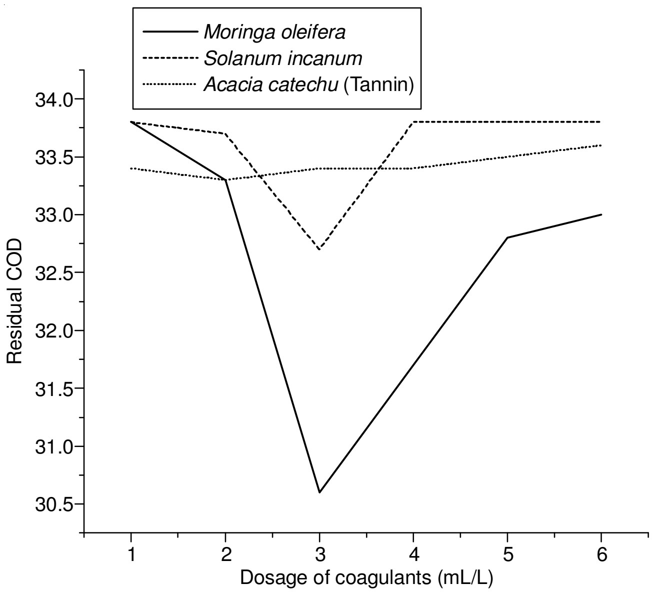

Fig. 4. Plot of residual COD *vs*. the dosage of coagulant

Conclusion

The aim of this study was to analyze applicability of widely available plants *Moringa oleifera*, *Solanum incanum* and *Acacia catechu* (Tannin) as a natural coagulants and their coagulation efficiency to treat medium turbid pond water. Results showed that the extract of *Solanum incanum* has a maximum potential to remove turbidity of pond water by 98 % turbidity. Total dissolve solid content was 60 % removed by *Acacia catechu* (Tannin) extract and *Moringa oleifera* extract has a potential to neutralize to pH of raw water sample. Parameters like COD change appreciably by *Moringa oleifera* extract while other parameters like alkalinity, hardness and dissolved oxygen was not change by dosage of these coagulants. It was concluded that each coagulants has a potential to purify water depends on water quality. The natural coagulant is biodegradable, eco-friendly, non-toxic and non-carcinogenic. Therefore, making it a potentially feasible substitute to alum and other costly purifying chemical materials in deal with the challenges facing potable water supply especially in rural areas of developing countries as well as developed countries.

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