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Use of Tannin based natural coagulants for water treatment: An alternative to inorganic chemicals

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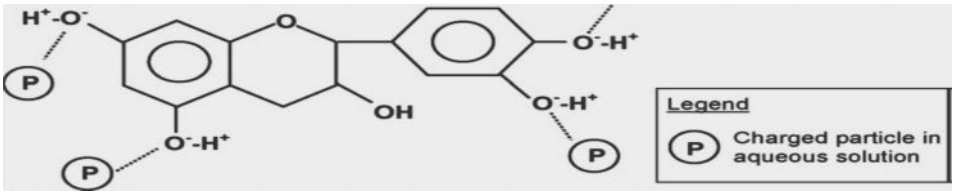
Abstract: In this study, a natural indigenous coagulant is suggested as a substitute for alum. Tannins are found in the leaves, fruits, barks, roots and wood of trees. The coagulant characteristics of the tannins obtained from Acacia catechu were examined and whether or not tannins could be used as a primary coagulant was determined. The powdered material extract obtained from bark of acacia catechu was used to test coagulant rate and dose. The turbidity and other physico-chemicals of surface water sample were measured before and after the jar-test by using portable instruments. Turbidity meter was used to measure turbidity, while digital pH meter was used to measure pH. Total suspended solids were analyzed using gravimetric method. The experiments were carried out with coagulant dosage of 1.0, 2.0, 3.0, 4.0 and 5.0 mL with the intervals of 1 mL in each raw water sample. The results have shown that acacia catechu powder can remove turbidity up to 91% at the optimal dosage of 3.0 mL/L. On the other hand, the powder of acacia catechu can remove total dissolve solids by 57.3% but not other parameters.
Keywords: Coagulant, Tannins, Acacia catechu, Turbidity, Total dissolve solids

Introduction

Water covers 75% of the blue planet, it is distributed in the form of oceans, rivers, lakes, etc. in spite of that, only a small part of this water – in the order of 113 trillion m^3 is available to life on Earth [1]. Availability of Clean drinking water has become scarce nowadays due to poor land use management. Surface water was polluted by many ways such as sewage, industrial water discharge and run off from the land clearing, while ground water was polluted by salt water intrusion and waste dumping site. This polluted water will have to go through treatment process before it can be circulated to the consumers for domestic use including for drinking [2]. Treatment of Drinking water typically relies on coagulation, sedimentation, and filtration and disinfection process [3]. Coagulants play a major role in the treatment of water and wastewater and in the treatment and disposal of sludge. Many coagulants used in conventional treatment process it includes inorganic coagulants such as Aluminum sulfate, alum, and organic coagulants are polyelectrolyte that may synthetic or plant origin materials, is the common chemical coagulant used in the coagulation process.[4, 5]. Residue left after treatment process may cause several health hazards. Aluminium is characterized in poisoning factor for encephalopathy, study of various reports on impact of aluminum on human health; it is strongly evidenced aluminium based coagulants linked in the development of neurodegenerative ill-nesses as sesil dementia [6] and with Alzheimer's disease [7]. Synthetic polyelectrolytes are cuestionated due to the toxicity and carcinogenetic potential of the mono- mers used for their synthesis [8]. Therefore, it is need to progressively replacement of these inorganic and organic coagulants with alternative natural coagulants. Natural coagulants (bio-polymers) would be of great interest since they are natural low-cost products, characterized by their environ-mentally friendly behavior, and presumed to be safe for human health [9]. There has been considerable interest in development and usage of plant based natural coagulants [10]. Use of Plant based material for water treatment agents have long history, particularly wood charcoal are considered as a excellent adsorbents.[11] . Natural

polyelectrolyte of plant origin has been used for many centuries in developing countries for purification of turbid water [12]. For home water treatment, the materials have to be used in the form of powder or paste, 90% of which consists of substances other than the polyelectrolytes. Even under such conditions, a few plant seeds make effective coagulants [13]. Several plant based material were identified as a natural coagulants such as Moringa oleifera[14-16], Nirmali[17], cactus[18].

Recently tannin based coagulants have been utilized in coagulation/flocculation processes for water purification. Tannins are high molecular weight polycyclic aromatic compounds, general name given to large polyphenol compounds. Tannins are widely distributed in the plant kingdom obtained from natural materials, for example, the organic extract from bark and wood of trees such as Acacia, Castanea, or Schinopsis. The various studies that have been conducted on water treatment using the tannins as a coagulant have revealed that the electiveness of tannins depends mainly on the chemical structure of tannins that have been extracted from the plant and the degree of tannin modification [19-21]. An interesting study on application of commercial tannin containing both amine and phenolic groups for water treatment suggests that tannin is cationic in nature since there is a single tertiary amine group per monomer. This tannin also exhibits amphoteric nature as a consequence of presence of phenolic groups (Scheme1) [22].



Schem1.Representation of basic tannin structure in aqueous solution and possible Molecular interactions [22]

Due to its natural character as it has no metals in their structure, do not consume alkalinity of the medium as it does not undergo hydrolysis in solution and its effectiveness as a coagulant is always optimal. Water purification can be done by using water soluble amphoteric tannins which, after combining with suspended impurities in water form co precipitate. Remained no residual salts or ions in the treated water. One of the advantage of use of tannin derived coagulant it does not alter the pH of the suspension. Another advantage is the formation of flakes. Their irregular shape provides greater surface contact which enhances the efficiency of flocculation. [23-24]

By using tannin based coagulant it was shown that optunia spp. reduced turbidity by 98% [25]. Beltra´n-Heredia et al. [26] reported tannin as a new and feasible source of treatment agents. They have investigated, the ability of these new products in several fields is more than evident: removing turbidity [27], surfactants [28] to heavy metals [29]. Couto et. al. [30] has investigated the optimization of time of coagulation, flocculation, and sedimentation of the chemical coagulant by aluminum sulfate as a coagulant and tannin as coagulant aid. It was performed an economic analysis of the process, checked the removal efficiency of color, turbidity, COD, and treatment characterization using metals, BOD, and total solids. On the other hand, very little work has done acacia catechu to explore its coagulation activity.

In this paper, we reported the tannin derived natural coagulant for treatment of surface water. Their coagulation activity was measured through optimization of coagulant dose for removal of turbidity and total dissolve solids.

2.0 Materials and Method

All reagents used in this study were of analytical grade and distilled water was used for preparation of extract solution. Powder of Acacia catechu bark was purchased from nearby market.

Acacia catechu belongs to leguminosae family, commonly known as black catechu or cutch. It is deciduous, thorny tree which grows up to 50 ft height, widely distributed in central and northern part of India. It is well known as khair. Ayurveda recognizes the use of Acacia catechu heartwood (known as Khadira) invaluable for its powerful astringent and anti –oxidant properties. Acacia catechu extract is derived from heartwood of the tree and is known to contain catechins, which have wide range of therapeutic actions. [31]


2.1 Collection of sample water

Water sample were collected from 'Budha Talab' pond of Raipur city. Sample water was kept in Teflon sealed plastic bottles and kept at 0^{o}C. All tests were conducted within 24 hours.

2.2 Preparation of coagulant extracts

Plant origin material bark of Acacia catechu were taken and air dried, grinded in a mortar and pestle into powder-form and sieved to remove large particles. 1 g of powder was mixed with 100 ml distilled water to form 100 ml of suspension (approximately 0.01 g/ml concentration). The suspension was then thoroughly mixed using a clean magnetic stirrer for 5 min to extract the active component, followed by filtration of the solution through a piece of clean white cloth so as to remove solid materials. The filtrate was then centrifuged at 30 rpm for 5 min, followed by filtration using what man filter paper. The obtained stock solutions from each of these methods were preserved at -4°C until analyzed

2.4 Jar Test Experiments

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 revolution per minutes (rpm).The experiment was performed by using water sample having constant turbidities. For each water sample, six beakers was filled up to 1000ml, placed in the jar tester, agitated at 30 rpm for 5 min. various concentrations of stock solutions was added to each of the beakers and then agitated further 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, followed by Sedimentation for 30 min, after which 5 ml of sample was collected at approximately 5 cm from the top of water surface for residue turbidity measurement.

3.0 Results and discussion

3.1Study of coagulant dose on removal of turbidity

Turbidity of water sample due to presence of suspended impurities of organic and inorganic salts. It is the measure of the degree to which the water loses its transparency due to the presence of suspended particulates. Jar test experiment was conducted to measure the turbidity removal efficiency of coagulant extract. Different amount of coagulant doses was added to five water samples with 1mL/L interval (Table1). One sample was used as reference sample. After experiment, it was clear from figure1; extract of acacia catechu has potential to remove turbidity of raw water sample. It was observed that as the amount of coagulant dose increase its capacity to remove turbidity also increases. Best result was observed at optimum dose of 3 mL/L at which 91% turbidity was removed from water sample

Table1. Coagulant dosage Vs Residual Turbidity

Sl.No.	Volume of Sample	Coagulant dosage used (mL)	Residual turbidity(NTU)	% of Residual turbidity
1	1000ml	1	86	43
2	1000ml	2	32	16
3	1000ml	3	18	09
4	1000ml	4	34	17
5	1000ml	5	43	21.5
6	1000ml	Blank	200	-

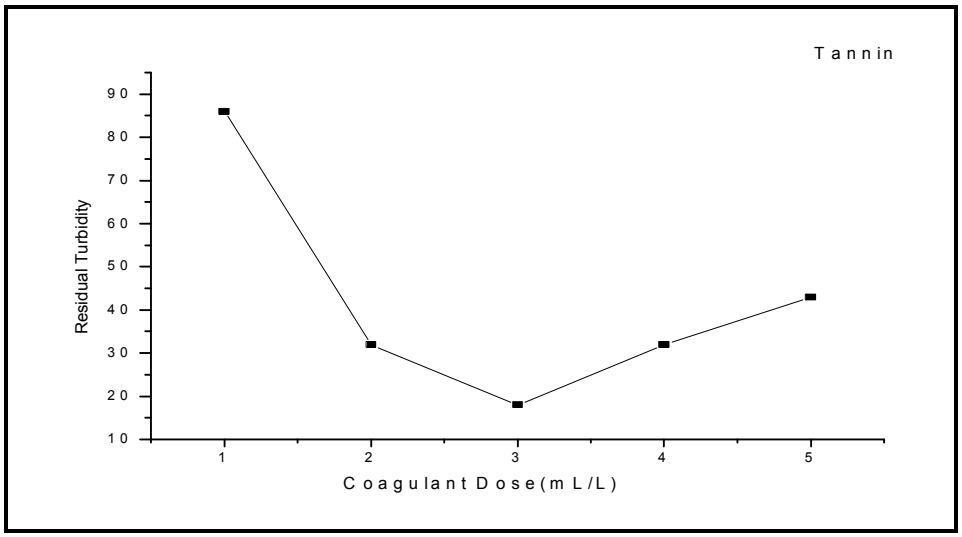


Figure1. Plot of Turbidity removal efficiency of Coagulant dose

3.2 Study of coagulant dose on removal of

Total dissolve solid

Total dissolved solids (TDS) were determined by gravimetric method. It was due to dissolved inorganic and organic salts. It was observed from table2, the amount of total dissolved solid decreases with increase of coagulant dosage, showed maximum efficiency at 4 mL/L. At this optimum dose of coagulant 57.3% TDS were removed from water sample.

Table 2. Coagulant Dosage Vs Residual Total suspended solids

Sl. No.	Volume of Sample	Coagulant dosage used (mL)	Residual Total dissolve solid	%of Residual Total dissolve solid
1	1000mL	1	288	72.3
2	1000mL	2	263	66.08
3	1000mL	3	217	54.5
4	1000mL	4	170	42.7
5	1000mL	5	196	49.2
6	1000mL	Blank	398	-

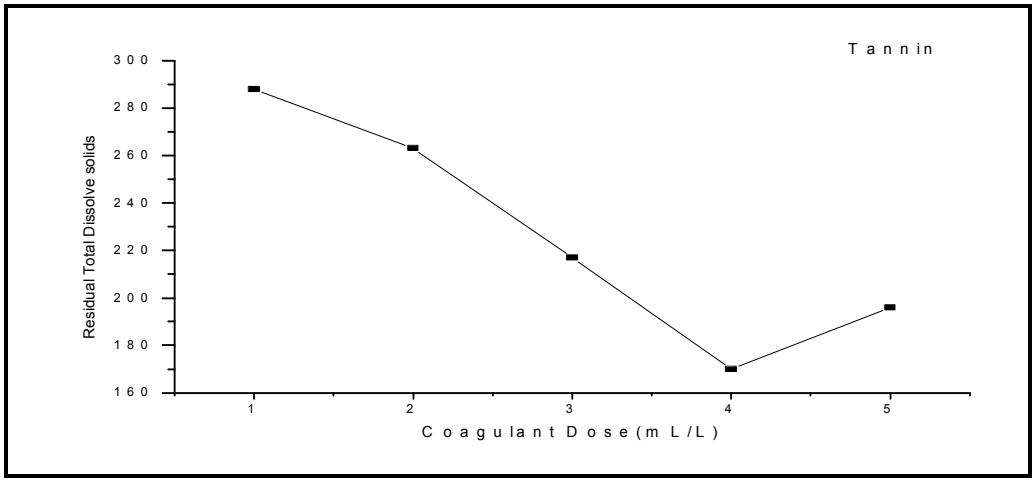


Figure 2. Plot of coagulant efficiency on TDS removal

3.3 Study of effect of coagulant dose on pH of water sample

It was observed from table 3, as coagulant dose added in water, pH of water sample decreases from 7.8 to 6.5. There is no significant change on pH before and after experiment. Therefore it was concluded that extract of acacia catechu has no measurable potential to neutralize surface water sample. pH of the water sample was measured 'systronics' make digital pH meter

Table 3. Coagulant Dosage Vs pH

Sl.No.	Volume of Sample	Coagulant dosage used	PH of sample
1	1000ml	1	7.3
2	1000ml	2	6.8
3	1000ml	3	6.6
4	1000ml	4	6.5
5	1000ml	5	6.5
6	1000ml	Blank	7.8

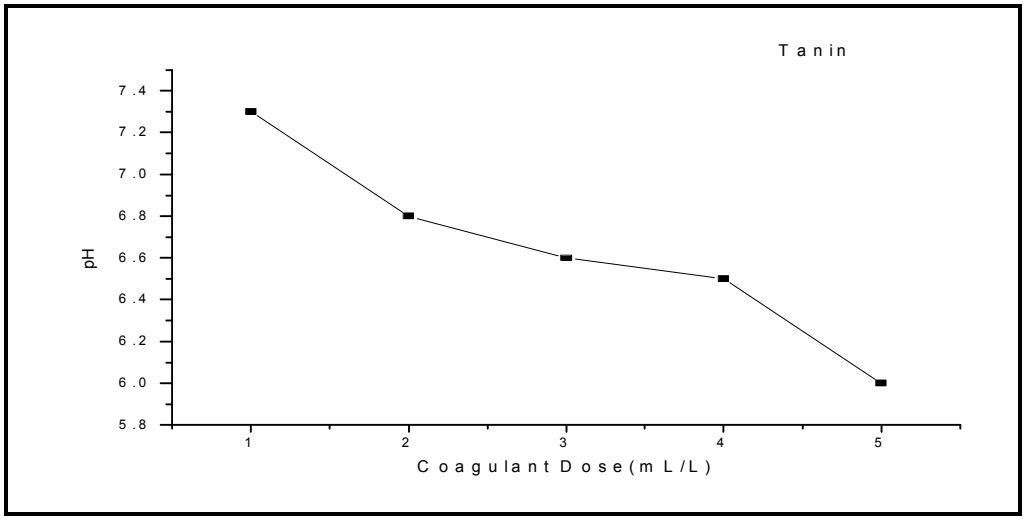


Figure 3. Plot of effect of coagulant dose on pH of water sample

4.0 Conclusion

The aim of this study to investigate the feasibility of using widely distributed acacia catechu plant as natural coagulant to purify surface water. It was evidenced from this study tannin derived coagulant stands as real alternative to traditional inorganic metal coagulants in the removal of turbidity and Total dissolve solids. It presents the functional working advantages that may encourage further studies with regard to purifying and refining the active coagulant principal.

Figure-1 shows, extract obtained from bark powder of Acacia catechu has reduced 91% turbidity of pond water sample at the optimum dosage of 3.0 mL/L. Extracts has a good potential to be used as a natural coagulant for its ability to remove turbidity. Figure-2 shows, where after being treated with4.0 mL/L of the bark extracts there was a substantial reduction of TDS from 390mg/L at the start to 170 mg/L. The ability to remove total dissolve solids by 57.3%. It was another remarkable feature. The potential for using bark powder of Acacia catechu extracts to remove total suspended solids in drinking water. Figure-3 shows the pH reading for pond water sample decreased from 7.8 to 6.5 after being treated with the coagulant extracts. The pH reading was almost similar before and after treatment. Therefore, we can suggest that bark powder of Acacia catechu extract could not be use as neutralizer for drinking water.

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