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ASSESSMENT OF TURBIDITY REMOVAL EFFICIENCY OF NATURAL COAGULANTS

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ABSTRACT

Existing fresh water supplies could be contaminated with organic, inorganic and biological matters that have potential harm to the society. Water from all sources must have some form of purification before consumption. Due to its simplicity and effectiveness, coagulation and flocculation are one of the most widely adopted techniques to restore the palatability and improve the aesthetic appearance of turbid water. Conventionally used chemical coagulants cause considerable adversities to both treatment systems as well as human health. It is therefore desirable to replace these chemical coagulants with plant-based coagulants to counteract the drawbacks. The ability of two plant materials, Cactus and barks of acacia to act as natural coagulants was tested using synthetic water. Turbidity was added as clay. The coagulation ability of the two materials was assessed by the use of standard jar test measurements. Both materials produced comparable turbidity removals and were able to produce a final water with required standard of 5NTU with high (200 NTU) initial turbidity.

I. INTRODUCTION

Water is undoubtedly the most vital element among the natural resources. In many developing countries, access to clean and safe water is a crucial issue. Water pollution is an appalling problem, powerful enough to lead the world on a path of destruction. Water is an easy solvent, enabling most pollutants to dissolve in it easily and contaminate it. The most basic effect of water pollution is directly suffered by the organisms and vegetation that survive in water, including amphibians. On a human level, several people die each day due to consumption of polluted and infected water. Rapid industrial developments coupled with surging population growth have complicated issues dealing with water scarcity as the quest for clean and sanitized water intensifies globally.

Need of water treatment is so important that we can avoid many possible water borne diseases like cholera, typhoid jaundice and so on. Turbidity in general is a measure of water cloudiness induced by such colloidal and suspended matters and is also one of the major criteria in raw water monitoring to meet the stipulated water quality guidelines. Coagulation and flocculation technique results in the destabilization of colloidal particles and subsequently, the increment in particle size for the ease of sedimentation. In raw water, inorganic salts of aluminium or iron can be added, these salts neutralizes the charge on the particles that are responsible for the raw water turbidity. These salts also hydrolyze to form insoluble precipitates entrapping the particles. Some of the common inorganic coagulants are aluminium sulphate, alum, ferric sulphate and aluminium chloride. In flocculation, these agglomerations of destabilized particles take the form of large particles. This can also be achieved by adding high molecular weight, water soluble organic polymers. Due to these polymers, the size of the floc increases and then the particles settle down. It is very important to gently mix the flocculating agent at a slow speed so that small flocs can easily agglomerate into large particles, and finally settle down.

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There are disadvantages associated with usage of these metal coagulants such as ineffectiveness in low-temperature water, relatively high procurement costs, detrimental effects on human health, production of large sludge volumes and the fact that they significantly affect pH of treated water. There is also strong evidence linking aluminium-based coagulants to the development of Alzheimer's disease in human beings. In contrast to chemical coagulants, plant-based natural coagulants are safe, eco-friendly and generally toxic free. Natural coagulants have been found to generate not only a much smaller sludge volume of up to five times lower but also with a higher nutritional sludge value. As such, sludge treatment and handling costs are lowered making it a more sustainable option. The raw plant extracts are often available locally and hence, a low cost alternative to chemical coagulants. Since natural coagulants do not consume alkalinity unlike alum, pH adjustments can be omitted and this provides extra cost savings. Natural coagulants are also non-corrosive which eliminate the concerns of pipe erosions [1].

Natural coagulants are mostly either polysaccharides or proteins. Bio-flocculants can destabilise the colloidal particles by increasing the ionic strength and giving some reduction in the zeta potential and thus a decreased thickness of the diffuse part of the electrical double layer. Or, they could specifically adsorb counter ions to neutralise the particle charge because they have particular macromolecular structures with a variety of functional groups (e.g. carboxyl and hydroxyl groups) which can interact with contaminants. Polymeric coagulants are generally associated with mechanisms adsorption and charge neutralization and adsorption and inter particle bridging as their long-chained structures (especially polymers with high molecular weights) greatly increase the number of unoccupied adsorption sites. It appears that these two mechanisms provide underlying principles to the inner workings of plant based coagulants as well [2]. For many years, biopolymers based flocculants such as chitosan, tannins, cellulose, alginate, gums and mucilage have been attracting wide interest of researchers.It was interesting to notice that most of the mucilage extracted from plants (plant-based bio-flocculants) is either anionic or non-ionic, and they can be used in wastewater treatment without addition of coagulant

In the age of climate change, depletion of earth's natural resources and widespread environmental degradation, application of natural coagulants is a vital effort in line with the global sustainable development initiatives. In recent years, the use of natural coagulants has been promoted as a solution to environmental problems because their intermediates are harmless and biodegradable. Application of cacti species for water treatment is rather recent compared to other natural coagulants such as nirmali or Moringa oleifera [2]. The most commonly studied cactus genus for water treatment is Opuntia. Recently tannin based coagulants have been utilized in coagulation/flocculation processes for water purification. 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 [2]. The objective of the present study is to investigate the coagulation/flocculation potential of natural coagulants, such as cactus mucilage and Acacia catecheu to remove the turbidity from synthetic turbid water prepared from local clay.

II. MATERIALS AND METHODS

2.1 Experimental set up

The apparatus used for assessing the performance of a particular primary coagulant is the standard jar test apparatus, an example of which is shown in Figure 1. It consists essentially of a rack of stirrers, driven by one motor, under which 1 litre glass beakers are arranged**.**

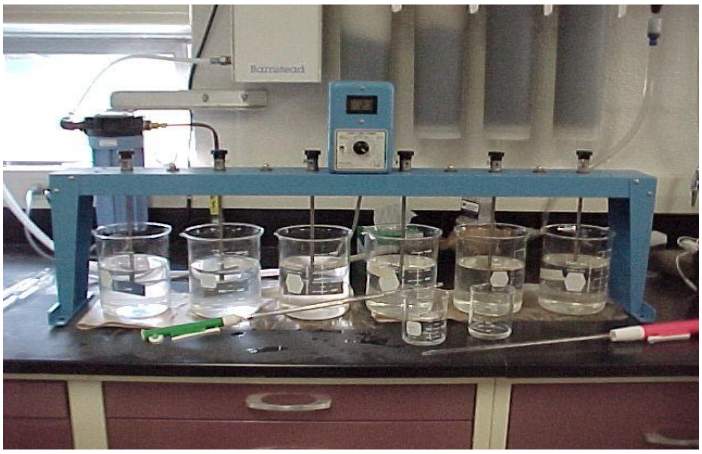

Fig.1 Jar test apparatus

III. EXPERIMENTAL PROCEDURE

The procedure adopted for the study is given in the following sections.

3.1 Preparation of synthetic waste water

Natural clay was used for the preparation of synthetic turbid water. The 10 g of clay was added in 1 L of distilled water. Suspension was stirred slowly at 20 rpm for 1 hour to achieve uniform suspension. This was allowed to settle for 24 hours. This suspension was used as a stock solution for the preparation of water sample.

3.2 Extraction of acacia catechu

Plant origin material bark of Acacia catechu are collected from college campus and air dried, grinded in a mortar and pestle into powder-form and sieved to remove large particles as shown in figure 2. 1 g of powder is mixed with 100 ml distilled water to form 100 ml of suspension (approximately 0.01 g/ml concentration). The suspension is 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 is then centrifuged at 30 rpm for 5 min, followed by filtration using whatman filter paper.

Fig.2 Bark of Acacia catechu

IJARSE
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3.3 Extraction of Opuntia ficus indica

A batch of locally available fresh leaves of Opuntia Ficus Indica (Cactus) is collected. The cladodes are washed thoroughly with water in order to remove dirt. The chemicals used in the experiment are of analytical grade.

Fresh cactus pads are cleaned (thrones were removed) and diced into 1cm width then boiled in demonized water for 30. The mixture is then liquidized with help of household blender. pH is altered to 7-7.5 with 1.0 M NaOH and the resulting mixture was centrifuged at rpm 4000 for 10 minutes and the supernatant is separated and filtered using regular filter paper. After filtration, extract is precipitated from water using acetone. The extracted mucilage was washed with isopropanol approximately 10 minutes and drawn out. The mucilage was spread on sterile Petri dish and dried in fume hood at room temperature for 48 to 60 hours. Extracted procedure was depicted in figure 3.

(a) **(b)** **(c)** **(d)**

Fig.3 (a) Slices of cactus (b) Boiling cactus-distilled water mixture (c) Filtering through filter paper (d) Precipitate

IV. METHODOLOGY

The basic procedure adopted to study the effects of coagulant dosage, pH and settling time is Standard Jar Test procedure. Standard Jar Test procedure with rapid stirring for 100-200 rpm for 2 minute is carried out followed by slow stirring 30 rpm for 30 minutes. The speed of mixing was reduced to 50 rpm and allowed for slow mixing for varying contact period i.e. multiples of 5 and continued till 30 minutes. Supernatant samples are withdrawn using pipette from a depth of 5 cm from surface for further studies at varying settling time of 25 minute and 45 minute.

A slightly modified procedure is followed if flocculant is used. After adding primary coagulant to all vessels simultaneously, rapid stirring for 1 min is done. Then flocculant is added and rapid stirring is continued for 1 min. It is followed by slow stirring for 30 min to allow flocculation. Settling, Decanting and measurements are as above.

4.1 Analysis of parameters

Jar test using natural coagulants (Opuntia Ficus Indica and bark of Acacia,)

4.1.1 Optimization of pH

The coagulation-flocculation process was a pH dependent. In this regard, the effect of the pH on the efficiency of the coagulation-flocculation treatment was studied over the pH range from 3 to 10. The pH was adjusted by adding a few drops of 0.5N of NaOH or 0.5N of H_2SO_4. Before the first step of the physico-chemical treatment,the pH of the dyeing solutions was adjusted to 3, 5, 7, 9 and 10. For these experiments, fixed coagulation-flocculation conditions were fixed at: coagulant dose, flocculants dose, mixing speed and settling time.

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4.1.2 Optimization of dosage

The effect of the flocculants dose was studied for the bio-flocculants in order to determine the optimal dose. After a rapid mixing coagulation, different flocculants quantities were added to a 500 ml of synthetic turbid water. The coagulation-flocculation treatment carried out at the optimum pH determined previously with keeping all other parameters constant.

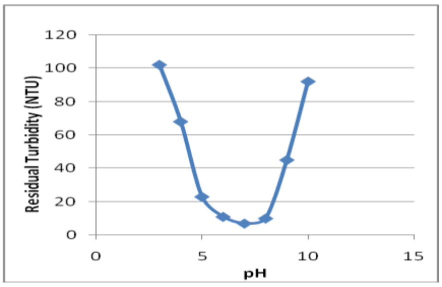
4.1.3 Optimization of flocculation mixing time and settling time

The flocculation mixing time is a significant parameter for flocculation treatment performance. In fact, series of jar tests were investigated at different mixing time and settling time. These experiments were carried out at the optimal pH and using the optimal flocculants dose previously determined. The optima pH values, optima dosages of the flocculation agent and optimum mixing time were recorded for the maximum turbidity removal for different synthetic turbid water.

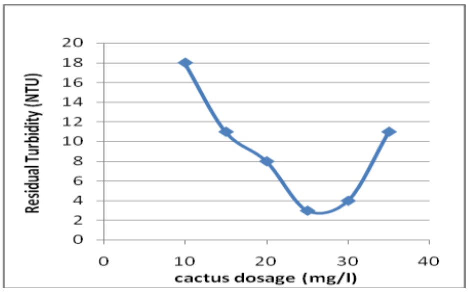
V. RESULTS AND DISCUSSION

5.1Treatment Of Synthetic Sample Using cactus

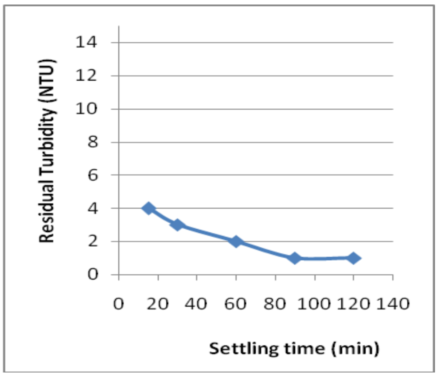
Synthetic sample was treated using coagulation flocculation process by Jar test. Jar tests were conducted with extracted active component of cactus at various pH, ranging from 3-11 to find out the optimum pH range in which cactus is active. Dosage used was 20 mg/l at a slow mixing time of 20 minutes and settling time 60 minutes. Table 4 shows the results of experimental runs.



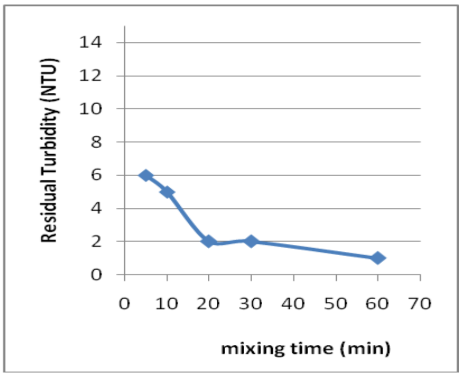
a) Effects of pH



b) Effects of dosage



c) Effects of settling time



d) Effects of mixing time

Fig.4 Effects of different parameters on turbidity removal using cactus.

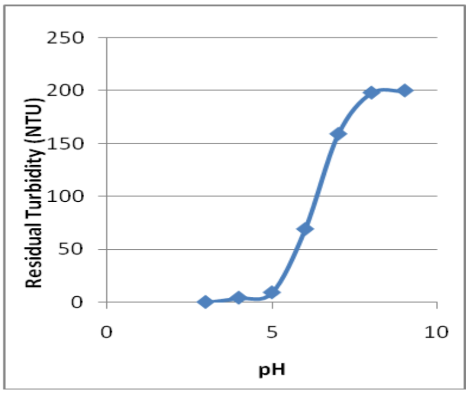
Cactus performs coagulation effectively in pH range of 6-8 .Optimum pH is found to be 7. Optimum dosage was found to be 25 mg/l at which residual turbidity is 3 NTU. Cactus mucilage has the potential to reduce the turbidity at low dosage than alum

As settling time increases, residual turbidity decreases. Unlike alum, residual turbidity is decreased due to more dense floc formation [3].The use of cactus forms flocs of larger size than that shown by aluminum sulfate, increasing the settling velocity of the aggregate material. Thus, it is expected to reduce the time of flocculation and decantation [4]. Slow mixing time of 5 minute inadequate for the floc formation, from 20 minute onwards turbidity decreases. Only slight variation occurs at 60 minutes.

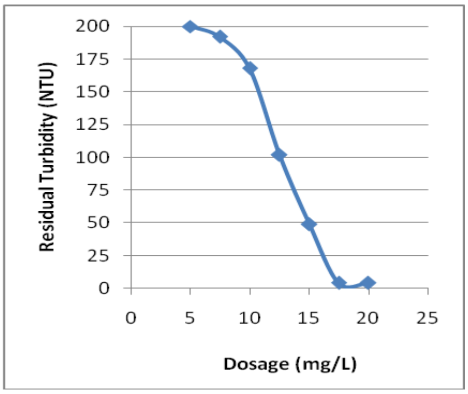
The clotting ability of Opuntia, the presence of mucilage, a complex with viscous large water retention capacity, made of carbohydrate molecules such as arabinose, galactose, xylose and galacturonic acid, and stored in internal and external parts of the cactus. The ability Opuntia spp coagulation occurs through the mechanism of forming chemical bridges, through hydrogen bonds or dipole interactions [5]. Anionic nature of the chain is due to partial deprotonation of the carboxyl and hydroxyl groups in aqueous solution, involving chemisorption between the charged particles and these groups [6].

5.2 Treat ment using acacia

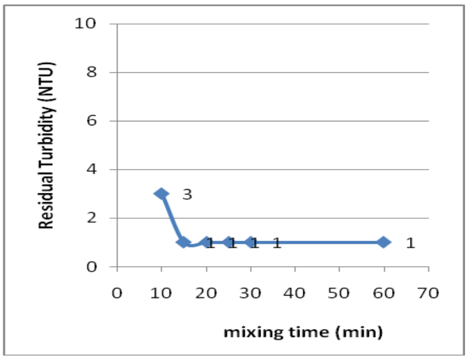
Synthetic sample of 200 NTU was treated using coagulation flocculation process. Extracted active component of acacia was used as coagulant. Number of jar tests was conducted to analyse the effects of pH, dosage of natural coagulant, slow mixing time and settling time on turbidity removal. The results are depicted in figure 5.



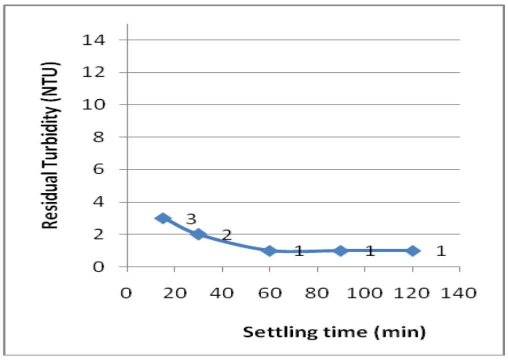
a) Effects of pH



b) Effects of Dosage



c)**Effects of settling time**



d)Effects of settling time

fig.5 Effects of different parameters on turbidity removal using acacia

Acacia performs coagulation effectively in pH range of 3-5.5. As residual turbidity is found to be 4 at pH= 4.5, studies regarding the effect of other Parameters are carried out at this pH. At low pH both -OH and -COOH units of Natural coagulant molecules get protonated and assume positive potentials. But close to pH 6, units ionize due to weak acidity and potential assumes negative values. Further at pH 7.0 and 9.4, the potentials become strongly negative due to ionizations of both –O-H and -COOH units of Natural coagulant. After 15

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minutes of mixing time, residual turbidity is found to be constant, Residual turbidity slightly decreases in the first 1 hour, later on it remains constant.

Tannins are plant secondary metabolites occurring in leaves, bark and fruit polyphenol compounds being obtained from plants such as acacia. Tannins could replace coagulating due to its chemical structure phenolic groups of anionic nature which can be deprotonates and form phenoxide stabilized resonance, allowing coagulation [6]. Acacia generate little sludge volume and being biodegradable [3]. Acacia extract is found to be very effective at pH=4.5 in removing the turbidity over 98%.

VI. CONCLUSION

Amongst the available methods of water treatment, coagulation and flocculation is a low cost, simple, reliable, and low energy consuming process that is commonly practiced. Despite the wide applicability of chemical coagulants, they have also exhibited some shortcomings; such as relatively high costs, harmful effects on human health, production of large sludge volumes as well as the fact that they considerably affect the pH of the treated water. Cactus is found to be more effective in the neutral pH itself with more than 95 % turbidity removal. Acacia is more effective in the acidic pH with 98% turbidity removal. we can treat turbid water near to mining sites or pretreatment to effluents with acidic nature like metal plating. The usage of natural coagulants derived from plant based sources represents a vital development in 'grassroots' sustainable environmental technology since it focuses on the improvement of quality of life for underdeveloped communities.

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