ENHANCING FILTRATE QUALITY OF TURBID WATER INCORPORATING SEEDS OF *Strychnos potatorum*, PADS OF *Cactus opuntia* AND MUCILAGE EXTRACTED FROM THE FRUITS OF *Coccinia indica* AS COAGULANTS

C. Nirmala Rani *1 and Jadhav M. V.2

1. Department of Civil Engineering, Late G.N. Sapkal Collage of Engineering, Anjaneri, Nasik, University of Pune (INDIA)
2. Department of Civil Engineering, SRES’ College of Engineering, Kopargaon, University of Pune (INDIA)

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ABSTRACT

In the present study the plant based coagulants namely, the seeds of *Strychnos potatorum*, pads of *Cactus opuntia* and mucilage extracted from the fruits of *Coccinia indica* in powder forms were applied to a water treatment sequence comprising coagulation-flocculation-sedimentation-sand filtration. The study was conducted on synthetic turbid water created by kaolin. Emphasis was given to the filtration aspect of the treatment using synthetic turbid water. The performance of filter was defined by the quality of water and the head loss development across the filter bed. The optimum dose obtained from Batch coagulation-sedimentation test conducted for *S. potatorum*, *Cactus* and *Coccinia indica* were 1.5 mg/l, 30 mg/l, 0.5 mg/l were applied for filtration test and turbid waters with the supernatant turbidities obtained from batch coagulation-sedimentation test (14 NTU in the case of *S. potatorum*, 17 NTU in the case of *Cactus* and 13 NTU in the case of *Coccinia indica*) were fed as an influent to the filter. The filtrate turbidities obtained after filtration were 0 NTU, 1 NTU and 0 NTU which are lesser than 5 NTU (the guideline value recommended by WHO). Thus the use of natural coagulants improved the filtrate quality.

Key Words: Coagulation, Filtration, Polymer, Polyelectrolyte, Turbidity

INTRODUCTION

In rural areas of developing countries ground water is the preferred source of drinking water since it requires no or minimal treatment. In rural areas if no suitable aquifers are available, then clean water from the lakes, streams or rivers are preferred by people. The simple technologies used in such places are gravity chemical feed with solution, hydraulic rapid mixing and flocculation, horizontal flow sedimentation and manually operated filters1. Water obtained from lakes and streams are in turbid form. Coagulation is an essential process in the treatment of turbid water. Coagulants used for turbid water treatment may be chemical based or plant based. Plant based coagulants are natural polyelectrolytes and have been used in many developing countries to clarify turbid water. For home water treatment the coagulants have to be used in the form of powder or paste 90% of which consists of substances other than polyelectrolytes. Even under such conditions, a few plant seeds proved to be effective coagulants2 examples of seeds of the plant species of the family Loganiaceae-*Strychnos potatorum* and Moringaceae- *Moringa oleifera* and *Moringa stenopetala*. The plant based coagulants used in this study are seeds of *Strychnos potatorum*, pads of *Cactus opuntia* and mucilage extracted from the fruits of *Coccinia indica*.

The batch coagulation-flocculation test conducted using all three natural coagulants proved to be more effective. Eventhough the natural coagulants appeared effective in
clarifying turbid water, the supernatant turbidities of water after batch coagulation-sedimentation test were more than 5 NTU.³

AIMS AND OBJECTIVES
In the present study, a coagulation-filtration test was used to examine the improvement in the quality of turbid water by direct filtration by applying the optimum dosages of each coagulant obtained from the batch coagulation-sedimentation test. The goal of this study is to assess the suitability of this method for turbid water in rural areas of developing countries.

MATERIAL AND METHODS
The natural coagulants used in this study are powder of Strychnos potatorum seeds, powder obtained from the pads of Cactus opuntia and the powder of mucilage extracted from the fruits of Coccinia indica. The seeds of S. potatorum were purchased from an ayurvedic medical shop at Chennai. Cactus opuntia pads were purchased from a nursery at Bhagur. The preparation of synthetic turbid water and coagulant solutions are described below.

Preparation of turbid water sample
Turbid water used in this study was prepared by adding 10gm of kaolin powder. It was purchased from Space Laboratories Ltd, Ambad at Nasik, India. Kaolin powder was dried in an oven with the temperature of 105°C for 5 hours. After that it was removed from the oven and was embedded in desiccators for 30 minutes.100ml of distilled water was added to the kaolin power and the suspension was kept at room temperature for 24 hours and was completely mixed for 20 minutes by electrical blender. The suspension was left undisturbed for 4 hours in order to settle the coarser particles. One litre supernatant was transferred to Erlenmeyer flask and was kept as stock solution.⁴⁻⁶ From this stock solution, desired turbidities were generated. In this study high turbidity of 192 NTU was generated and utilized for experimentation.

Powder of Strychnos potatorum seeds
S. potatorum seeds were purchased from the ayurvedic medical shop at Chennai. They were powdered and sieved through 150µm sieve, and a 2% suspension was prepared with distilled water.⁴ These seeds due to their hard structure, could not be powdered in a grinder. In such a case the seeds were kept immersed in 50 ml water containing 2ml conc.HCl. After a week, the mixture was mashed to a soup-like solution and was washed through a nylon cloth. The material retained on the cloth was oven dried for 24 hours at 103°C to 105°C and weighed. By calculating the weight of the seeds dissolved, the strength of the stock solution was determined.

Powder of pads of Cactus opuntia
Cactus opuntia pads were purchased from the nursery at Bhagur, Nasik, India. They were stored in the refrigerator at 4°C. Pads were initially washed with water and skin was peeled from the pad. The outer pad was considered the outer layer of bright green tissue composed of chlorenchyma and the inner pad was considered the inner layer of off-white tissue composed of parenchyma.⁷ The inner pads were then sliced into small pieces to facilitate drying. The sliced cactus was kept in oven at 80°C for 8 hours to dry. The dried cactus was ground into fine powder using mixer and subsequently sieved to sizes 53-106µm.

Powder of mucilage extracted from the fruits of Coccinia indica
Coccinia indica ripped fruits were purchased from the market at Nasik Road, Nasik, India. They were collected from the market and thoroughly washed with water, cut into small pieces and soaked in distilled water overnight. The mucilaginous extract was filtered through muslin cloth. Alcohol was added to precipitate the extract.⁸ The precipitate was then washed with acetone 2-3 times and then dried by keeping in an oven at the temperature of 40°C for 24 hours. The filtered extract was then used in the experiment. Alum is a most commonly used coagulant in some rural areas of India. The alum used in this study was reagent grade aluminium sulphate Al₄(SO₄)₃, 16H₂O. It was supplied by Space Laboratories Ltd, Ambad and Nasik, India.

The various chemicals used in this study are alum, acetone and alcohol to obtain coccinia indica powder and Kaolin powder to obtain turbid water samples of required turbidity.
They were purchased from Space Laboratories Ltd, Ambad, and Nasik, India.

**Laboratory scale sand filter**

A Perspex transparent column having an internal diameter of 50mm and length 1000mm was used to prepare the filtration assembly. This filtration assembly was purchased from Space Laboratories, Ambad at Nasik by giving the order with design specifications. The sand and gravel of 300mm and 200mm depth were collected from the construction worksite of COE, Kopargaon.

In this column, the sand of 300mm depth was supported by 200mm gravel. The sand used to prepare the filter had the effective size ($d_{10}$) of 0.45mm and ($d_{60}$) size of 0.62mm, uniformity coefficient (U.C) of 1.3555, specific gravity of 2.65 and porosity of bed as 0.445. Two 10mm diameter flexible transparent tubes were used as piezometric tubes and were inserted at depths of 550mm and 700mm from the top of the column. The supernatant from the coagulation-flocculation-sedimentation stage was used as an influent to the filter using peristaltic pump at a steady flow rate of 5m/h. Prior to each filter run the sand and gravel beds have been cleaned.

**Experimental procedure**

Synthetic turbid water of high turbidity (192NTU) was taken in 500ml capacity beakers of 7 numbers and was used in standard jar test apparatus. Pre-determined optimum doses of coagulant were added and stirred approximately 100 rpm for 1 minute. The rapid mix stage helps to disperse the coagulant throughout each container. At the end of rapid mixing period slow mixing was continued at 5 to 35 rpm for 20 minutes. This slower mixing speed helps to promote floc formation by enhancing particle collisions which lead to larger flocs. After slow mixing, the beaker were carefully removed from the jar test set up and the contents left to settle for 30 minutes. These jar testing criteria were established from a preliminary study. The supernatant from the settled water was filtered through Whatman No. 40 filter paper or through a laboratory sand filter. Filter paper used to establish the optimum doses of each coagulant for initial screening studies. After determining the optimum dose, a sand filter run was conducted at optimum dose. Turbidity and head losses were measured at intervals of 30 minutes throughout the filter run.

To ensure a proper compaction and cleanliness of the filter bed, clean bed head loss was determined by Carman-Kozeny equation modified by Fair and Hatch and the computed value (1.84 cm per 5cm depth of sand) was verified with actual clean filter bed head loss before commencement of the filter run. To monitor the head loss development head losses at 5cm filter bed depth were recorded at regular intervals and filtered water quality was monitored. (Fig. 1).

**RESULTS AND DISCUSSION**

Sand filtration with *Strychnos potatorum* seeds as coagulant

Fig. 2 shows the filtration characteristics of *Strychnos potatorum* seeds dosed at 1.5mg/l. The initial turbidity 14 NTU reduced to 0 NTU after 30 minutes settling. It was this supernatant that was filtered at the flow rate of 5 m/h. Filtrate turbidity attained a value of 5 NTU from the beginning indicating that ripening of the filter was quite rapid. *Strychnos potatorum* seed extract is an anionic poly-electrolyte which
contains carboxyl (COO\(^-\)) and hydroxyl (OH\(^-\)) as main active groups. It also contains proteins, alkaloids, carbohydrates and lipids\(^{9,10}\). The presence of divalent cations in water can greatly increase the ability of anionic polyelectrolyte to aggregate negative colloids\(^{11}\). The seeds of \textit{S. potatorum} also contain strychnine which was supposed to be responsible for the coagulating properties\(^{9,12}\). The filtrate turbidity at the beginning of the filter run was 5 NTU and it decreased to 2 NTU after 90 minutes and remained the same up to 150 minutes. After 150 minutes, the filtrate turbidity started to decrease again and attained a value of 0 NTU at 210 minutes. It can be observed from the figure that the head loss profile increases with filter run up to 120 minutes. This showed that most of the flocs/particles were retained in the top 5cm layer with no or very little penetration of flocs in the lower layers. The profiles started to diverge after 120 minutes indicating deposition/penetration of flocs below a 5cm depth which was an indication of turbidity breakthrough.

**Sand filtration with Cactus opuntia pads as coagulant**

Fig.3 shows the filtration characteristics of \textit{Cactus opuntia} pads dosed at 30mg/l. The initial turbidity 17 NTU reduced to 6 NTU after 30 minutes settling. There was rapid ripening of filter and the filtrate turbidity obtained a value of 6 NTU at the beginning. Previous studies have established that mucilage in \textit{Cactus opuntia} contains carbohydrates such as L-arabinose, D-galactose, L-rhamnose, D-xylose and galacturonic acid\(^{13-15}\). Zimmerman and co-researchers recently report that galacturonic acid is possibly the active ingredient that affords the coagulation capability of \textit{Opuntia sapp}. through it should be noted that it only accounts for only 50% of turbidity removal. Nonetheless this is still a significant percentage and therefore, this compound was evaluated by further on its contribution to the overall coagulating capability. They suggest that \textit{Opuntia Sp.} Operates predominantly through a bridging coagulation mechanism where solution particulates do not directly contact one another but are bound to a polymer like material that originates from the \textit{Cactus} species. Galacturonic acid was also reported by Japanese researchers. All these studies point to the importance of galacturonic acid which possibly acts as one of the major active coagulating agents in plants. The filtrate turbidity at the beginning of the filter run was 6 NTU and it decreased to 3 NTU after 90 minutes and remained the same up to 150 minutes. After 120 minutes, the filtrate turbidity started to decrease again and attained a value of 0 NTU at 210 minutes. It can be observed from the figure that the head loss profile increases with filter run up to 120 minutes. This showed that most of the flocs/particles were retained in the top 5cm layer with no or very little penetration of flocs in the lower layers. The profiles started to diverge after 120 minutes indicating deposition/penetration of flocs below a 5cm
Fig. 3: Filtrate turbidity and head loss for Cactus Opuntia depth. This is also an indication of turbidity breakthrough. 

**Sand filtration with mucilage extracted from the fruits of coccinia indica as coagulant**

Fig. 4 shows the filtration characteristics of Coccinia indica dosed at 0.5 mg/l. The initial turbidity 13 NTU reduced to 5 NTU after 30 minutes settling. There was rapid ripening of filter and the filtrate turbidity obtained a value of 5 NTU at the beginning. The filtrate turbidity at the beginning of the filter was 5 NTU and it decreased to 2 NTU after 120 minutes and remained the same up to 150 minutes. After 150 minutes, the filtrate turbidity started to decrease again and attained a value of 0 NTU after 210 minutes.  

The Coccinia indica fruit extracts are also anionic polyelectrolytes that destabilize particles in water by means of interparticle bridging. Previous studies by Syed et al. indicate that the fruit extract contains alkaloids, tannins, saponins, flavonoids, glycosides and phenols. The presences of alkaloids containing COOH and OH surface groups present in Coccinia indica fruits enhance the coagulation capability. The natural anionic polysaccharide present in Coccinia indica mucilage is found to be a very effective floculent capable of reducing turbidity from turbid water samples. These anionic polymers present in the mucilage make larger flocs with suspended
particles in the turbid water by bridging mechanism, finally settled them down and can be easily removed from turbid water.26-32

CONCLUSION

After carrying out the study the following conclusions were made. All the three natural coagulants are more effective for turbidity removal and among them, Coccinia indica proved to be more effective with less dosage of 0.5mg/l. The filtered water turbidity obtained when Strychnos potatorum, Cactus opuntia and Coccinia indica were used as coagulant was approaching zero NTU for Strychnos potatorum and one NTU in the case of Cactus and Coccinia indica. Head loss development in filtered bed with time was more in the case of Strychnos potatorum in comparison with Cactus opuntia and Coccinia indica.

The filtrate turbidity approaches the values of 0 NTU, 1 NTU and 0NTU in the case of Strychnos potatorum, Cactus opuntia and Coccinia indica respectively. The turbidity value recommended by WHO for drinking water is <5NTU. Since the turbidity values obtained was lesser than 5 NTU, we can conclude from this study that all the three natural coagulants can be used efficiently for turbid water treatment.

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REFERENCES

15. Gidde M.R. and Bhalerao A.R., Optimisation of physical parameters of