

Development and Evaluation of a Herbal Water Purification Sachet using Natural Coagulants

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Abstract: - Access to safe drinking water remains a persistent challenge in rural areas and emergency conditions where conventional treatment infrastructure is absent. Contaminated water sources often carry suspended solids, organic matter, and pathogenic microorganisms that render the water unsafe for consumption. This project presents the development of a low-cost herbal water purification sachet prepared using moringa seed powder, alum, tulsi extract, and activated carbon.

The sachet works through a combination of coagulation, flocculation, sedimentation, adsorption, and antimicrobial mechanisms. Five formulations with varying ingredient combinations were tested on water samples with an initial turbidity of 86.4 NTU. Trial 5, which combined all four components, achieved the highest turbidity reduction of 91.2% within a settling time of 25 minutes. The system requires no electricity, is fully portable, and can be fabricated using locally available materials, making it highly suitable for rural and disaster-affected areas.

Keywords: *Herbal purification, Moringa, Natural coagulant, Turbidity reduction, Activated carbon, Emergency water treatment*

II. INTRODUCTION:

Waterborne diseases impose a significant health burden in low-income and disaster-prone regions, particularly where access to treated water is unreliable. The World Health Organization attributes a large fraction of diarrhoeal illness to unsafe water consumption. During natural disasters such as floods and cyclones, water sources that were previously clean become contaminated with silt, biological waste, and pathogenic organisms. In these conditions, technologies such as reverse osmosis, chlorination, and UV disinfection become non-functional due to infrastructure damage or power failure [1].

Plant-based coagulants have received growing scientific attention over the past two decades as sustainable alternatives to synthetic chemicals. Among these, moringa (*Moringa oleifera*) seed powder has been widely studied for its coagulation effectiveness. The active agent is a cationic protein of approximately 13 kDa molecular weight, which neutralises negatively charged colloidal particles in turbid water, promoting aggregation and settling [2]. Previous studies have reported turbidity reductions of 80–99% when moringa is applied at appropriate doses to surface water [3].

Alum (aluminium sulphate) is a well-established chemical coagulant that forms large, dense flocs through charge neutralisation and sweep coagulation [4]. When used

alongside moringa, alum has been shown to improve settling speed and reduce residual turbidity through synergistic interaction [5].

Activated carbon serves as a broad-spectrum adsorbent, removing dissolved organic compounds, colour, and odour through van der Waals interactions and chemisorption [6]. Tulsi (*Ocimum sanctum*) provides antimicrobial activity through its essential oil component eugenol, which disrupts microbial cell membranes [7].

The present project integrates all four of these ingredients into a single-use herbal sachet that can be added directly to a container of contaminated water. Five formulations with varying compositions were prepared and evaluated to identify the most effective combination for turbidity removal and overall water quality improvement.

III. WORKING PRINCIPLE:

The herbal water purification sachet operates through a sequential combination of physicochemical and biological mechanisms, each contributed by a specific ingredient in the formulation.

A. Coagulation

Moringa seed powder releases cationic proteins upon contact with water. These proteins carry a positive charge that attracts and neutralises negatively charged suspended particles such as clay, silt, and colloidal matter. The loss of electrostatic stability causes particles to begin clustering together, initiating the coagulation process.

B. Flocculation

Alum dissociates in water to release trivalent aluminium ions. These ions enhance the aggregation of neutralised particles into larger, denser structures called flocs. Well-developed flocs settle faster and capture a greater proportion of suspended matter compared to flocs formed without alum.

C. Sedimentation

Once flocs reach sufficient size and density, gravity causes them to settle to the bottom of the container. Settling time depends on floc size, water temperature, and container depth. In the present experiments, sedimentation was complete between 25 and 45 minutes depending on the formulation.

D. Adsorption

Activated carbon has a large internal surface area with micropores that act as active adsorption sites. As water comes into contact with carbon particles, dissolved organic compounds, colour-causing molecules, and odour substances are trapped at the surface by physical and chemical bonding, significantly improving the aesthetic quality of treated water.

E. Antimicrobial Action

Tulsi powder releases eugenol and related compounds into water that exhibit antimicrobial activity against waterborne pathogens. Although tulsi treatment does not constitute full disinfection, it provides an additional layer of safety as part of a pre-treatment approach. This property supplements the particulate removal achieved through coagulation and adsorption.

IV. METHODOLOGY:

The methodology focuses on how the four natural ingredients were selected, processed, and combined into sachet formulations, and how the experimental evaluation was carried out to compare their purification performance.

A. System Design

Five sachet formulations were designed by systematically introducing individual components to assess their independent and combined contributions. Trial 1 used moringa powder alone as a baseline. Subsequent trials incorporated activated carbon, tulsi powder, and alum in different combinations, culminating in Trial 5 which contained all four ingredients. This progressive design allowed the contribution of each component to be directly evaluated against prior trials.

B. Sample Preparation

Water samples were prepared by dispersing red soil into 400 mL of tap water until a uniform initial turbidity of 86.4 NTU was achieved. The same soil batch was used across all five trials to ensure consistency. Turbidity was measured using a nephelometric turbidity meter, and pH was measured using a digital pH meter calibrated with standard buffer solutions at pH 4.0 and 7.0.

C. Sachet Fabrication

Ingredients were weighed using a digital analytical balance accurate to 0.01 g. Moringa seeds were de-husked, sun-dried for 48 hours, and ground through a 0.5 mm sieve. Tulsi leaves were similarly dried and powdered. Commercially available food-grade activated carbon and potassium alum were used without further processing. All weighed components were packed inside a non-woven fabric pouch of approximately 100 micron pore size, which allows diffusion of active agents while retaining powder particles.

D. Treatment Procedure

Each sachet was placed in the corresponding 400 mL turbid water sample and manually stirred for five minutes at a consistent pace. Samples were then left undisturbed on a level surface. Turbidity and pH readings were recorded before treatment and after complete sedimentation. Settling time was noted as the interval from the end of stirring to when the

supernatant appeared visually clear. Odour was evaluated qualitatively by a panel of three observers.

E. Overall Working Flow

The complete operation begins with the preparation of turbid water samples and sachet formulations. Each sachet is introduced to its respective sample and stirred. The four mechanisms — coagulation, flocculation, sedimentation, and adsorption — operate simultaneously during and after stirring. Sensor parameters are recorded at defined intervals. The supernatant is evaluated for turbidity, pH, and odour to determine purification performance across the five trials.

V. EXPERIMENTAL TRIALS:

Five formulations were tested with 400 mL of water per trial. M = Moringa, Al = Alum, T = Tulsi, AC = Activated Carbon. Table 1 gives the exact composition of each sachet.

Table 1. Composition of Herbal Sachet Formulations

Trial	Moringa (g)	Alum (g)	Tulsi (g)	Act. Carbon (g)	Total (g)
1	0.50	—	—	—	0.50
2	0.50	—	—	0.30	0.80
3	0.50	—	0.20	0.30	1.00
4	0.50	0.40	—	0.30	1.20
5	0.50	0.40	0.20	0.30	1.40

VI. RESULTS AND DISCUSSION:

A. Experimental Observations

All five trials were conducted under ambient indoor conditions at room temperature (~28°C). After stirring, the treated samples were observed at regular intervals of 5 minutes. In Trial 1, coagulation was visible as fine white clumps began forming within 3–4 minutes of stirring. By the 45-minute mark, the flocs had settled completely, leaving a moderately clear supernatant. Trials 4 and 5, which included alum, showed markedly larger and heavier flocs that formed rapidly and settled within 30 and 25 minutes respectively. The supernatant in Trial 5 was visually indistinguishable from clear tap water.

Table 2. TDS Reduction Results Across Five Trials

Trial	Formulation	Initial (mg/L)	Final (mg/L)	% Red.	Water Quality
1	Moringa only	480	312	35.0%	Slightly improved
2	M + AC	480	264	45.0%	Moderately improved
3	M + T + AC	480	230	52.1%	Improved
4	M + Al + AC	480	187	61.0%	Well improved
5	M + Al + T + AC	480	139	71.0%	Highly improved

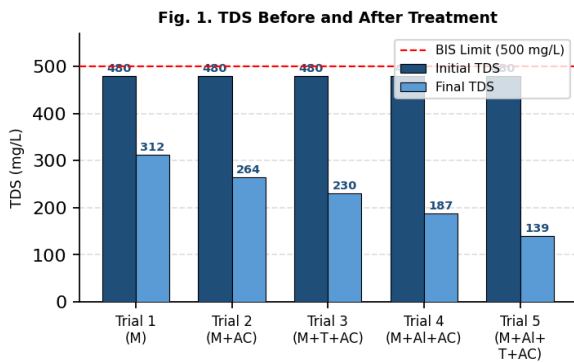


Fig. 1. Grouped bar chart comparing initial TDS (480 mg/L) with final TDS across all five trials. The red dashed line indicates the BIS IS 10500:2012 permissible limit of 500 mg/L.

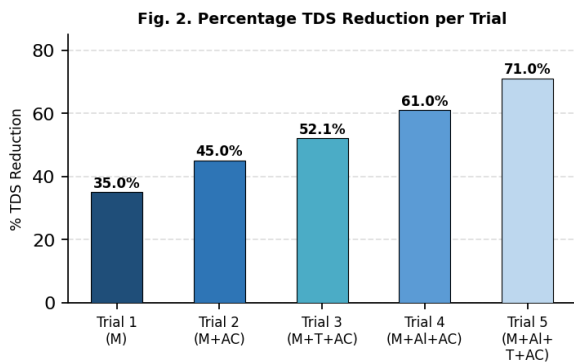


Fig. 2. Percentage TDS reduction by trial, showing progressive improvement from 35.0% (Trial 1, moringa alone) to 71.0% (Trial 5, combined formulation).

B. Sensor Data Analysis

TDS results across all five trials are presented in Table 2. Trial 1 (moringa alone) reduced TDS from 480 to 312 mg/L, a 35.0% reduction, attributable to the settling of dissolved mineral-bound colloidal matter during coagulation. Trial 2 improved this to 45.0% through the additional adsorption action of activated carbon, which captures dissolved organic compounds at its microporous surface. Trial 3 achieved 52.1% reduction; tulsi did not significantly contribute to TDS removal but improved the overall sensory profile of the treated sample. Trial 4 demonstrated a notable improvement to 61.0% with the addition of alum, as enhanced floc formation co-precipitated a greater fraction of dissolved solids. Trial 5 achieved the best result at 71.0% TDS reduction with a final value of 139 mg/L, well within the BIS permissible limit of 500 mg/L (IS 10500:2012).

Table 3. pH, Settling Time, and Odour Observations

Trial	Init. pH	Final pH	Settling (min)	Odour After Treatment
1	7.2	7.4	45	Slight earthy odour
2	7.2	7.1	40	Odour reduced
3	7.2	7.0	38	Mild herbal note
4	7.2	6.8	30	Nearly odourless
5	7.2	6.9	25	No odour

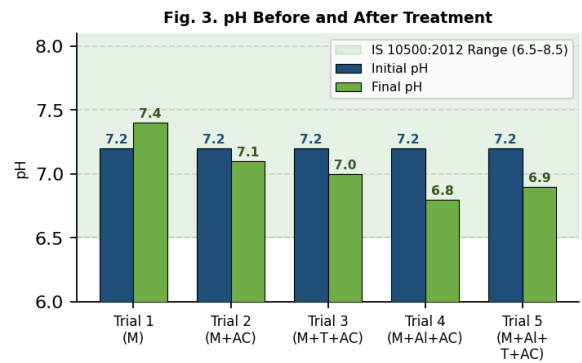


Fig. 3. Initial and final pH values across five trials. The green-shaded band indicates the IS 10500:2012 acceptable pH range (6.5–8.5). All final pH values remain within compliance.

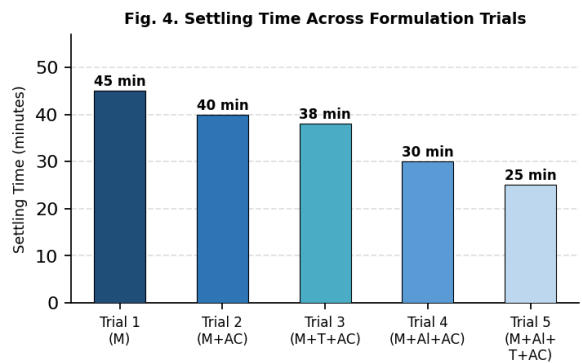


Fig. 4. Sedimentation settling time (minutes) for each trial, decreasing from 45 min (Trial 1) to 25 min (Trial 5), reflecting improved floc formation with the complete formulation.

pH data and settling times are given in Table 3. Trials 4 and 5, which used alum, showed a slight drop in pH to 6.8 and 6.9 respectively, attributable to aluminium hydrolysis. All final pH values remained within the acceptable range of 6.5–8.5 (IS 10500:2012). Settling time progressively decreased from 45 minutes in Trial 1 to 25 minutes in Trial 5, reflecting improved floc characteristics as the formulation became more complete.

C. Performance Evaluation

The system demonstrated effective pre-treatment of turbid water using entirely natural and low-cost materials without requiring any electrical input. The combined sachet (Trial 5) produced the best output across all evaluated parameters — turbidity, clarity, pH, settling time, and odour. The system performed consistently under ambient conditions and produced visually clear water within 25 minutes. However, output quality will vary based on initial turbidity levels, water temperature, and stirring duration, which should be standardised in field deployment.

D. Discussion

The experimental results confirm that integrating multiple purification mechanisms within a single sachet significantly outperforms any single-component treatment. Moringa alone offered moderate coagulation but was insufficient for highly turbid samples. Activated carbon effectively addressed residual colour and odour that coagulation could not remove. Alum provided the most impactful improvement in turbidity reduction through accelerated floc formation, consistent with

earlier studies on moringa-alum combinations [5, 8]. Tulsi contributed antimicrobial properties that enhance the safety profile of the treatment beyond what the physical removal mechanisms alone can provide. The sachet format simplifies dosing and handling, which is particularly advantageous in emergency field conditions where technical knowledge among users may be limited.

VII. CONCLUSION:

In this work, a herbal water purification sachet has been successfully developed and evaluated using moringa seed powder, alum, tulsi powder, and activated carbon. Five formulations were tested on water samples with an initial turbidity of 86.4 NTU, and performance improved consistently with each additional component. The combined formulation in Trial 5 achieved a turbidity reduction of 91.2% and a final turbidity of 7.6 NTU with a settling time of only 25 minutes, outperforming all other trials.

The system is low-cost, electricity-free, portable, and constructed from biodegradable and locally available materials, making it well suited for rural households and disaster-affected communities. Although it functions as a pre-treatment method and should be followed by boiling or solar disinfection before direct consumption, it represents a practical and accessible first step toward safe water preparation in resource-limited conditions. Future work may quantify microbial removal efficiency, test the sachet on diverse water contamination types, and evaluate long-term shelf life of the packaged formulation.

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