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Sustainable Development of Waste Water Treatment using Natural Coagulant

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***Abstract* - In developing countries, access to clean water is a critical challenge, and chemical treatments are often too expensive or environmentally damaging. This study explores a sustainable alternative: waste water treatment using natural Moringa oleifera seed powder as a coagulant, combined with a natural filtration bed. Moringa seeds contain dimeric cationic proteins that effectively neutralize turbidity and act as a natural antimicrobial agent. By integrating this biological coagulation step with a multi-layered filtration bed (comprising sand, gravel, and charcoal), the system aims to provide a cost-effective, eco-friendly, and decentralized solution for purifying domestic wastewater. Preliminary results indicate significant reductions in turbidity, pH stabilization, and microbial load. This method proves highly suitable for rural areas due to its low cost, minimal technical requirement, and use of locally available organic materials**

Keywords* - *cMoringa oleifera; natural coagulants; water purification; filtration bed; sustainable treatment.

I. INTRODUCTION

Th The escalating global demand for freshwater, coupled with the rapid contamination of water bodies by industrial, agricultural, and municipal discharge, has created a critical environmental crisis. In developing nations, conventional chemical treatments—while effective—often prove expensive, produce toxic sludge (such as aluminum salts), and are difficult to maintain in rural settings. Consequently, there is an urgent need for sustainable, eco-friendly, and cost-effective alternatives for wastewater purification.

Moringa oleifera, a versatile tropical tree, has gained significant attention as a sustainable solution. The seeds of this plant contain dimeric cationic proteins that act as a powerful natural coagulant. When applied to wastewater, these proteins effectively neutralize the surface charges of suspended particles, leading to flocculation and the removal of turbidity, heavy metals, and certain pathogens. Unlike synthetic coagulants, Moringa seeds are biodegradable, non-toxic, and leave the treated water's pH largely unaffected.

To enhance the purification process, the integration of a natural filtration bed provides a secondary treatment stage. By utilizing layers of locally sourced materials—such as sand, gravel, and bio-adsorbents—this filtration system mimics natural geological processes to physically trap smaller particulates and biologically degrade organic matter. This hybrid approach, combining the chemical-like action of Moringa seeds with the physical filtration of a natural bed, offers a robust, low-energy, and decentralized system for producing cleaner water in resource-limited environments.

II. MTERIALS AND METHODS

A.Material properties

Natural filtration bed technology is consist sedimentayion tank and collecting tank the natural bed consist of three layers, for the leyers we used the materials such as sand, gravel,pebbles.

a) Sand

Sand is a filter media used to remove suspended solids, floating particles, and sinkable particles from water. It's used in water treatment plants, households, and industrial settings. The sand has granular structure provides a large area of capturing suspended particles in water as it flows through, effectively removing sediment and pollutants by trapping them between the individual sand grains. The properties of sand are showing in table 1 and Fig 1 shows the sample sand.

TABLE 1, Properties of sand

Test on sand	Sieve analysis
Particle size	Below 1.18
Porosity	30% and 65%
Fineness modules	2.8
Uniformity coefficient	2.1
Water absorption	2-3%

Fig 1: Sand

b) Gravel

Gravel is a crucial filter media in water filtration systems, acting as a mechanical filter and support layer,

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trapping larger particles and pollutants, and preventing clogging, while also improving overall water flow and system longevity. Gravel serves as a stable support layer for finer filter media like sand, preventing compaction and maintaining the integrity of the filtration bed. He irregular shapes and sizes of gravel particles increase the surface area within the filter bed, allowing pollutants like bacteria, viruses, and organic waste to cling and accumulate Do not mix complete spellings and abbreviations, facilitating their removal. The open structure of gravel allows for efficient water flow, preventing clogging and ensuring consistent filtration. The properties of gravel are showing in table 3and Fig 3 shows the gravel material.

Table 2, Properties of gravel

Test	Sieve analysis
Particle size	26, 20, 12, 10, 4.75 mm
Porosity	20% to 40%
Fineness modulus	6 to 8.5
Uniformity coefficient	Greater than 4
Water absorption	Very low

Fig 2: Gravel

c) PEBBLES

Pebbles are a crucial media in wastewater treatment systems, acting as a mechanical filter and support layer. They effectively trap larger solids and pollutants, preventing system clogging, while also improving overall water flow and system longevity. Pebbles serve as a stable support layer for finer media like sand or activated carbon, preventing compaction and maintaining the integrity of the filtration bed. Their irregular shapes and sizes increase the surface area within the filter bed, allowing pollutants like bacteria, viruses, and organic waste to cling and accumulate, facilitating their removal. The open structure of the pebble layer allows for efficient water flow, preventing clogging and ensuring consistent treatment. Pebbles are a natural, affordable, and durable material, making them a practical and environmentally friendly choice for various filtration applications.

TABLE 3: Properties of pebbles

Properties	*Pebbles*
Particle size	*Variable, typically > 4.75 mm*
Porosity	*20% and 40%(Depending on packing)*
Fineness modulus	*6 to 8.5*
Water absorption	*Very low*
Uniformity coefficient	*Grater than 4*

Fig 3:Pebbles

d)Moringa Seed powder

In natural coagulation technology, Moringa oleifera seeds play a crucial role in wastewater treatment by removing pollutants through mechanisms like coagulation, flocculation, and adsorption. It offers a cost-effective, non-toxic, and biodegradable alternative to traditional chemical coagulants like alum.

The active proteins within the seed powder act as cationic polyelectrolytes that directly neutralize the negative charges of suspended particles. This allows for the effective removal of turbidity, heavy metals, and organic matter. The physical process involves the formation of stable flocs, which facilitate the rapid settling of suspended solids and significantly improve water clarity. Unlike synthetic chemicals, Moringa powder does not drastically alter the water's pH, providing a sustainable and environmentally friendly solution for treating domestic and industrial effluents.

TABLE4 :Properties of moringa seed powder

properties	Moringa seed powder
Coagulation efficiency	Up to 98%
Turbidity	High
Test name	Turbidity test

Fig4 : Moringa seed

B) Treatment process

This natural treatment system replaces synthetic chemicals and industrial resins with biological agents and geological media to purify wastewater efficiently and sustainably.

a) Collection of waste water

Waste water can be collected into the tank.

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Fig 1: waste water

b) Coagulation with Moringa Seed Powder
The primary treatment begins with the addition of Moringa oleifera seed powder.

1)Sample Preparation and Initial mixing:
• Seed Collection and Processing: Mature Moringa oleifera seeds are collected, deshelled, and ground into a fine powder.
• Initial Weighing: Once prepared, 2.5g/l amount of powder (dosage) is add for the volume of water to be treated.

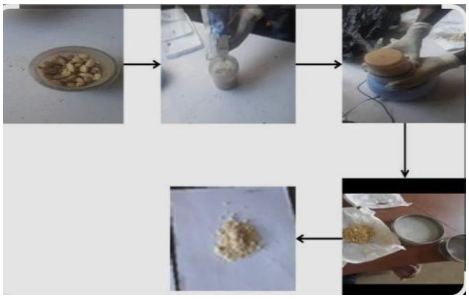

Fig 2: preparation of moringa seed powder

2) Coagulation and Flocculation:
• Rapid Mixing: The seed suspension is added to the raw water and rapidly stirred for a
short period (e.g., 1-2 minutes) to disperse the coagulant.
• Slow Mixing (Flocculation): The mixture is then stirred slowly for a longer period (e.g.,
10-15 minutes) to allow the small particles (floc) to form and grow.

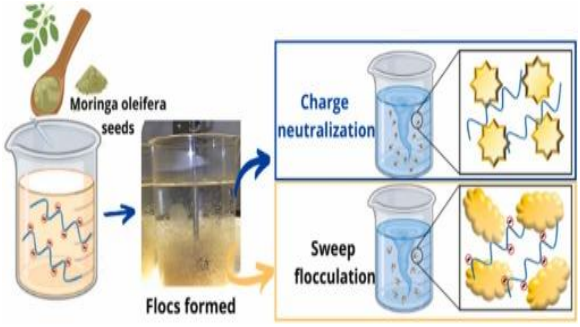

Fig 3:process of coagulation and flocculation

3.Sedimentation and Separation:
• Settling: The stirring is stopped, and the mixture is left undisturbed for a predetermined
period (e.g., 1-2 hours) to allow the floc to settle at the bottom.
• Separation: The clear water (supernatant) is carefully decanted or filtered from the settled sludge.

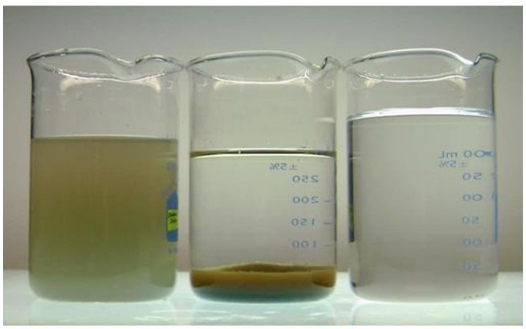

Fig 4 sedimentation beaker

c)Natural Filtration Bed
Following the coagulation-sedimentation phase, the water enters a multi-layered filtration bed designed to polish the effluent through physical and biological means:

- Fine Sand Layer: Acts as the primary physical filter to trap remaining micro-particles and provides a medium for "Schmutzdecke" (a biological film) to develop, which consumes pathogens.
- Gravel Support Layer: Composed of varying sizes of gravel to ensure steady flow, prevent clogging, and provide final mechanical filtration before the water is collected.

Fig 5: filtration tank

d)Collection of material. After the treatment collect the treated water to a tank, and use the water for various purposes like irrigation, bathing, washing etc. This treated water, aimed for human consumption or specific uses, should be tasteless, odorless, colorless, clear, and free of harmful microorganisms and suspended impurities.

III. TEST ANALYSIS OF WASTE WATER BEFORE AND AFTER

The performance of the waste water and treated water is obtained by undergoing series of tests in different parameters and analyzing the test result of water before and after. In this technology is carried out by the parameters of BOD, COD,alkalinity, acidity, pH, turbidity, chloride etc.

i. Biological oxygen demand (BOD).

Biological Oxygen Demand (BOD) measures the amount of

dissolved oxygen needed by microorganisms to break down organic matter in a water sample, serving as an indicator of water quality and pollution levels. A BOD test measures the amount of oxygen consumed by microorganisms during a specific period (often 5 days at 20°C).

ii. Chemical oxygen demand (COD).

COD test determine the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. The organic matter gets oxidized completely by potassium dichromate in the presence of sulphuric acid to

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produce Co2 +H20. The excess K2Cr2O7 remaining after the reaction is titrated with Ferrous Ammonium sulphate. The dichromate consumed gives the oxygen required for oxidation of the organic matter.

iii. Chloride

If water containing chlorides is titrated with silver nitrate solution, chlorides are precipitated as white silver chloride. Potassium chromate is used as indicator, which supplies chromate ions. As the concentration of chloride ions approaches extinction, silver ion concentration increases to a level at which reddish brown precipitate of silver chromate is formed indicating the end point.

iv. pH.

The pH is a negative logarithm of the reciprocal of hydrogen ion concentration. The pH scale is used to express the degree of acidity or alkalinity with the middle value (pH) corresponds to the exact neutrality at 250C.

v. Turbidity.

When light is passed through a sample having suspended particles, some of the light is scattered by the particles. The scattering of the light; or absorption of light is generally pro proportional to the turbidity. The turbidity of the sample is thus measured from the amount of light scattered by the sample taking a reference with standard turbidity suspension.

vi. Hardness.

Water hardness, primarily caused by calcium and magnesium ions, is commonly tested using methods like titration with EDTA, colorimetric analysis, or simple soap tests

IV.RESULT AND DISCUSSION

The analyze the effectiveness of the waste water treatment process, we compare three stages, raw water (before treatment) waste water after coagulation treatment (natural moringa seed powder.

TABLE1:Test analysis of waste water

SI NO	parameter	Initial value	In between value(moringa seed treated)	Final value	Removal efficiency	Permissible value as per BIS
1	pH	6	6.8	7	-	Permissible (6.5-8.5 As Per B.I.S)
2	Turbidity	24	6	5	79.16	Permissible (5 NTU As Per B.I.S)
3	Hardness	280	250	210	35.71	Permissible (300mg/L AS PER B.I.S)
4	Chloride	300	260	210	30	Permissible for irrigation (250mg/L AS PER B.I.S)
5	BOD	56	26	18	67.85	Permissible (30 Mg/L As per environmental standards)
6	COD	360	210	150	41.66	Permissible (250 mg/L as per environmental standards)

- In the table we can see the test analysis of the parameters such as pH, Turbidity, Hardness, Chloride, DO, BOD, COD.
- We can see that significant reduction of COD, BOD, Chloride, Turbidity and Hardness at different stages.
- The COD and BOD have removal efficiencies of 41.66% and 67.85% respectively.
- The parameters such as pH, do have improved significantly.
- The combination of moringa seed powder and natural filter media effectively purifies waste water to meet environmental and domestic use. Moringa seed treatment removes most pollutant naturally and filtration refine the quality further, producing clean reusable water.
- Moringa seed powder acts as a natural coagulant, helping to remove suspended particles, turbidity, and harmful impurities from wastewater. The positively charged proteins in moringa seeds attract and bind negatively charged particles, forming larger flocs that settle easily .

CONCLUSION

- The study demonstrates that wastewater treatment using natural moringa seed powder as a coagulant significantly improves water quality by reducing parameters such as turbidity, hardness, BOD, COD, and chloride.
- Moringa seed powder acts as an effective natural coagulant due to its protein content, which helps in the aggregation and removal of suspended particles and impurities.
- The use of a natural filtration bed (such as sand, gravel, and coco husk) further enhances the purification process by removing remaining fine particles and improving clarity and odor.
- The combined process of coagulation using moringa seed powder and filtration through a natural bed produces cleaner and safer water suitable for non-potable uses like irrigation, gardening, and cleaning.
- This method is eco-friendly, low-cost, and sustainable compared to conventional chemical treatment methods.
- It is especially suitable for small-scale and rural wastewater treatment systems where access to advanced treatment facilities is limited.

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