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Design of Solar-Powered Coagulation Unit for Watermelon Seed Powder (*Citrullus lanatus*) Coagulant in Water Treatment

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Abstract

This study presents the design and testing of a solar-powered coagulation unit aimed at evaluating the efficacy of watermelon seed powder (WMSP) as a natural coagulant for raw water treatment. The system was fabricated using a 12mm thick transparent glass tank (51×46×46 cm), equipped with a 12V DC motor, solar panel, and stirrer system for coagulant mixing. Laboratory Scale experiments were conducted to determine the optimal coagulant dosage and pH using jar tests on medium turbid water from an abandoned well. The results showed that WMSP at 0.2 g/L dosage and pH 7.0 effectively reduced turbidity to 2.23 NTU and color to 15 TCU, meeting WHO standards for drinking water. This study confirms the potential of WMSP as a viable, eco-friendly alternative to alum in water treatment.

Keywords: Watermelon Seed Powder; Natural Coagulant; Solar-Powered Coagulation Unit; Water Treatment; Turbidity Removal

1. Introduction

Access to safe drinking water is a global challenge, particularly in developing countries where water treatment infrastructure is inadequate. Surface water sources are often contaminated with suspended solids and colloidal particles, especially during rainy seasons. Conventional treatment methods involve the use of chemical coagulants such as aluminum sulfate (alum), which, although effective, have raised concerns about health and environmental safety. Studies have associated high residual aluminum levels with neurodegenerative diseases such as Alzheimer's Adejumo *et al*. 2018. Additionally, these chemicals contribute to high sludge volumes and require complex handling. Natural coagulants derived from plants have been studied as safer alternatives. Moringa oleifera seeds, for example, have shown strong coagulation potential and are widely cited in literature for their effectiveness in treating turbid water Ali *et al.,* 2019 and Daniyan, et al., 2016. Other natural materials including mesquite beans, corn, red beans, and common legumes have demonstrated varying degrees of coagulation efficiency Mirjana *et al.,* 2017 and Arnoldsson *et al*., 2018.

Recent interest has turned to the use of watermelon (Citrullus lanatus) seed powder as a coagulant. These seeds, commonly discarded as waste, are rich in proteins that serve as active coagulating agents Muhammed *et al.*, 2015. In regions where watermelon is readily available, WMSP presents a low-cost, biodegradable, and sustainable alternative to alum.

Meanwhile, energy supply continues to be a barrier to widespread implementation of water treatment in off-grid communities. Solar power offers a sustainable solution, especially in sub-Saharan Africa where sunlight is abundant. A

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solar-powered coagulation unit combines environmental sustainability with technological innovation for decentralized water treatment (Seyrig and Shan, 2017).

This research aims to investigate the effectiveness of WMSP for turbidity and color removal in raw water, and to design a solar-powered coagulation unit suitable for use in rural and semi-urban areas.

2. Materials and Methods

2.1. Coagulation Unit Design

The coagulation unit was fabricated from 12 mm-thick transparent glass (51×46×46 cm), with a 12V DC motor mounted on top to drive a galvanized stirrer. The stirrer consisted of a 10 mm pipe rod with transverse flat plates for mixing. The system included a solar panel (15V), 12V battery, and manual switches for operation.

2.2. Preparation of Coagulant

Watermelon seeds were sourced locally, cleaned, sun-dried, shelled, and ground. Oil was extracted using a Soxhlet apparatus with n-hexane as the solvent. The defatted powder was sieved (355 μm) and used as the coagulant.

2.3. Water Sample Collection

Raw water was collected from an abandoned well within the Ladoke Akintola University of Technology (LAUTECH), Ogbomoso. The sample was classified as medium turbid water with an initial turbidity of 60.5 NTU.

2.4. Jar Test Procedure

Six 1-liter beakers were used to test different WMSP dosages: 0.2 g, 0.4 g, 0.6 g, 0.8 g, 1.2 g, and 1.4 g per liter. Rapid mixing was done at 150 rpm for 2 minutes, followed by slow mixing at 80 rpm for 8 minutes. The samples were left to settle for 15 minutes, then filtered. Parameters such as turbidity, pH, TDS, conductivity, and color were measured.

To test the effect of pH, six samples were adjusted to pH values between 6.0 and 8.5 using NaOH and H_2SO_4, keeping the WMSP dosage constant at 0.2 g/L.3. Results and Discussion

3. Results and Discussion

3.1. Proximate Composition of WMSP

The powder contained 27.6% protein, supporting its efficacy as a coagulant due to the active protein-based compounds.

3.2. Water Quality Analysis

Initial turbidity and color values of 60.5 NTU and 158 TCU respectively exceeded WHO limits (5 NTU and 15 TCU). Other parameters were within acceptable limits.

Table 1 Watermelon Seeds Proximate Analysis

Parameter	Values
Moisture	6.7 ±0.1
Protein	27.6±0.5
Fat	47.5±0.2
Ash	4.5±0.1
Crude fiber	3.4±0.1
Carbohydrate	9.6±0.2

Table 2 Initial Raw Water Properties

Parameter	Initial result	WHO Standard
Temperature (^{0}C)	25.7	25 - 30
Ph	6.72	6.5 - 8.5
Conductivity (µS/cm)	342	1400Max
Total dissolved solids (mg/L)	108	933Max
Turbidity (NTU)	60.5	5Max
Colour (TCU)	158	15Max

3.3. Coagulant Dosage Optimization

At 0.2 g/L, turbidity was reduced to 6.59 NTU and color to 30 TCU. Although turbidity exceeded WHO limits, this dosage was optimal based on efficiency and minimal sludge production.

Table 3 Water Coagulation Dosage

s/No	Dosage (g/L)	Temperature (^{0}C)	pH	Conductivity (µS/cm)	TDS (mg/L)	Turbidity (NTU)	Colour (TCU)
1	0.2	25.2	6.24	339	107	6.59	30
2	0.4	25.5	6.33	356	110	7.39	35
3	0.6	25.5	6.42	322	98	9.69	60
4	0.8	25.4	6.39	334	95	10.68	70
5	1.2	25.4	6.30	373	116	11.71	70
6	1.4	25.3	6.26	385	123	13.98	100

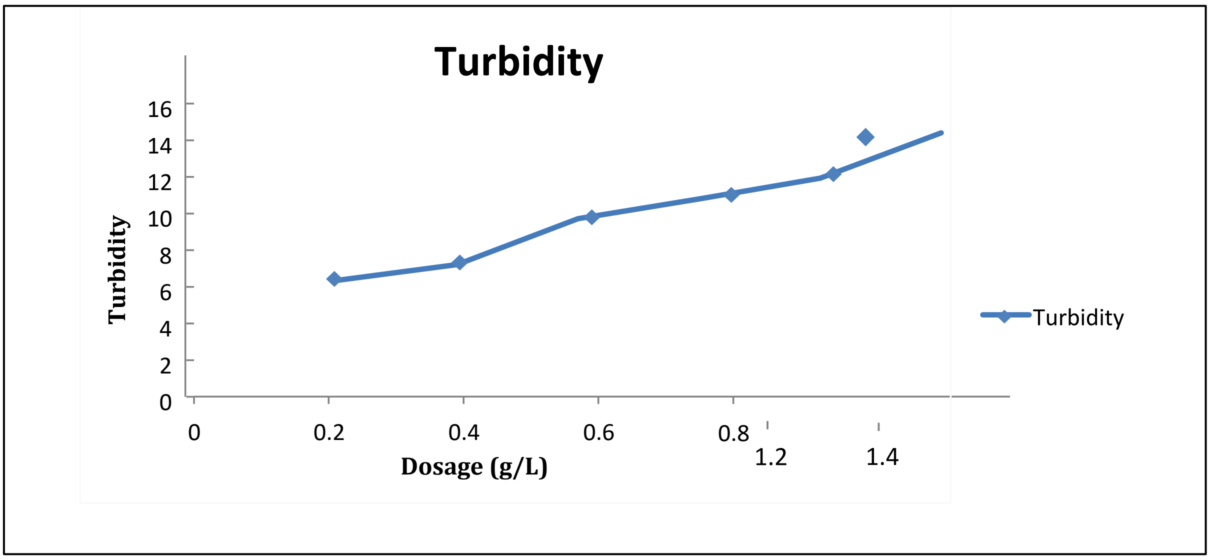

Figure 1 Graph showing the Effect of Coagulant dosage on Turbidity Removal

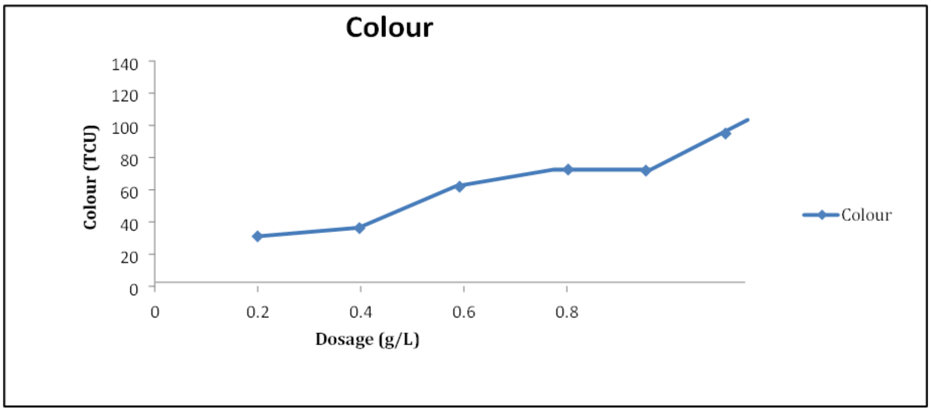

Figure 2 Graph showing the Effect of Coagulant Dosage on Colour Removal

3.4. pH Optimization

At constant 0.2 g/L dosage, pH 7.0 yielded turbidity of 2.23 NTU and color of 15 TCU, meeting WHO standards. This suggests that pH plays a vital role in enhancing coagulant performance.

Table 4 Effect of pH on coagulation results at dosage of 0.2 g/L of WMSP

s/No	pH	Temperature (⁰C)	Conductivity (µS/cm)	TDS (mg/L)	Turbidity (NTU)	Colour (TCU)
1	6.0	23.4	1726	863	3.28	20
2	6.5	23.7	1588	795	5.47	30
3	7.0	23.8	1660	831	2.23	15
4	7.5	23.6	351	177	3.13	20
5	8.0	23.7	406	203	2.69	25
6	8.5	23.6	413	206	3.76	35

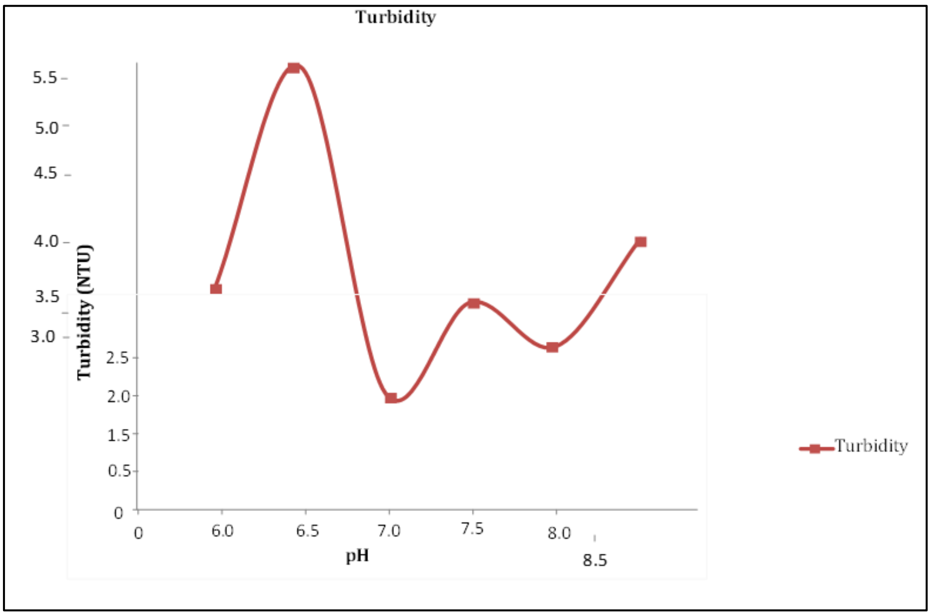

Figure 3 The effect of pH on Turbidity Removal

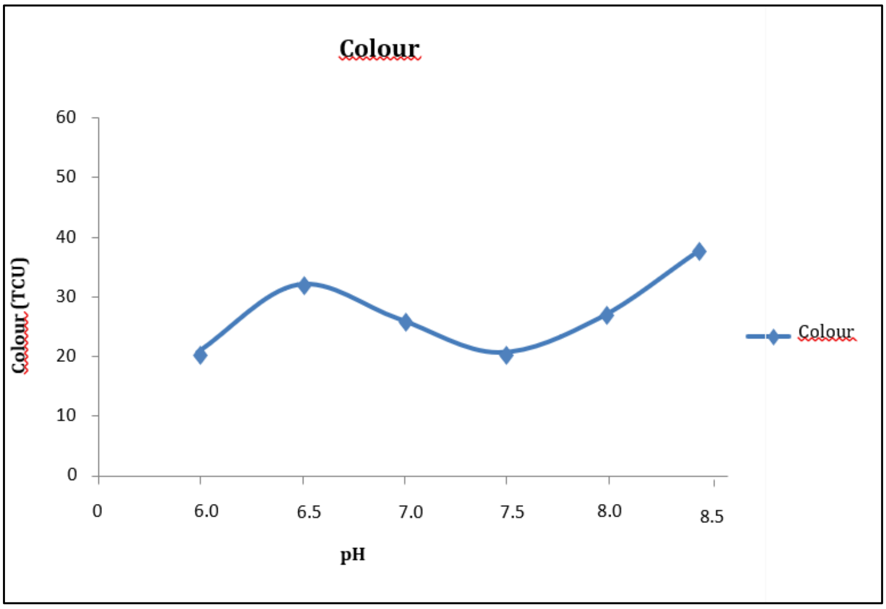

Figure 4 Graph showing the effect of pH on Colour Removal

4. Conclusions

This study demonstrated the feasibility of using watermelon seed powder (WMSP) as a natural coagulant for water treatment. The solar-powered coagulation unit was successfully fabricated and operated. Optimal performance was achieved at a WMSP dosage of 0.2 g/L and a pH of 7.0, reducing turbidity and color to within WHO standards.

WMSP should be promoted as a natural coagulant in rural areas where access to chemicals and treated water is limited.

The solar-powered unit can be adapted for larger community-scale water treatment.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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