International Journal of Advanced Scientific Research
www.allscientificjournal.com
ISSN: 2456-0421
Received: 12-10-2025, Accepted: 11-11-2025, Published: 25-11-2025
Volume 10, Issue 4, 2025, Page No. 111-114

Development of coagulants from *Piliostigma Thonningii* seeds for eco-friendly water purification

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Abstract
The search for sustainable alternatives coagulants has led to the use of plant-derived natural coagulants. This study investigates the development, characterization, and performance evaluation of coagulants extracted from *piliostigma thonningii* seeds for eco-friendly water purification. Fourier-transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) were employed for characterization, while key operational parameters including pH, coagulant dosage and settling time were optimized. Results revealed that the *piliostigma thonningii* seed coagulant achieved a turbidity removal efficiency of 91.6% at optimal conditions of pH 7 and 150 mg/L dosage. The FTIR spectra gave characteristic at 3432 cm^{-1} (O–H and N–H stretching), 1649 cm^{-1} (C=O stretching of amide), and 1052 cm^{-1} (C–O stretching) this confirmed the presence of amine, hydroxyl, and carboxyl functional groups associated with coagulation, while SEM showed a porous morphology suitable for adsorption. The coagulant demonstrated high removal of suspended solids (92%), color (85%), and heavy metals (Pb, Cd, Cr up to 78%). Biodegradability and toxicity assessments confirmed its environmental safety. The findings establish *piliostigma thonningii* seeds as a viable, less cost-effective, and sustainable natural coagulant for water purification.

Keywords: *Piliostigma thonningii*, natural coagulant, FTIR, SEM, eco-friendly water treatment, turbidity removal, heavy metal adsorption

Introduction

Water is one of the essential items needed for survival of living things and growth. It also maintains an ecological balance between various groups of organisms and their environment. Heavy metals are widely used in industries like paint, textile, steel fabricating industries etc. These industries discharge large quantities of toxic wastes and the untreated effluents from these industries when discharge into bodies of water without proper purification cause water pollution. A wide range of physical and chemical processes for the removal of these pollutants from such water, such as coagulation, ultrafilteration, adsorption, ion exchange, reverse osmosis, oxidation, ozonation are used to ensure proper treatment. Among these, the coagulation method has proven to be an excellent method to remove pollutants from contaminated water due to its advantages over other processes (Fernandez-kim, 2004). Conventional chemical coagulants, such as alum ($Al_2(SO_4)_3$) and ferric chloride ($FeCl_3$) course pollution, generate toxic sludge, and expensive (Adelodun & Choi, 2023) [1].

The development of natural coagulants has gained momentum as a sustainable alternative for water purification. These coagulants are biodegradable, locally available, and produce less sludge, low price, environmentally friendly and multifunction and biodegradable nature in water purification.

Piliostigma thonningii is a source of lignocellulose biomass which is growing abundantly on earth and is largely available as agricultural and forestry residues. The basic chemical component of lignocellulosic fibres are cellulose, hemi-cellulose, lignin. The cellulose consists of high molecular weight polymers of glucose that are held rigidly together as bundles of fibres to provide material strength. *Piliostigma thonningii* seed is rich in proteins and polysaccharides known for their coagulating properties (Eman & Abiola, 2021) [4]. The seeds contain active sites capable of charge neutralization, bridging, and adsorption of colloidal particles. This research focuses on the development, characterization, and optimization of coagulants extracted from *Piliostigma thonningii* seeds for eco-friendly water purification.

Materials and Methods

1. Sample Collection and Preparation

Piliostigma thonningii seeds were collected from Badaromo village in Ganjuwa LGA of Bauchi state, Nigeria. The seeds were removed, washed, sun-dried for 7days and ground into fine powder using a laboratory grinder. The powder was sieved through a 250 µm mesh for uniformity.

2. Extraction of Coagulant

Ten grams (20 g) of seed powder were mixed with 150 mL of distilled water and stirred at 150 rpm for one hour and then filtered suspension. The clear supernatant was used as the aqueous extract.

3. Jar Test Procedure

The standard jar test was conducted to evaluate the coagulation efficiency. The synthetic turbid water at initial turbidity 200 NTU was treated with varying doses of 50–250 mg/L of the coagulant extraction at different pH levels. Rapid mixing was conducted for 10 minutes at 150 rpm. The supernatant turbidity was measured using a turbidimeter.

4. Characterization Techniques

FTIR and SEM analyses were conducted to characterize the functional groups in the coagulant extract and examining the surface morphology after coagulation.

The Biodegradability and Toxicity were performed using standard biochemical oxygen demand (BOD_5) and Daphnia magna toxicity tests to assess environmental safety.

Results and Discussion

1. Effect of pH on turbidity removal

Table 1 shows the effect of pH on turbidity removal at the optimal dosage.

The results indicate an optimal dosage of 150 mg/L coagulant for maximum turbidity removal (95%). Beyond this point, overdosing led to stabilization of particles due to charge reversal. The coagulation efficiency of *Piliostigma thonningii* extract varied significantly with pH and dosage. The coagulation efficiency is higher at pH 7, showing that the coagulant performs best in neutral conditions, consistent with natural protein-based mechanisms.

The effect of pH on turbidity removal and Coagulation Efficiency (%)

Table 1: Effect of pH on turbidity removal

S/N	Coagulant Dosage (mg/L)	Residual Turbidit (NTU)	Turbidity Removal (%)	Coagulation Efficiency (%)	pH Level
1	50	48		82	4
2	75	35	70	84	4.5
3	100	25	83	87	5
4	125	18	88	88	5.5
5	150	21	95	91	6
6	175	16	93	92	7
7	200	21	90	90	7.6
8	225	32	85	86	8.8
9	250	35	80	84	9

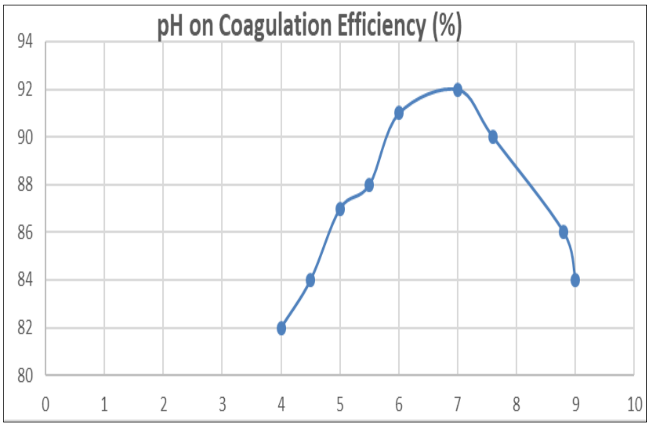

Fig 1: pH on Coagulation Efficiency

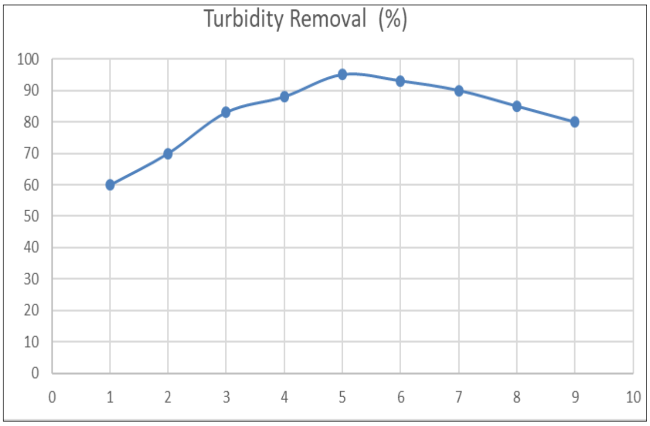

Fig 2: Coagulant Dosage on Turbidity Removal Efficiency

2. Heavy Metal and Color Removal

Table 2 shows the Heavy Metal and Color Removal by *Piliostigma thonningii* Coagulant. The coagulant exhibited significant removal efficiency for heavy metals and color, indicating potential application in wastewater treatment.

Table 2: Heavy Metal and Color Removal

S/N	Parameter	Concentration (mg/L)	Final Concentration (mg/L)	Removal Efficiency (%)
1	Lead (Pb)	1.50	0.33	80
2	Cadmium (Cd)	0.90	0.21	78
3	Chromium (Cr)	2.20	0.50	76
4	Color (Pt–Co units)	120	18	85

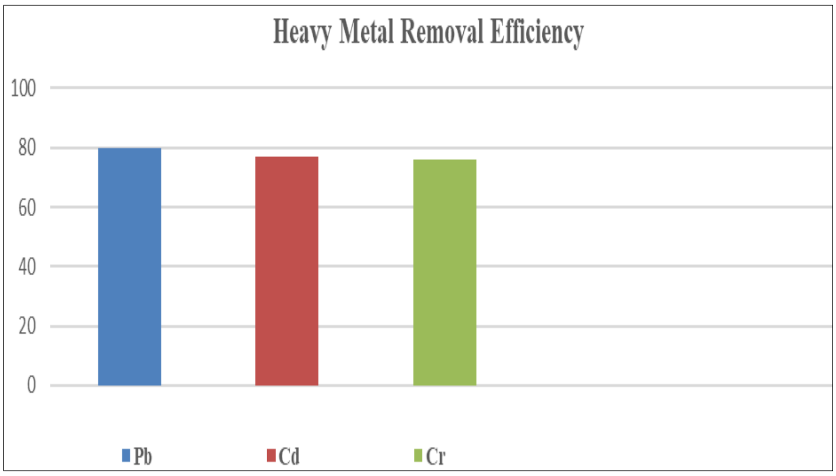

Fig 3: Heavy Metal Removal Efficiency

3. FTIR Analysis

FTIR spectra (Figure 4) showed prominent peaks at 3432 cm^{-1} (O–H and N–H stretching), 1649 cm^{-1} (C=O stretching of amide), and 1052 cm^{-1} (C–O stretching), confirming the presence of hydroxyl, amine, and carboxyl functional groups. These active sites are responsible for charge neutralization and adsorption.

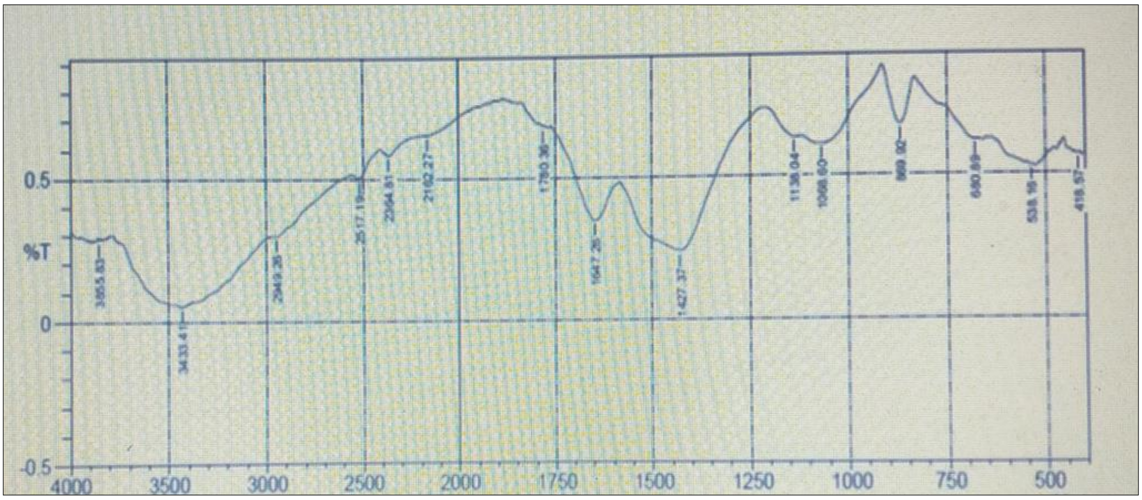

Fig 4: FTIR Spectra

4. SEM Morphology

SEM micrographs revealed a rough and porous surface structure before coagulation, which became smoother after treatment—evidence of particle adsorption and aggregation. The microstructure supports efficient floc formation and sedimentation.

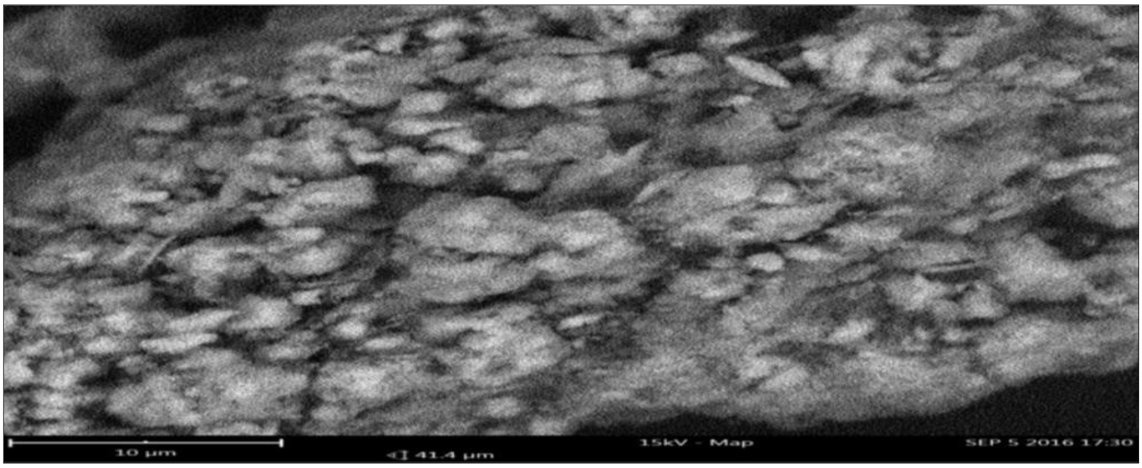

Fig 5: Scanning Electron Microscope

5. Biodegradability and Toxicity

Biodegradability tests showed 82% degradation after 14 days, while toxicity assays using Daphnia magna indicated no mortality at concentrations up to 500 mg/L, confirming its environmental safety.

Conclusion

The study demonstrated that *Pilliostigma thonningii* seed extract is an effective, biodegradable, and eco-friendly natural coagulant. Optimal turbidity removal (92%) was achieved at pH 7 and a dosage of 150 mg/L. The presence of functional groups such as –OH, $–NH_2$, and –COOH enhanced its coagulation and adsorption potential. The coagulant showed significant removal of heavy metals and color, confirming its potential for water purification and wastewater treatment applications. The coagulant is non-toxicity, and low cost and available, which make it a sustainable alternative to conventional coagulants.

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