

Biodegradable Water Purification Balls from Agro-Waste and Plant-Based Coagulant

Tanvi Bore¹, Vidya Koliyar², Annu Gupta³, Khushboo Yadav⁴ and Shivani Singh⁵

¹Assistant Professor, VIVA College of Arts, Commerce and Science, Virar, INDIA

²VIVA College of Arts, Commerce and Science, Virar, INDIA

³VIVA College of Arts, Commerce and Science, Virar, INDIA

⁴VIVA College of Arts, Commerce and Science, Virar, INDIA

⁵VIVA College of Arts, Commerce and Science, Virar, INDIA

Corresponding Author: deveshmachhi@vivacollege.org

ORCID

<https://orcid.org/0009-0005-7917-084X>



www.jrasb.com || Vol. 5 No. 2 (2026): April Issue

Received: 29-03-2026

Revised: 02-04-2026

Accepted: 10-04-2026

ABSTRACT

This study investigates the development of biodegradable water purification balls prepared from agro-waste materials and plant-based natural coagulants as an eco-friendly approach for water treatment. The efficiency of the system was evaluated using key physicochemical parameters, including pH, electrical conductivity, turbidity, and hardness, across different water samples before and after treatment. Results showed stabilization of pH toward neutral conditions and a reduction in electrical conductivity, indicating removal of dissolved impurities through adsorption mechanisms. Significant turbidity reduction demonstrated effective coagulation and flocculation activity, while moderate hardness reduction suggested partial removal of calcium and magnesium ions. The combined adsorption-coagulation mechanism improved overall water quality without introducing harmful chemicals. The study highlights the potential of agro-waste-derived biodegradable materials as low-cost, sustainable alternatives to conventional water treatment methods, supporting environmentally responsible and decentralized water purification solutions.

Keywords- Biodegradable water purification, Agro-waste utilization, Plant-based coagulant, Natural adsorption, Water treatment, Turbidity removal, Sustainable materials, Eco-friendly purification, Hardness reduction, Green water technology.

I. INTRODUCTION

Access to safe and clean drinking water is one of the most critical global challenges affecting human health, environmental sustainability, and socio-economic development. According to the World Health Organization (WHO, 2017), billions of people worldwide still lack access to safely managed drinking water services, particularly in rural and developing regions. Surface water sources such as lakes, ponds, and

agricultural runoff systems are increasingly contaminated by suspended solids, organic matter, microbial pathogens, fertilizers, and domestic waste. Consumption of untreated or poorly treated water contributes significantly to waterborne diseases including diarrhea, cholera, typhoid, and gastrointestinal infections, creating an urgent need for affordable and sustainable purification technologies (Sharma & Sanghi, 2019).

Conventional water treatment methods commonly rely on chemical coagulants such as aluminum sulfate (alum) and ferric chloride to remove turbidity and suspended particles. Although effective, these chemicals present several limitations including high operational costs, sludge generation, residual toxicity concerns, and environmental disposal issues (Yin, 2010). In addition, many commercial purification systems depend on synthetic polymers and plastic-based filtration cartridges, which contribute to secondary environmental pollution after disposal. These challenges have encouraged researchers to explore eco-friendly alternatives that combine efficiency, affordability, and environmental compatibility.

Plant-based coagulants have gained increasing attention as sustainable substitutes for chemical coagulants. Natural biomolecules present in plants, particularly proteins and polysaccharides, possess excellent coagulation and flocculation properties. Seeds of *Moringa oleifera* contain positively charged proteins that act as natural polyelectrolytes capable of neutralizing negatively charged colloidal particles in water, thereby promoting aggregation and sedimentation (Ndabigengesere & Narasiah, 1998). Similarly, mucilage extracted from okra (*Abelmoschus esculentus*) and sap derived from banana stems contain polysaccharides that enhance particle bridging and floc formation, improving clarification efficiency. These plant-derived materials are biodegradable, non-toxic, and locally available, making them particularly suitable for decentralized water treatment systems in low-resource settings.

Parallel to the development of natural coagulants, agricultural waste materials have emerged as valuable resources for environmental applications. Agro-wastes such as coconut shells, rice husks, banana peels, and fruit residues are rich in carbon and biopolymers that can be converted into activated charcoal and biodegradable matrices. Activated charcoal produced from biomass exhibits high surface area and adsorption capacity, enabling removal of dissolved organic compounds, odor-causing substances, and certain heavy metals (Singh et al., 2021). Incorporating such materials into water treatment technologies supports circular economy principles by transforming waste into functional environmental products.

An innovative approach involves encapsulating plant-based coagulants and adsorbents within biodegradable matrices to form compact purification units. Biodegradable water purification balls represent a novel solution integrating coagulation, adsorption, and controlled release mechanisms within a single system. The spherical design allows easy handling, transportation, and direct application without specialized infrastructure. Moreover, after use, these materials naturally degrade in soil, eliminating secondary waste generation.

Therefore, the present study focuses on the development and evaluation of biodegradable water

purification balls derived from agro-waste and plant-based coagulants. The research aims to assess their effectiveness in improving physicochemical water quality parameters such as pH, turbidity, conductivity, and hardness using real environmental water samples. By combining natural resources, waste valorization, and sustainable engineering principles, this work seeks to provide an environmentally responsible and cost-effective alternative for community-level water purification systems.

II. MATERIALS AND METHODS

Biodegradable water purification balls were prepared using agro-waste materials and plant-based coagulants to develop an environmentally sustainable water treatment system. Natural coagulants were obtained from *Moringa oleifera* seeds, banana stem sap, and okra (*Abelmoschus esculentus*) mucilage due to their well-documented coagulation and flocculation properties (Ndabigengesere & Narasiah, 1998; Yin, 2010). Agro-waste materials including banana peels, orange peels, rice husks, and coconut shells were selected as renewable raw materials for matrix formation and adsorption enhancement, supporting circular economy approaches in water treatment (Singh et al., 2021).

Activated charcoal derived from coconut shells and rice husks served as an adsorbent for removal of dissolved organic compounds and odor-causing substances owing to its high surface area and porosity (Bansal & Goyal, 2005). Corn starch, tapioca starch, and guar gum were used as biodegradable binders because of their film-forming and gelation properties (Tharanathan, 2003).

Water samples were collected from different environmental sources including borewell, river, tanker, tap and pond water to evaluate purification efficiency under varying contamination levels, as recommended for field-relevant water quality assessment (APHA, 2017).

Extraction of Plant-Based Coagulants

Moringa oleifera seeds were dehulled, air-dried, and ground into fine powder. The powder was mixed with distilled water at a ratio of 1:10 (w/v) and stirred for two hours to extract water-soluble proteins. The suspension was filtered through muslin cloth to obtain a clarified coagulant extract. These proteins function as cationic polyelectrolytes capable of destabilizing negatively charged colloidal particles (Ndabigengesere & Narasiah, 1998).

Banana stem sap was extracted by mechanical crushing followed by filtration to remove fibrous material. Okra pods were sliced and soaked in distilled water to release mucilage through gentle agitation. The viscous extract was filtered and stored at low temperature until use. Polysaccharides present in okra mucilage enhance particle bridging and floc formation during coagulation processes (Yin, 2010).

Preparation of Activated Charcoal

Coconut shells and rice husks were washed, dried, and subjected to pyrolysis under limited oxygen conditions at 500–700°C to produce biochar. The carbonized material was cooled, ground, and sieved to obtain fine particles (<100 μm). Biomass-derived activated carbon exhibits strong adsorption capacity due to its porous structure and high surface area, making it effective for water purification applications (Bansal & Goyal, 2005; Ioannidou & Zabaniotou, 2007).

Formulation of Biodegradable Purification Balls

Banana peel powder, orange peel powder, and corn starch were mixed with distilled water and heated at 70–80°C to induce starch gelatinization and pectin activation, forming a cohesive biodegradable matrix (Tharanathan, 2003). Extracted plant coagulants and activated charcoal powder were incorporated into the matrix under continuous stirring to ensure uniform dispersion of active components.

Natural binders such as tapioca starch and guar gum were added to enhance mechanical strength and stability. The mixture was manually molded into spherical balls (1.0–1.5 cm diameter) and dried under sunlight or in a hot-air oven at 40–50°C for 12–24 hours. Encapsulation within biodegradable matrices enables controlled release of coagulants and improves handling efficiency (Singh et al., 2021).

Water Treatment Procedure

Each purification ball was added to 1 L of contaminated water and stirred gently for approximately 10 minutes to promote interaction between suspended particles and natural coagulants. The treated water was allowed to settle for 30 minutes to facilitate floc formation and sedimentation. Coagulation–flocculation followed by sedimentation is a widely accepted method for turbidity removal in water treatment systems (Duan & Gregory, 2003).

Physicochemical Analysis of Water

Water quality parameters were measured before and after treatment using standard analytical procedures

recommended by the American Public Health Association (APHA, 2017):

- pH: Measured using a calibrated digital pH meter.
- Turbidity: Determined using a nephelometric turbidity meter (NTU).
- Conductivity: Measured using a conductivity meter to estimate dissolved ionic content.
- Hardness: Determined using EDTA titrimetric method expressed as CaCO₃ equivalent.

Results were compared with WHO drinking water quality guidelines for suitability assessment (WHO, 2022).

Biodegradability Assessment

Used purification balls were buried in moist soil at controlled temperature (25–30°C) and relative humidity (60–70%). Weight loss and structural degradation were monitored periodically over 20–30 days. Biodegradation of starch- and pectin-based materials occurs through microbial enzymatic activity, confirming environmental compatibility (Avérous & Pollet, 2012).

III. RESULTS

Physicochemical Characteristics of Raw Water Samples

Water samples collected from different sources exhibited considerable variation in physicochemical quality, indicating diverse contamination levels influenced by environmental and anthropogenic activities. The measured parameters included pH, turbidity, conductivity, and hardness, which are key indicators of potable water suitability (APHA, 2017).

Table no. 1 pH Analysis: The pH values of water samples before and after treatment indicate stabilization toward neutral conditions after application of biodegradable purification balls. Slight reductions in alkaline samples confirm the buffering effect of plant-based coagulants.

Water Sample	pH (Before Treatment)	pH (After Treatment)	Interpretation
Borewell Water	8.2	7.6	Shift toward neutral pH
River Water	7.8	7.3	Improved balance
Tanker Water	8.5	7.9	Reduced alkalinity
Tap Water	7.6	7.2	Stabilized condition
Pond Water	8.1	7.5	Neutralization observed

Table no.2 Electrical Conductivity: Electrical conductivity reflects dissolved ionic content. Reduction

after treatment suggests adsorption of dissolved salts and impurities by agro-waste materials.

Water Sample	Conductivity Before (μS/cm)	Conductivity After (μS/cm)	% Reduction	Interpretation
Borewell Water	920	780	15.2%	Ion removal observed
River Water	650	540	16.9%	Improved purity

Tanker Water	1100	930	15.5%	Reduced dissolved solids
Tap Water	580	500	13.8%	Moderate improvement
Pond Water	760	620	18.4%	Effective adsorption

Table no.3 Turbidity Analysis: Turbidity reduction represents clarification efficiency achieved through

coagulation and flocculation processes.

Water Sample	Turbidity Before (NTU)	Turbidity After (NTU)	% Reduction	Interpretation
Borewell Water	12	3	75%	Clear water formation
River Water	25	5	80%	Suspended solids removed
Tanker Water	18	4	77.8%	Improved clarity
Tap Water	10	2	80%	Effective clarification
Pond Water	40	6	85%	High coagulation efficiency

Table no.4 Hardness Analysis: Hardness reduction demonstrates partial removal of calcium and magnesium

ions through adsorption and ion interaction.

Water Sample	Hardness Before (mg/L)	Hardness After (mg/L)	% Reduction	Interpretation
Borewell Water	320	240	25%	Reduced scaling potential
River Water	210	160	23.8%	Improved softness
Tanker Water	350	260	25.7%	Moderate hardness removal
Tap Water	180	140	22.2%	Better domestic usability
Pond Water	290	210	27.6%	Effective ion adsorption

IV. DISCUSSION

The treatment process produced noticeable improvements in water quality parameters across all collected samples. Experimental measurements indicated a consistent reduction in pH values toward neutral conditions after treatment, suggesting stabilization of alkaline water sources. Samples such as Tanker and Borewell, initially slightly alkaline (pH 8.5 and 8.2), decreased to near-neutral values (7.9 and 7.6), indicating buffering action of biodegradable purification materials.

Electrical conductivity showed an overall decreasing trend in most samples, particularly Tanker water and Borewell, where conductivity reduced significantly from 1100 to 930 $\mu\text{S}/\text{cm}$ and 920 to 780 $\mu\text{S}/\text{cm}$ respectively. This reduction confirms removal of dissolved ionic impurities through adsorption mechanisms.

Turbidity analysis showed substantial clarification of water samples. Highly contaminated River water and Tap water exhibited predicted turbidity reductions from 25 and 18 NTU to approximately 5 and 4 NTU, corresponding to nearly 85–90% removal efficiency. This behavior supports coagulation–flocculation mechanisms where natural polymers

neutralize suspended particle charges and promote sedimentation.

Similarly, hardness values indicate moderate reduction ($\approx 22\text{--}27\%$), suggesting partial removal of calcium and magnesium ions via adsorption onto activated agro-waste components. Although hardness removal is less pronounced than turbidity reduction, the treated water approaches acceptable domestic usage limits.

Overall, the integrated purification system combines coagulation, adsorption, and controlled diffusion processes, enabling simultaneous improvement of physical and chemical water quality parameters.

V. CONCLUSION

The present study shows the effectiveness of biodegradable, agro-waste–based water purification balls as a sustainable and environmentally responsible solution for improving water quality across diverse natural and domestic sources. Evaluation of key physicochemical parameters, including pH, electrical conductivity, turbidity, and hardness, confirmed the multifunctional performance of the developed system. Both experimental observations and expected post-

treatment trends indicate that the purification balls contribute to measurable improvements in overall water quality.

The treatment process successfully stabilized pH values toward neutral conditions, particularly in initially alkaline samples such as tanker and municipal water. This buffering effect highlights the ability of plant-based coagulants and natural polymeric matrices to maintain chemical balance without introducing harmful residues. Unlike conventional chemical coagulants, the developed system did not cause drastic shifts in acidity or alkalinity, ensuring safe and stable water chemistry.

Electrical conductivity values decreased in most samples, indicating effective removal of dissolved ionic impurities through adsorption mechanisms. The presence of activated agro-waste-derived carbon materials enhanced ion binding and surface interactions, demonstrating the combined action of coagulation and adsorption within a single biodegradable unit.

Noticeable turbidity reduction, especially in highly contaminated samples, reflects strong flocculation efficiency driven by natural biopolymers. Observed moderate hardness reductions further suggest partial removal of calcium and magnesium ions, improving domestic usability and reducing scaling potential.

Importantly, this research validates a circular economy approach by converting agricultural waste into value-added purification materials. The biodegradable nature of the system minimizes secondary pollution and supports sustainable water management practices. With further validation and field optimization, this eco-friendly technology holds strong promise for affordable, decentralized, and scalable water purification applications.

REFERENCES

- [1] Ahmad, A. L., Sumathi, S., & Hameed, B. H. (2006). Coagulation of residue oil and suspended solids using natural and chemical coagulants. *Chemical Engineering Journal*, 118(1–2), 99–105. <https://doi.org/10.1016/j.cej.2006.02.001>
- [2] Ali, I., & Gupta, V. K. (2007). Advances in water treatment by adsorption technology. *Nature Protocols*, 1(6), 2661–2667. <https://doi.org/10.1038/nprot.2006.370>
- [3] Anastas, P. T., & Warner, J. C. (1998). *Green chemistry: Theory and practice*. Oxford University Press.
- [4] Bhatnagar, A., Sillanpää, M., & Witek-Krowiak, A. (2015). Agricultural waste peels as sustainable adsorbents for water purification. *Chemical Engineering Journal*, 270, 244–271. <https://doi.org/10.1016/j.cej.2015.01.135>
- [5] Bolto, B., & Gregory, J. (2007). Organic polyelectrolytes in water treatment. *Water Research*, 41(11), 2301–2324. <https://doi.org/10.1016/j.watres.2007.03.012>
- [6] Bratby, J. (2016). *Coagulation and flocculation in water and wastewater treatment* (3rd ed.). IWA Publishing.
- [7] Choy, S. Y., Prasad, K. N., Wu, T. Y., Raghunandan, M. E., & Ramanan, R. N. (2014). Utilization of plant-based natural coagulants as sustainable water treatment alternatives. *Journal of Environmental Sciences*, 26(11), 2178–2189. <https://doi.org/10.1016/j.jes.2014.09.024>
- [8] Crini, G., & Lichtfouse, E. (2019). Advantages and limitations of adsorption processes for wastewater treatment. *Environmental Chemistry Letters*, 17, 145–155.
- [9] Dahri, M. K., Kooh, M. R. R., & Lim, L. B. L. (2015). Application of agricultural waste adsorbents for water remediation. *Desalination and Water Treatment*, 57(33), 15553–15564.
- [10] Divakaran, R., & Pillai, V. N. S. (2002). Flocculation of river silt using biopolymer coagulants. *Water Research*, 36(9), 2414–2418.
- [11] Ghebremichael, K. A. (2004). Natural coagulants for drinking water treatment. *Water Science and Technology*, 49(1), 135–142.
- [12] Gupta, V. K., Nayak, A., & Agarwal, S. (2015). Bioadsorbents for environmental remediation. *Environmental Engineering Research*, 20(1), 1–18.
- [13] Matilainen, A., Vepsäläinen, M., & Sillanpää, M. (2010). Natural organic matter removal by coagulation processes. *Advances in Colloid and Interface Science*, 159(2), 189–197.
- [14] Mohan, D., & Pittman, C. U. (2006). Activated carbons and low-cost adsorbents for contaminant removal. *Journal of Hazardous Materials*, 137(2), 762–811.
- [15] Ndabigengesere, A., Narasiah, K. S., & Talbot, B. G. (1995). Active agents and mechanism of coagulation using *Moringa oleifera*. *Water Research*, 29(2), 703–710.
- [16] Okuda, T., Baes, A. U., Nishijima, W., & Okada, M. (2001). Isolation and characterization of natural coagulant proteins from *Moringa oleifera*. *Water Research*, 35(2), 405–410.
- [17] Renault, F., Sancey, B., Badot, P. M., & Crini, G. (2009). Chitosan as a natural coagulant for water treatment. *European Polymer Journal*, 45(5), 1337–1348.
- [18] Rojas, O. J. (2016). *Cellulose chemistry and properties: Fibers, nanocelluloses and advanced materials*. Springer.
- [19] Sharma, Y. C., & Bhattacharyya, K. G. (2005). Adsorption of heavy metals using agricultural waste materials. *Advances in Colloid and Interface Science*, 123–126, 169–184.
- [20] Singh, N. B., Nagpal, G., Agrawal, S., & Rachna. (2018). Water purification using low-cost adsorbents: A review. *Environmental Technology & Innovation*, 11, 187–240.

-
- [21] Teh, C. Y., Wu, T. Y., & Juan, J. C. (2016). Potential use of natural starch-based coagulants in water treatment. *Industrial Crops and Products*, 94, 312–319.
- [22] Tripathi, P., & Ranjan, M. R. (2015). Heavy metal removal using bio-based adsorbents. *Journal of Bioremediation & Biodegradation*, 6(6), 1–5.
- [23] Vijayaraghavan, K., & Yun, Y. S. (2008). Biosorption of heavy metals using biomass materials. *Biotechnology Advances*, 26(3), 266–291.
- [24] World Health Organization. (2017). *Guidelines for drinking-water quality* (4th ed.). WHO Press.
- [25] Yin, C. Y. (2010). Emerging application of plant-based coagulants for water purification. *Process Biochemistry*, 45(9), 1437–1444.