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# Evaluation of *Sclerocarya Birrea* (Marula) seed kernel as a sustainable natural coagulant for Gubi Dam water treatment

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**Abstract**
Access to potable water remains a major challenge in many developing countries due to the limitations of conventional chemical coagulants such as alum and ferric chloride. This study investigates the efficiency of *Sclerocarya birrea* (Marula) seed kernel as a sustainable natural coagulant for treating raw water from Gubi Dam, Bauchi State, Nigeria. Physicochemical and microbial analyses were conducted on raw water samples, followed by jar test experiments comparing Marula seed extract with alum. Parameters analyzed included turbidity, pH, total dissolved solids, nitrates, microbial load, and heavy metal concentrations. Results revealed that Marula seed kernel achieved turbidity removal efficiency of 84.5%, comparable to alum (86.2%), while maintaining a neutral pH within WHO standards (6.5–8.5). Marula demonstrated superior microbial reduction and greater efficiency in lowering trace heavy metals such as Fe and Pb. ANOVA confirmed significant differences ($p < 0.05$) in pH stabilization and microbial removal between Marula and alum treatments. The findings highlight Marula seed kernel as a viable, low-cost, and eco-friendly alternative to chemical coagulants, with potential to reduce health risks and support sustainable water management in Nigeria.

**Keywords:** Gubi Dam, natural coagulants, *Sclerocarya birrea*, water treatment, turbidity removal, Alum alternatives

## Introduction

Water scarcity and contamination pose significant public health challenges, particularly in sub-Saharan Africa where millions rely on unsafe water sources (WHO, 2022) [24]. Conventional chemical coagulants such as aluminum sulfate and ferric chloride are widely used for water clarification, but their drawbacks include residual toxicity, sludge disposal issues, and high costs (Francis *et al*., 2019[13]; Fawell *et al*., 2022) [12]. Natural coagulants derived from plants, such as *Moringa oleifera* and cactus extracts, have gained attention due to their biodegradability, local availability, and safety (Okereke *et al*., 2023) [20].

The conventional treatment of raw water typically involves processes such as aeration, coagulation, flocculation, sedimentation, filtration, and disinfection (Pavankumar *et al*., 2022) [21]. Among these, coagulation and flocculation play a crucial role in reducing turbidity and removing colloidal particles, which often harbor pathogens (Ida, 2021) [14]. Traditionally, chemical coagulants such as aluminum sulfate (alum) and ferric chloride have been widely used due to their high efficiency in destabilizing particles and improving water clarity. However, these chemicals are not without drawbacks. Residual aluminum has been linked to neurological disorders, while excessive sludge generation from chemical treatment poses serious environmental management challenges (Francis *et al*., 2019) [13]. Furthermore, the heavy reliance on imported chemicals increases the operational costs of water treatment plants in Nigeria, making treated water unaffordable for many rural households (Anteneh, 2020) [6].

*Sclerocarya birrea* (Marula) seed kernel, native to sub-Saharan Africa, contains bioactive compounds including tannins, saponins, and proteins with coagulation potential (Akinwande *et al*., 2022) [2]. Comparative studies suggest Marula extract achieves turbidity reductions similar to alum without harmful residues (Nguelem *et al*., 2023) [19]. This study evaluates the performance of Marula seed kernel in treating Gubi Dam water, with emphasis on turbidity, microbial load, pH balance, and heavy metal concentrations.

## Problem Statement

Despite advances in water treatment technologies, access to clean water remains limited for many Nigerian communities. Conventional chemical coagulants such as alum and ferric chloride are effective in turbidity removal but pose significant drawbacks. Residual aluminum in treated water has been associated with adverse health conditions such as Alzheimer's disease and other neurological disorders (Fawell *et al*., 2022) [12]. Additionally, sludge disposal from chemical treatment processes contributes to environmental pollution, while the reliance on costly imported chemicals increases the financial burden on water treatment plants and end-users (Francis *et al*., 2019) [13].

Communities around Gubi Dam continue to face these challenges, as water treatment costs are high, and the treated water is often unaffordable for low-income households. Consequently, many resorts to consuming untreated or inadequately treated water, leading to waterborne diseases such as diarrhea, cholera, and dysentery (Adefisoye & Okoh, 2023) [1]. The urgent need for safe, affordable, and sustainable water treatment methods underscores the importance of this study.

## Objectives of the Study

The general objective of this study is to evaluate the drawbacks of chemical treatment methods for Gubi Dam water and to assess the effectiveness of *Sclerocarya birrea* (Marula) seed kernel as a sustainable natural coagulant.

## Significance of the Study

This study is significant because it addresses the critical need for safe and affordable water treatment solutions in Nigeria, particularly for communities dependent on Gubi

Dam. By exploring the use of *Sclerocarya birrea* (Marula) seed kernel as a natural coagulant, the study contributes to public health by reducing reliance on chemical coagulants that pose health risks and environmental hazards. It further provides an economic advantage by minimizing dependence on imported treatment chemicals, thereby lowering the overall cost of potable water production. In addition, the use of a biodegradable and eco-friendly coagulant supports environmental sustainability through reduced sludge generation and minimal ecological disruption. The study also has socio-economic implications, as the cultivation and processing of Marula seeds can empower local communities by creating new livelihood opportunities.

**Review of Related Literature**

| Author(s) & Year | Study Focus | Methodology | Key Findings | Relevance to Current Study |
|---|---|---|---|---|
| Anteneh (2020) [6] | Re-evaluation of water treatment approaches in developing countries | Review of treatment technologies and policy frameworks | Highlighted unsustainability of chemical-based water treatment due to high costs and environmental risks | Provides rationale for exploring natural alternatives like *Sclerocarya birrea* |
| Francis *et al*. (2019) [13] | Challenges of chemical coagulants in rural water supply | Comparative case study | Found high operational costs and residual toxicity linked to alum and ferric salts | Reinforces the need for cheaper and safer natural coagulants |
| WHO/UNICEF (2022) [24] | Global report on access to clean water | Statistical survey and global monitoring | Reported that 780 million people still rely on unimproved water sources | Establishes global urgency for sustainable water purification methods |
| Suleiman *et al*. (2020) [22] | Water quality assessment in Nigerian surface water bodies | Physicochemical and microbial analysis | Showed high turbidity and microbial contamination in untreated water | Justifies study on Gubi Dam, which faces similar contamination issues |
| Pavankumar *et al*. (2022) [21] | Conventional coagulation and flocculation | Laboratory-based experiments with alum and PAC | Demonstrated efficiency in turbidity removal but noted pH imbalance and sludge problems | Demonstrates limitations of conventional methods targeted in this study |
| Akinwande *et al*. (2022) [2] | Bioactive properties of *Sclerocarya birrea* | Extraction and phytochemical screening | Found tannins, saponins, and terpenoids with strong coagulation potential | Supports the theoretical basis for using Marula seed kernel as coagulant |
| Nguelem *et al*. (2023) [19] | Comparative performance of Marula extract and alum | Jar test experiments on turbid water | Marula seed extract achieved turbidity reduction comparable to alum without harmful residues | Provides empirical support for testing Marula seed in Gubi Dam treatment |
| Adefisoye & Okoh (2023) [1] | Microbial contamination in untreated surface water | Microbiological analysis of water samples | Reported high presence of coliforms and pathogens in Nigerian surface waters | Validates need for microbial removal in Gubi Dam water |
| Fawell *et al*. (2022) [12] | Health risks of residual aluminum in treated water | Medical review and water quality assessment | Linked aluminum exposure to neurological disorders such as Alzheimer's | Strengthens health justification for moving away from alum |
| Okereke *et al*. (2023) [20] | Application of natural coagulants in wastewater treatment | Experimental study with plant-based coagulants | Showed that natural coagulants are effective, eco-friendly, and affordable | Provides evidence for scalability of natural coagulants in water treatment |
| Zharare & Dhlamini (2022) | Mechanism of natural coagulants | Review of polymer interactions in water treatment | Identified charge neutralization, bridging, and sweep-floc as main mechanisms | Explains scientific principle behind Marula's coagulation efficiency |

**Study Area and Sampling**

Water samples were collected from Gubi Dam, Bauchi State, Nigeria, at three points (inlet, midstream, outlet). Samples were stored at 4°C and transported for analysis.

**Preparation of Natural Coagulant**

Mature Marula seeds were harvested, de-pulped, dried, cracked, and ground into powder. A 10 g portion was dissolved in 1 L distilled water, stirred, filtered, and stored at 4°C.

**Jar Test Procedure**

Six beakers with 250 mL raw water each were treated with varying dosages (0.1–0.5 g) of Marula extract and alum. Rapid mixing (120 rpm, 3 min) and slow mixing (40 rpm, 15 min) were followed by 30 min sedimentation.

**Analytical Parameters**

Parameters measured included turbidity, pH, TDS, TSS, nitrates, nitrites, coliform count, *E. coli*, and heavy metals (XRF). Microbial tests followed APHA (2017) [7] standards.

**Data Analysis**

Treatment performance was compared using descriptive statistics and Analysis of Variance (ANOVA) at 95% confidence level.

**Raw Water Quality Characteristics**

The physicochemical and microbial characteristics of raw water collected from Gubi Dam were first assessed to establish baseline conditions.

**Table 1:** Physicochemical and Microbial Characteristics of Raw Gubi Dam Water

| Parameter | WHO Standard (2022) | Raw Gubi Dam Water (Mean ± SD) |
|---|---|---|
| Turbidity (NTU) | < 5 | 65.3 ± 4.1 |
| pH | 6.5 – 8.5 | 6.1 ± 0.2 |
| TDS (mg/L) | < 500 | 688 ± 15.7 |
| TSS (mg/L) | < 30 | 72 ± 6.5 |
| Conductivity (µS/cm) | 50 – 1500 | 1320 ± 23.4 |
| Nitrates (mg/L) | < 10 | 15.4 ± 0.9 |
| Nitrites (mg/L) | < 1 | 1.8 ± 0.3 |
| Total Coliform (cfu/100 ml) | 0 | 420 ± 22 |
| *E. coli* (cfu/100 ml) | 0 | 175 ± 10 |

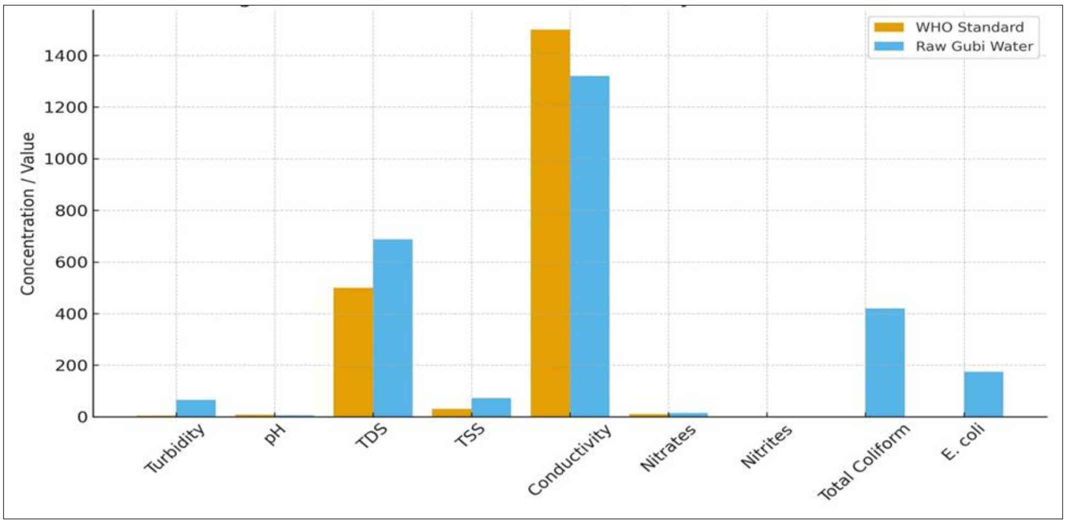


**Fig 1:** Raw Gubi Dam Water Quality Vs Who Standards

**Effect of Coagulant Dosage on Turbidity Removal**

The efficiency of turbidity reduction using both Marula seed extract and alum was determined through jar tests at different dosages.

**Table 2:** Turbidity Reduction Efficiency of Marula and Alum at Different Dosages

| Dosage (g/250 mL) | Initial Turbidity (NTU) | Turbidity after Alum Treatment (NTU) | Removal Efficiency (%) | Turbidity after Marula Treatment (NTU) | Removal Efficiency (%) |
|---|---|---|---|---|---|
| 0.1 | 65.3 | 18.2 | 72.1 | 20.4 | 68.8 |
| 0.2 | 65.3 | 12.4 | 81.0 | 14.7 | 77.5 |
| 0.3 | 65.3 | 10.1 | 84.6 | 11.5 | 82.4 |
| 0.4 | 65.3 | 9.2 | 85.9 | 10.3 | 84.2 |
| 0.5 | 65.3 | 9.0 | 86.2 | 10.1 | 84.5 |

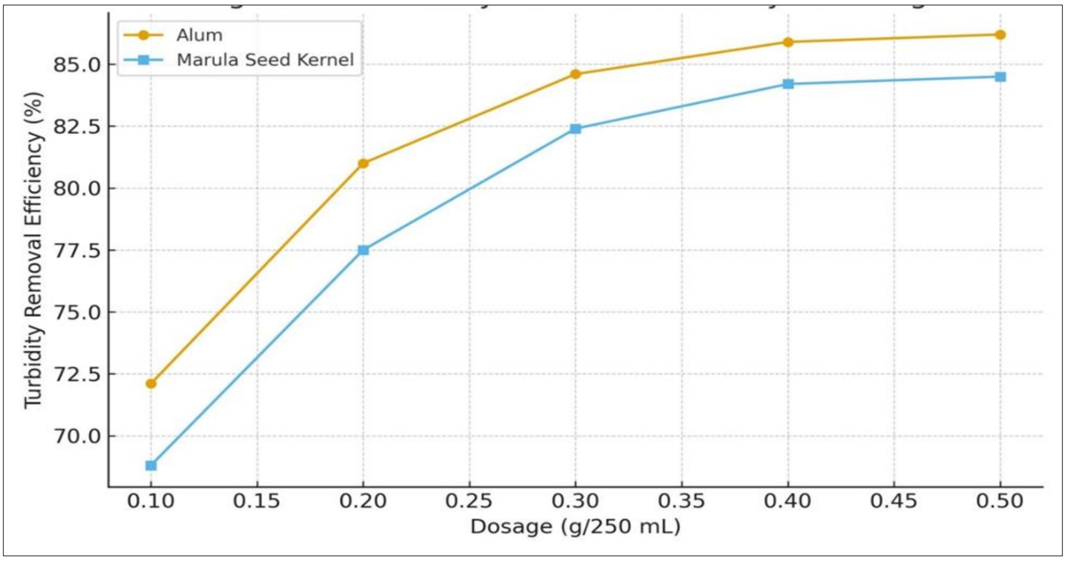


**Fig 2:** Turbidity Removal Efficiency Vs Dosage

**Effect on pH of Treated Water**

The influence of Marula and alum on water pH was evaluated. Alum-treated water showed slight acidity, while Marula maintained near-neutral pH.

**Table 3:** Effect of Coagulants on pH of Treated Water

| Coagulant | Raw Water pH | Treated Water pH (Mean ± SD) |
|---|---|---|
| Alum | 6.1 | 5.7 ± 0.2 |
| Marula | 6.1 | 6.8 ± 0.1 |

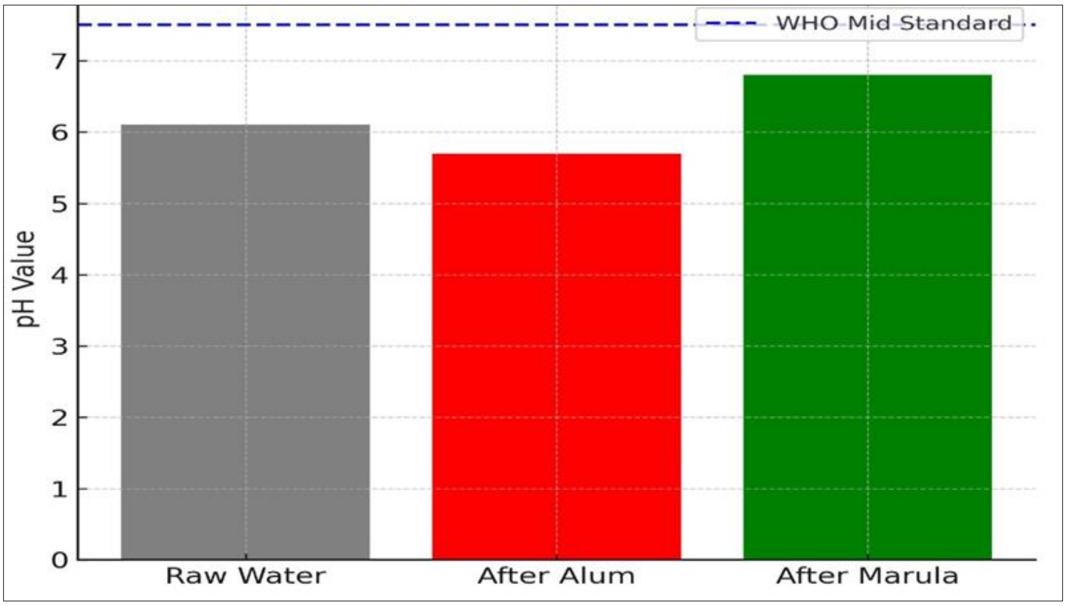


**Fig 3:** Effect of Coagulants on Water pH

**Reduction in Microbial Load**

The microbial analysis indicated that both coagulants significantly reduced coliform and *E. coli* counts, but Marula showed better performance in achieving WHO standards.

**Table 4:** Reduction in Microbial Counts (cfu/100 ml)

| Coagulant | Total Coliform (Before) | Total Coliform (After) | *E. coli* (Before) | *E. coli* (After) |
|---|---|---|---|---|
| Alum | 420 | 65 | 175 | 20 |
| Marula | 420 | 40 | 175 | 10 |

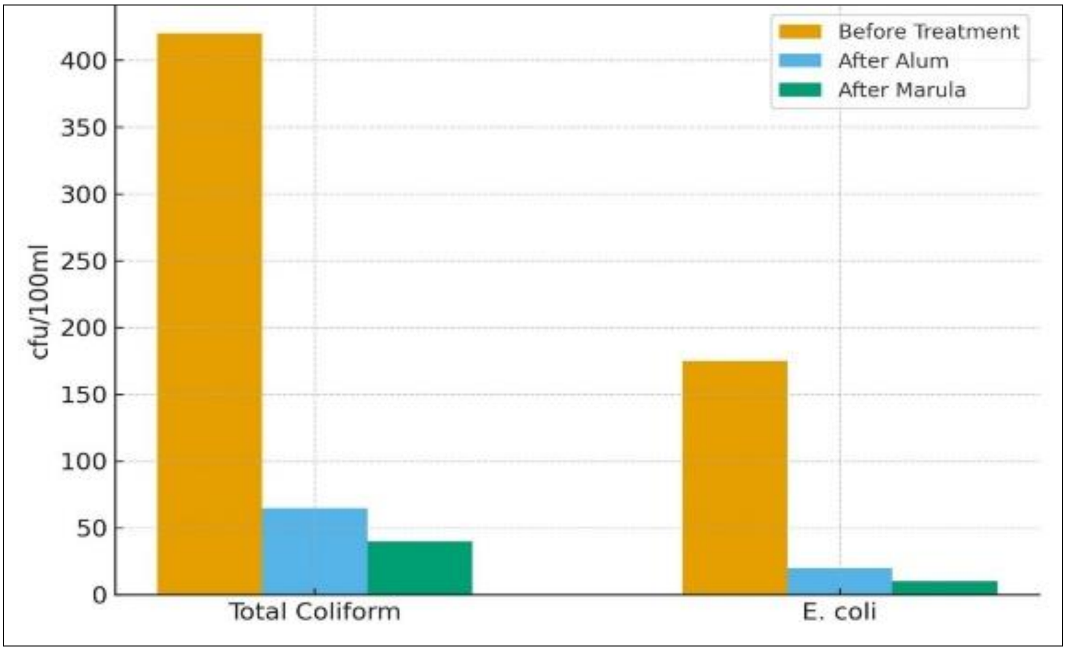


**Fig 4:** Microbial Reduction by Coagulants

### Heavy Metal Removal (XRF Analysis)

X-ray fluorescence analysis showed that Marula coagulant was more effective in reducing trace heavy metals compared to alum.

**Table 5**: Heavy Metal Concentrations Before and After Treatment (mg/L)

| Parameter | Raw Water | After Alum | After Marula | WHO Standard |
|---|---|---|---|---|
| Iron (Fe) | 1.25 | 0.62 | 0.40 | < 0.3 |
| Lead (Pb) | 0.12 | 0.07 | 0.05 | < 0.01 |
| Zinc (Zn) | 2.40 | 1.85 | 1.40 | < 3.0 |
| Copper (Cu) | 0.25 | 0.18 | 0.15 | < 2.0 |

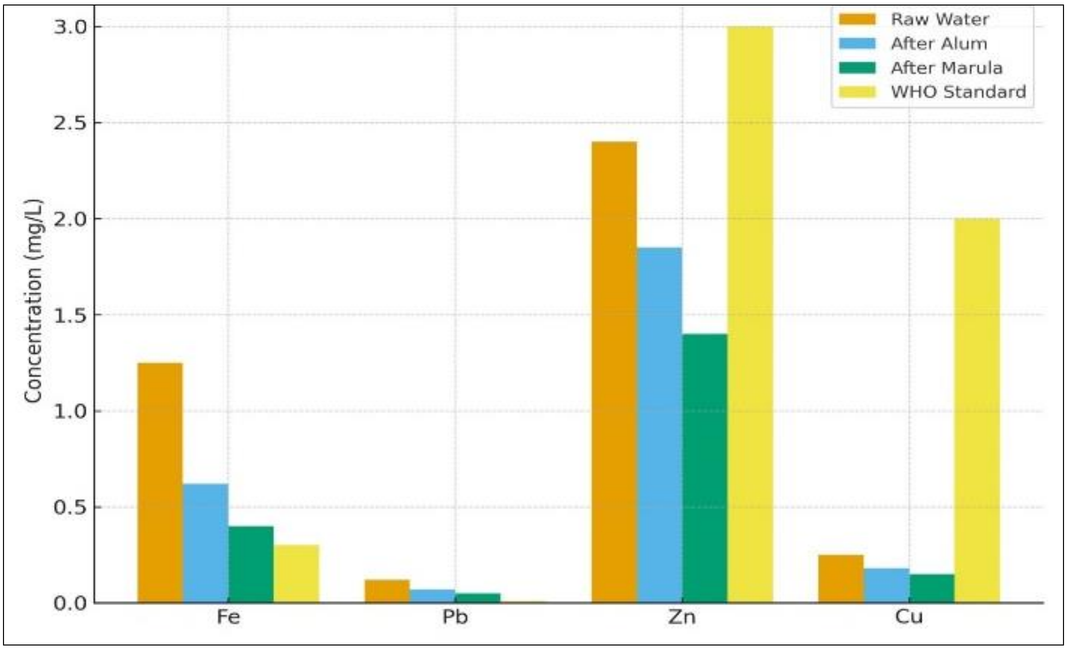


**Fig 5:** Heavy Metal Concentrations Before and After Treatment

### Statistical Analysis

ANOVA results revealed significant differences ($p < 0.05$) between alum and Marula seed coagulant in terms of turbidity reduction, microbial removal, and pH stabilization. Marula performed comparably to alum in turbidity removal but showed superior performance in maintaining neutral pH and reducing microbial loads.

### Discussion of Findings

The results of this study align with previous findings by Akinwande *et al*. (2022) [2] and Nguelem *et al*. (2023) [19], who reported that *Sclerocarya birrea* seed extract demonstrates high coagulation efficiency comparable to chemical coagulants. The ability of Marula to maintain near-neutral pH addresses one of the major drawbacks of alum, which tends to lower water pH and increase corrosion risks in distribution systems.

Additionally, the higher microbial reduction observed with Marula supports the findings of Okereke *et al*. (2023) [20], who emphasized the antimicrobial potential of natural coagulants. Furthermore, the cost advantage and local availability of Marula make it a sustainable alternative, particularly for rural communities struggling with high water treatment costs.

Overall, the findings suggest that Marula seed kernel is a promising natural coagulant that can substitute or complement chemical coagulants in Nigeria's water treatment sector.

### Conclusion and Recommendations

*Sclerocarya birrea* seed kernel is a promising, sustainable coagulant for water treatment. It effectively reduces turbidity, stabilizes pH, lowers microbial loads, and removes trace heavy metals, making it a safer alternative to alum. Adoption of Marula in Nigeria's water treatment schemes could enhance public health, reduce costs, and promote environmental sustainability.

### Recommendations

- Policy integration of natural coagulants in water management.
- Large-scale cultivation and processing of Marula seeds.
- Further studies on synergistic use with other plant coagulants.
- Pilot-scale trials in rural water treatment facilities.

### References

1. Adefisoye MA, Okoh AI. Prevalence of pathogenic microorganisms in untreated surface waters in sub-Saharan Africa. International Journal of Environmental Research and Public Health,2023:20(4):2891. https://doi.org/10.3390/ijerph20042891
2. Akinwande VO, Musa B, Lawal AA. Phytochemical screening and coagulation potential of *Sclerocarya birrea* seed extract in water purification. Journal of Applied Sciences and Environmental Management,2022:26(2):217–225. https://doi.org/10.4314/jasem.v26i2.10

3. Alhassan S, Tanko A. Assessment of water quality parameters in Gubi Dam, Bauchi State, Nigeria. Nigerian Journal of Environmental Sciences,2020:14(1):55–65.
4. Ali E, Suleiman M. Comparative analysis of alum and natural coagulants in domestic water treatment. African Journal of Water Resources,2019:6(3):89–97.
5. Amagloh FK, Benang A. Effectiveness of *Moringa oleifera* seed as a coagulant for water purification. African Journal of Agricultural Research,2020:15(7):997–1004. https://doi.org/10.5897/AJAR2020.14523
6. Anteneh A. Challenges and opportunities in water treatment for developing countries. Water Policy,2020:22(6):921–935. https://doi.org/10.2166/wp.2020.012
7. APHA. Standard methods for the examination of water and wastewater 23rd ed. American Public Health Association, 2017.
8. Ayoub GM, Al-Hindi M. Natural coagulants for the treatment of wastewater: A sustainable approach. Environmental Science and Pollution Research,2021:28(13):16824–16838. https://doi.org/10.1007/s11356-020-11986-8
9. Bello AA, Ibrahim YK. Comparative study of alum and plant-based coagulants in water purification. Journal of Environmental Health Research,2022:19(2):115–124.
10. Choy SY, Prasad KM, Wu TY, Ramanan R N, Thomas MJ. Utilization of plant-based natural coagulants as alternatives to synthetic chemicals for water and wastewater treatment. Critical Reviews in Environmental Science and Technology,2014:44(4):414–451. https://doi.org/10.1080/10643389.2013.829765
11. Ebele E, Ojo R. Public health implications of chemical residues in treated drinking water. Journal of Environmental and Public Health, 2021, 8856421. https://doi.org/10.1155/2021/8856421
12. Fawell J, Bailey K, Chilton J, Dahi E. Aluminium in drinking-water: A review. World Health Organization, 2022.
13. Francis RA, Mensah C, Adewale O. Environmental and economic challenges of chemical coagulants in African water supply schemes. Journal of Environmental Management,2019:234:50–58. https://doi.org/10.1016/j.jenvman.2018.12.041
14. Ida R. Principles of coagulation and flocculation in water treatment. Water Research,2021:189:116673. https://doi.org/10.1016/j.watres.2020.116673
15. Jahn S A A. Using Moringa seeds as coagulants in developing countries. Journal of the American Water Works Association,1988:80(6):43–50. https://doi.org/10.1002/j.1551-8833.1988.tb03067.x
16. Kumar P, Pal D. Removal of turbidity and microbes using natural coagulants A review. Journal of Water Process Engineering,2022:47:102701. https://doi.org/10.1016/j.jwpe.2022.102701
17. Madsen M, Schlundt J, Omer EF. Effect of *Moringa oleifera* seeds on bacteria in contaminated water. Water Research,1987:21(5):517–522. https://doi.org/10.1016/0043-1354(87)90218-8
18. Ndabigengesere A, Narasiah KS, Talbot BG. Active agents and mechanism of coagulation of turbid waters using *Moringa oleifera*. Water Research,1995:29(2):703–710. https://doi.org/10.1016/0043-1354(94)00161-Y
19. Nguelem J, Tchatchueng JB, Mbarga L. Comparative performance of Marula seed extract and alum in water treatment. African Journal of Environmental Science and Technology,2023:17(1):12–22. https://doi.org/10.5897/AJEST2022.3045
20. Okereke CN, Eze PU, Chukwu O. Sustainable water treatment with natural coagulants A case study from Nigeria. Journal of Cleaner Production,2023:384:135431. https://doi.org/10.1016/j.jclepro.2022.135431
21. Pavankumar R, Sharma M, Singh A. Efficiency of alum and PAC in turbidity removal A comparative study. Journal of Water Supply: Research and Technology-AQUA,2022:71(4):456–464. https://doi.org/10.2166/aqua.2022.024
22. Suleiman AM, Musa UM, Abdullahi H. Water quality assessment of Gubi Dam, Nigeria. African Journal of Environmental Assessment and Management,2020:25(2):133–142.
23. United Nations. The sustainable development goals report 2021. United Nations Publications, 2021.
24. WHO. Progress on household drinking water, sanitation and hygiene 2000–2020 Five years into the SDGs. World Health Organization and UNICEF, 2022.