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Physicochemical Quality and Bactericidal Efficacy of a Combined Moringa oleifera–Alum Coagulant on Borehole Water in Mubi North, Adamawa State, Nigeria

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ABSTRACT

Access to microbiologically safe drinking water remains a major public health challenge in rural and peri-urban communities of northern Nigeria, where reliance on shallow boreholes exposes residents to both physicochemical and microbial contamination. This study assessed the physicochemical characteristics of borehole water and evaluated the bactericidal efficacy of a combined Moringa oleifera seed powder and aluminium sulphate (alum) coagulant, applied in a 50:50 ratio at three dosages (10 g, 20 g and 30 g), against Escherichia coli and total coliform bacteria in borehole water sampled from eleven wards of Mubi North Local Government Area, Adamawa State, Nigeria. Water samples were analysed for pH, turbidity, total dissolved solids (TDS) and colour, and results were compared against the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) guideline values. Baseline E. coli counts ranged from 2.60×10^2 to 3.00×10^4 CFU/100 mL and total coliform counts from 27.7 to 158.0 CFU/100 mL, both well above their respective regulatory limits (0 CFU/100 mL for E. coli; 10 CFU/100 mL for total coliform). Treatment with the combined coagulant produced a clear dose-dependent reduction in bacterial load: E. coli was reduced to the compliant 0 CFU/100 mL level in all eleven wards only at the highest dose (30 g), while total coliform reached 0

CFU/100 mL in four wards (Bahuli, Betso, Digil, Kolere) at 30 g but plateaued at exactly the 10 CFU/100 mL limit in the remaining seven wards, indicating incomplete disinfection of this bacterial group even at the highest dose tested. Physicochemical results showed pH (6.3–7.1) largely within the acceptable range and turbidity (3.0–5.5 NTU) within the 5 NTU guideline value in all wards except Lokuwa (5.5 NTU), while TDS (92–281 mg/L) was well within the 500 mg/L limit at every location. These findings indicate that the Moringa oleifera–alum combination is a low-cost, locally sourced and effective bactericidal treatment for microbially contaminated borehole water, particularly against E. coli, although total coliform removal was less complete and would benefit from further optimisation.

Keywords: Moringa oleifera; alum; borehole water; Escherichia coli; total coliform; coagulation; Adamawa State, Nigeria

1. INTRODUCTION

Access to safe and adequate drinking water is a basic human need, yet more than a billion people worldwide still lack access to improved water sources, and diarrhoeal disease linked to contaminated water remains a leading cause of morbidity and mortality among children in developing countries (Pritchard et al., 2010). In Nigeria, the high cost and limited availability of conventional water-treatment chemicals mean that many rural and peri-urban households depend on untreated or minimally treated sources such as boreholes, wells, ponds and streams, which are frequently contaminated with faecal indicator organisms including Escherichia coli and total coliforms (Amagloh & Benang, 2009).

Aluminium sulphate (alum) is the most widely used chemical coagulant in conventional water treatment because of its established efficiency in removing turbidity and microbial load. However, its continued use in low-income settings is constrained by cost, import dependence, the acidifying effect of alum on treated water, and long-standing (though inconclusive)

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concerns regarding residual aluminium and its association with neurological disease (Amagloh & Benang, 2009). These limitations have driven interest in natural, plant-based coagulants as low-cost, biodegradable alternatives, among which Moringa oleifera seed has received the most research attention (Camacho et al., 2017. M.U Abba, 2015).

Moringa oleifera seeds contain water-soluble cationic proteins that neutralise the negative surface charge of colloidal particles, promoting flocculation and sedimentation in a manner comparable to conventional coagulants (Ndabigengesere et al., 1995). Beyond its coagulant action, M. oleifera seed extract has also demonstrated intrinsic antibacterial activity against a range of waterborne pathogens, giving it a dual coagulant–disinfectant role that is not shared by alum alone (Mohamed, 2025). Field and laboratory studies conducted across Nigeria and other developing countries have repeatedly shown that Moringa-based treatment, whether used alone or in combination with alum, can achieve substantial reductions in turbidity, total coliform and E. coli counts, in some cases performing comparably to or better than alum at equivalent doses (Agu, 2015; Mohamed, 2025).

Despite this growing evidence base, relatively few studies have quantified the dose-dependent bactericidal performance of a combined Moringa oleifera–alum coagulant applied directly to borehole water at the community level in northeastern Nigeria, where semi-arid conditions, shallow aquifers and limited treatment infrastructure combine to heighten the risk of waterborne disease. The present study therefore had two objectives: (i) to characterise the physicochemical quality (pH, turbidity, total dissolved solids and colour) of borehole water drawn from eleven wards of Mubi North Local Government Area, Adamawa State, Nigeria, relative to NSDWQ/WHO limits; and (ii) to evaluate the dose-dependent antibacterial efficacy of a 50:50 Moringa oleifera–alum combination, applied at 10 g, 20 g and 30 g doses, against E. coli and total coliform bacteria in the same water sources.

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2. MATERIALS AND METHODS

2.1 Study area

The study was carried out in Mubi North Local Government Area (LGA) of Adamawa State, in northeastern Nigeria. Borehole water samples were obtained from eleven wards within the LGA: Bahuli, Betso, Digil, Kolere, Lokuwa, Mayo-Bani, Mijilu, Muchella, Sabon Layi, Vimtim and Yelwa. The area lies within the Sudano-Sahelian ecological zone and depends predominantly on shallow boreholes and hand-dug wells for domestic water supply.

2.2 Sample collection

Water samples were collected in triplicate from a functional borehole in each of the eleven wards using sterile sample bottles, following standard aseptic sampling procedures. Samples were transported to the laboratory in a cool box and analysed within the recommended holding period.

2.3 Physicochemical analysis

pH was determined using a calibrated digital pH meter, turbidity was measured with a nephelometric turbidimeter and expressed in Nephelometric Turbidity Units (NTU), total dissolved solids (TDS) were determined using a calibrated TDS meter, and colour was assessed by visual observation. All physicochemical results are reported as mean ± standard deviation of triplicate determinations and were compared with the Nigerian Standard for Drinking Water Quality (NSDWQ, 2015) and WHO (2017) guideline values.

2.4 Preparation of the Moringa oleifera–alum coagulant

Mature, dried Moringa oleifera seeds were dehusked, air-dried, ground into a fine powder and sieved. Commercial-grade aluminium sulphate (alum) was obtained and combined with the Moringa seed powder in a 1:1 (50:50) ratio by weight to form the composite coagulant, which was then applied to the

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water samples at three dosage levels — 10 g, 20 g and 30 g — following the standard jar-test approach used in comparable studies (Amagloh & Benang, 2009; Agu, 2015).

2.5 Bacteriological analysis

Escherichia coli and total coliform counts were determined in raw (untreated) water and after treatment at each coagulant dose, following standard membrane filtration/pour-plate procedures on selective differential media, with incubation at 37 °C for 24 h. Colony counts were expressed as colony-forming units per 100 mL (CFU/100 mL). E. coli counts were compared with the NSDWQ requirement that E. coli be not detectable in any 100 mL sample (i.e., 0 CFU/100 mL), while total coliform counts were compared with the NSDWQ limit of 10 CFU/100 mL.

2.6 Statistical analysis

Data are presented as mean ± standard deviation of triplicate determinations. Results before and after treatment were compared descriptively against NSDWQ/WHO reference limits to evaluate treatment efficacy across wards and dosage levels.

3. RESULTS

3.1 Physicochemical characteristics of borehole water

Table 1 presents the mean physicochemical characteristics of borehole water sampled from the eleven wards. Mean pH values ranged from 6.3 ± 1.00 (Sabon Layi) to 7.1 ± 0.15–1.32 (Bahuli, Mayo-Bani, Mijilu), placing most wards within or close to the NSDWQ/WHO acceptable range of 6.5–8.5, with Kolere (6.4) and Sabon Layi (6.3) marginally below this range. Turbidity ranged from 3.0 ± 1.84 NTU (Mayo-Bani) to 5.5 ± 1.17 NTU (Lokuwa); all wards except Lokuwa were within the 5 NTU guideline value, with Lokuwa marginally exceeding it. TDS values were well within guideline limits across all wards, ranging from 92 ± 3.84 mg/L (Bahuli) to 281 ± 0.66 mg/L (Sabon

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Layi), all well below the 500 mg/L NSDWQ/WHO limit. All samples were colourless.

Ward	pH	Turbidity (NTU)	TDS (mg/L)	Colour
Bahuli	7.1 ± 0.15	4.6 ± 1.00	92 ± 3.84	Colourless
Betso	7.0 ± 3.33	4.7 ± 1.45	123 ± 1.76	Colourless
Digil	6.7 ± 0.24	3.7 ± 0.33	243 ± 1.15	Colourless
Kolere	6.4 ± 1.34	4.9 ± 2.22	271 ± 2.84	Colourless
Lokuwa	6.5 ± 1.20	5.5 ± 1.17	265 ± 1.25	Colourless
Mayo-Bani	7.1 ± 1.15	3.0 ± 1.84	181 ± 0.43	Colourless
Mijilu	7.1 ± 1.32	4.6 ± 1.27	131 ± 3.90	Colourless
Muchella	6.9 ± 2.90	3.9 ± 0.35	194 ± 0.78	Colourless
Sabon Layi	6.3 ± 1.00	4.1 ± 1.11	281 ± 0.66	Colourless
Vimtim	6.7 ± 3.21	3.8 ± 0.22	204 ± 1.20	Colourless
Yelwa	6.6 ± 2.72	4.0 ± 0.11	213 ± 2.33	Colourless
NSDWQ/ WHO limit	6.5–8.5	5	500	Colourless

Table 1. Mean physicochemical characteristics of borehole water from 11 wards in Mubi North LGA, Adamawa State.

3.2 Antibacterial efficacy of the Moringa oleifera–alum coagulant against E. coli

Table 2 shows the effect of the combined coagulant on E. coli counts. Untreated borehole water carried substantial E. coli loads, ranging from 2.60 × 10^2 CFU/100 mL (Mayo-Bani) to 3.00 × 10^4 CFU/100 mL (Lokuwa), all far above the NSDWQ requirement that E. coli be undetectable (0 CFU/100 mL). Treatment produced a marked, dose-dependent reduction, but detectable E. coli persisted in every ward at the 10 g dose (1.0–2.1 CFU/100 mL). At 20 g, seven of the eleven wards (Digil, Kolere, Mijilu, Muchella, Sabon Layi, Vimtim, Yelwa) reached 0 CFU/100 mL, while Bahuli, Betso, Lokuwa and Mayo-Bani retained low but detectable counts (1.0–1.3 CFU/100 mL). Full compliance with the zero-tolerance E. coli standard was achieved in all eleven wards only at the highest dose (30 g).

Ward	Untreated mean count (CFU/100 mL)	10 g dose	20 g dose	30 g dose	NSDWQ limit
Bahuli	2.70 × 10^4	1.9	1.0	0	0

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Ward	Untreated mean count (CFU/100 mL)	10 g dose	20 g dose	30 g dose	NSDWQ limit
Betso	2.47×10^3	1.1	1.2	0	0
Digil	1.97×10^4	0	0	0	0
Kolere	2.50×10^4	1.3	0	0	0
Lokuwa	3.00×10^4	2.1	1.3	0	0
Mayo-Bani	2.60×10^2	1.5	1.1	0	0
Mijilu	2.57×10^3	1.3	0	0	0
Muchella	2.20×10^3	1.0	0	0	0
Sabon Layi	2.10×10^4	1.1	0	0	0
Vimtim	2.57×10^3	1.2	0	0	0
Yelwa	2.03×10^3	1.0	0	0	0

Table 2. Antibacterial activity of the combined Moringa oleifera–alum coagulant (50:50 ratio) against E. coli in borehole water from 11 wards.

3.3 Antibacterial efficacy of the Moringa oleifera–alum coagulant against total coliform

Table 3 presents the corresponding results for total coliform counts, which were considerably higher than E. coli counts in raw water, ranging from 27.7 CFU/100 mL (Bahuli) to 158.0 CFU/100 mL (Kolere). At the 10 g dose, coliform counts remained well above the 10 CFU/100 mL limit in all wards (13.9–76.0 CFU/100 mL). At 20 g, counts were substantially reduced (2.9–23.1 CFU/100 mL), falling to or below the limit in nine of the eleven wards, while Digil (13.0) and Kolere (23.1) still exceeded it. At the highest dose (30 g), only four wards — Bahuli, Betso, Digil and Kolere — achieved complete elimination (0 CFU/100 mL); the remaining seven wards (Lokuwa, Mayo-Bani, Mijilu, Muchella, Sabon Layi, Vimtim, Yelwa) plateaued at exactly 10 CFU/100 mL, meeting but not falling below the regulatory limit even at the highest dose tested.

Ward	Untreated mean count (CFU/100 mL)	10 g dose	20 g dose	30 g dose	NSDWQ limit
Bahuli	27.7	18.7	6.3	0	10
Betso	44.7	28.4	7.9	0	10
Digil	71.0	45.8	13.0	0	10
Kolere	158.0	76.0	23.1	0	10
Lokuwa	33.3	13.9	4.8	10	10
Mayo-Bani	28.0	17.8	6.2	10	10

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Ward	Untreated mean count (CFU/100 mL)	10 g dose	20 g dose	30 g dose	NSDWQ limit
Mijilu	33.7	16.3	3.2	10	10
Muchella	46.0	22.1	5.7	10	10
Sabon Layi	78.0	51.3	11.3	10	10
Vimtim	40.0	16.9	5.7	10	10
Yelwa	89.7	37.9	2.9	10	10

Table 3. Effect of the combined Moringa oleifera–alum coagulant (50:50 ratio) on total coliform counts in borehole water from 11 wards.

4. DISCUSSION

The physicochemical results show that borehole water in Mubi North LGA is generally colourless, near-neutral in pH, within the WHO/NSDWQ turbidity guideline (with the marginal exception of Lokuwa), and well within the 500 mg/L TDS limit in every ward. This favourable baseline mineral and particulate profile indicates that the boreholes sampled are drawing from relatively low-mineralisation aquifers, and that the principal water-quality concern in this area is microbial rather than physicochemical contamination.

The bactericidal results demonstrate a consistent dose–response relationship for the combined Moringa oleifera–alum coagulant, but reveal an important difference between the two bacterial indicators studied. E. coli, though initially present at high loads, was fully eliminated in all eleven wards at the 30 g dose, indicating that this organism was highly susceptible to the combined coagulation and antibacterial action of the treatment. Total coliform, by contrast, was only fully eliminated in four of the eleven wards at the same dose, with the remaining seven wards plateauing exactly at the regulatory limit (10 CFU/100 mL) rather than falling below it. This pattern is consistent with the fact that total coliform is a broader, more heterogeneous group encompassing a wider range of environmental and enteric organisms, some of which may be less susceptible than E. coli to the coagulation–flocculation and cationic-protein-mediated bactericidal mechanisms attributed to Moringa oleifera (Ndabigengesere et al., 1995). Similar

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differential removal efficiencies between E. coli/faecal coliform and total coliform have been reported in other Nigerian and West African studies of Moringa-based coagulants (Amagloh & Benang, 2009; Agu, 2015; Mohamed, 2025).

The proposed removal mechanism combines physical entrapment of bacterial cells within settling flocs, formed as the cationic seed proteins neutralise negatively charged colloidal and microbial surfaces, with a direct antibacterial action attributed to phytochemical constituents of the seed (Camacho et al., 2017; Mohamed, 2025), while residual aluminium ions from the alum component may contribute an additional bactericidal effect. The plateau in coliform counts observed at exactly the regulatory limit in several wards, rather than a gradual approach toward zero, suggests that a subpopulation of more resistant coliform organisms — or organisms protected within larger floc aggregates may persist even at the highest dose tested, and that doses beyond 30 g, longer settling times, or a secondary polishing step (e.g., filtration) may be needed to achieve complete coliform removal in these wards.

From a public health and cost perspective, these findings support the use of a locally sourced Moringa oleifera–alum blend as a practical point-of-use or community-scale treatment option for microbially contaminated borehole water, particularly for E. coli control, in resource-limited settings such as Mubi North LGA. Because turbidity and TDS were already largely within guideline values, the main outstanding treatment gap is the incomplete coliform removal observed in seven of the eleven wards at the highest dose; complementary steps such as extended settling, a higher coagulant dose, or a secondary polishing filtration step would likely be needed to achieve consistent coliform compliance.

This study is subject to some limitations. The bacteriological and physicochemical determinations were based on composite/triplicate sampling from a single borehole per ward rather than repeated seasonal sampling, and the study did not assess residual aluminium concentration in treated water, viral or protozoan contamination, or the sensory/taste acceptability of treated water to end users. Future work should investigate why coliform removal plateaued in specific wards, test doses beyond 30 g, and evaluate the field-scale performance and cost-effectiveness of the combined coagulant under household conditions.

5. CONCLUSION

Borehole water across eleven wards of Mubi North LGA, Adamawa State, was found to be heavily contaminated with E. coli and total coliform bacteria, despite being visually colourless, near-neutral in pH, and largely compliant with WHO/NSDWQ limits for turbidity and total dissolved solids. A combined Moringa oleifera–alum coagulant, applied in a 50:50 ratio, produced a clear dose-dependent bactericidal effect: E. coli was eliminated to the zero-tolerance standard in all wards at the 30 g dose, while total coliform was fully eliminated in only four of the eleven wards at the same dose, plateauing at the regulatory limit in the remainder. These results support the combined coagulant as an effective, low-cost, locally available option for improving the microbiological safety of borehole water — particularly for E. coli control — while highlighting the need for either higher dosing, extended treatment, or a supplementary polishing step to achieve consistent total coliform compliance.

RECOMMENDATIONS

1. **Adoption of the Moringa–alum treatment:** The combined *Moringa oleifera* seed powder and alum coagulant should be considered as a low-cost treatment option for improving the microbiological quality of contaminated borehole water, particularly in rural and peri-urban communities.
2. **Use of an appropriate treatment dose:** Based on the results obtained, the 30 g dose of the 50:50 Moringa–alum mixture should be

preferred among the tested doses where effective *E. coli* removal is required, since it achieved 0 CFU/100 mL in all eleven wards.

3. **Additional treatment for total coliform:** Since the 30 g dose did not completely eliminate total coliform in seven wards, the treatment should be complemented with a secondary purification process such as filtration, extended settling, or another appropriate disinfection method.
4. **Optimization of the coagulant dosage:** Further studies should investigate doses above 30 g and different Moringa-to-alum mixing ratios to determine the optimum combination capable of achieving complete microbial removal without adversely affecting water quality.
5. **Routine monitoring of borehole water:** Relevant authorities and communities should undertake regular physicochemical and microbiological assessment of borehole water because visually clear water may still contain significant levels of disease-causing or indicator microorganisms.
6. **Assessment of residual aluminium:** Further investigation should determine the concentration of residual aluminium in treated water to ensure that repeated application of the Moringa–alum mixture does not introduce undesirable chemical residues. The present study did not assess residual aluminium.
7. **Field-scale evaluation:** Future studies should evaluate the effectiveness, operational feasibility, cost-effectiveness and user acceptability of the treatment under household and community-scale conditions and across different seasons before recommending widespread application.

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REFERENCES

Agu, M. O. (2015). Determination of degree of purity of some water sources treated with Moringa oleifera seed powder in Bali Metropolis, Taraba State, Nigeria.

Amagloh, F. K., & Benang, A. (2009). Effectiveness of Moringa oleifera seed as coagulant for water purification. African Journal of Agricultural Research, 4(1), 119–123.

Camacho, F. P., Sousa, V. S., Bergamasco, R., & Teixeira, M. R. (2017). The use of Moringa oleifera as a natural coagulant in surface water treatment. Chemical Engineering Journal, 313, 226–237.

Mohamed, W. S. (2025). Evaluation of Moringa oleifera seeds as a natural solution in comparison to alum for combatting common aquatic pathogenic bacteria by coagulation and antibacterial action. Applied Water Science, 15, 265. https://doi.org/10.1007/s13201-025-02624-w

M.U. Abba, 2015. Effect of Moringa Powder Application Rate on Purification of Microbiological Contaminated Hand Dug-Well Water Sources In Mubi Adamawa State, Nigeria. Continental J. Biological Sciences 8 (2): 42 - 51, 2015 ISSN: 2141 – 4122 *Wilolud Journals*, doi:10.5707/cjbiolsci.2015.8.2.42.51

Ndabigengesere, A., Narasiah, K. S., & Talbot, B. G. (1995). Active agents and mechanism of coagulation of turbid waters using Moringa oleifera. Water Research, 29(2), 703–710.

Nigerian Industrial Standard (NIS 554:2015). Nigerian Standard for Drinking Water Quality (NSDWQ). Standards Organisation of Nigeria, Abuja.

Pritchard, M., Craven, T., Mkandawire, T., Edmondson, A. S., & O'Neill, J. G. (2010). A comparison between Moringa oleifera and chemical coagulants in the purification of drinking water – an alternative sustainable solution for

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https://doi.org/10.5281/zenodo.21921841
NASARAWA STATE UNIVERSITY, KEFFI, NIGERIA

developing countries. Physics and Chemistry of the Earth, Parts A/B/C, 35(13–14), 798–805.

World Health Organization (WHO). (2017). Guidelines for Drinking-water Quality (4th ed., incorporating the 1st addendum). Geneva: World Health Organization.