



Moringa oleifera as a Natural Coagulant-Flocculant for the Removal of Turbidity and Heavy Metals from the Caplina Channel

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ABSTRACT

Driven by the high costs, residuals, and potential health impacts associated with chemical coagulants, this study evaluated a more environmentally and socially compatible bioprocess: the use of saline-activated (1 M NaCl) *Moringa oleifera* seed powder as a coagulant-flocculant to clarify surface waters from the Caplina Channel (Tacna, Peru). Raw water was collected, and jar tests were conducted at 125, 250, 500, and 750 mg.L⁻¹ (n = 3 per dose), measuring turbidity, electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), color, and dissolved metals (As, Cu, and Fe), in addition to a proximate analysis of the seeds. The optimal dose achieved 99.7% turbidity removal (from 3350 to 9.045 NTU) and reduced metals to As 0.005 mg.L⁻¹ (95%), Fe < 0.3 mg.L⁻¹ (94%), and Cu 0.045 mg.L⁻¹ (78%), with a pH 5.5, EC 936 μS.cm⁻¹, DO 7.24 mg.L⁻¹, TDS 762 mg.L⁻¹, and color < 5 Pt/Co, meeting Peru's ECA-Agua Category 1–A2 criteria for waters treatable by conventional processes. Although the EC increased with the dose, it remained below 1600 μS.cm⁻¹ at the optimal value. We highlight saline pretreatment and the activation of *M. oleifera* seed powder with 1 M NaCl as a high-efficiency clarification strategy. This strategy activates cationic proteins and increases the charge density of biopolymers, promoting particulate charge neutralization and metal-ion complexation/adsorption. This mechanism enables the simultaneous and high-efficiency removal of turbidity and metals using an accessible and sustainable biocoagulant suitable for settings with limited treatment infrastructure.

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1. INTRODUCTION

Limited access to safe water persists across large regions of the world and is aggravated by organic, inorganic, and biological contamination of surface sources. In this context, turbidity is an operational indicator of sanitary risk because of its association with colloids and particles that transport contaminants (Eichhorn et al. 2022, Ogunshina et al. 2023, Silva & Oliveira 2024). Conventional clarification using mineral coagulants, such as aluminum sulfate, is effective; however, it has disadvantages related to cost, availability, and chemical residues, motivating the search for more sustainable alternatives (Solis et al. 2012, Macías et al. 2017, Mera-Alegria et al. 2016).

Plant-derived natural coagulants have demonstrated favorable cost-effectiveness, low toxicity, and renewability and have been used historically to clarify surface and groundwater (Aguirre et al. 2018, Banchon et al. 2016, Pastrana-Pacho et al. 2023, Hadadi et al. 2022). In particular, *Moringa oleifera* seeds are known for their cationic proteins that neutralize charge and promote interparticle “bridging,” with reports of turbidity removal exceeding 90% and evidence of concurrent metal reduction (Silva & Oliveira 2024). Moreover, certain preparation conditions, such as dehusking and mortar grinding, improve efficiency at lower doses. An optimal dose of 30 mL.L⁻¹ of coagulant solution prepared from dehusked seeds achieved turbidity removal efficiencies between 92% and 100%. The seed-processing method that yielded the



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highest turbidity removal was manual mortar grinding, which outperformed blending (Silva & Oliveira 2024).

Nevertheless, a specific gap remains: few quantitative studies have evaluated the simultaneous removal of turbidity and dissolved metals using *Moringa* activated with NaCl. This saline activation (1 M NaCl) has a mechanistic rationale: it increases the extraction/activation of cationic proteins and the charge density of the biopolymer, favoring charge neutralization and bridging, which stabilize macroflocs and enable the binding/adsorption of metal ions. It also outperformed extracts obtained using water alone (Garcia et al. 2022, Hadadi et al. 2022). Despite this support, performance has been sparsely documented for coastal and high-Andean localities while verifying compliance with local regulatory guidelines.

Accordingly, this study quantitatively evaluated *Moringa oleifera* seed powder pretreated with 1 M NaCl as a coagulant–flocculant for surface water from the Caplina Channel (Tacna). Jar tests were conducted across a dose gradient (125–750 mg.L⁻¹), monitoring turbidity, electrical conductivity, dissolved oxygen, total dissolved solids, color, and dissolved metals (As, Cu, and Fe), and the results were benchmarked against Peru’s ECA-Agua Category 1–A2 criteria. This provides local, mechanistically grounded evidence of the potential of saline-activated *Moringa* for simultaneous clarification and metal removal, which is relevant to contexts with constrained infrastructure and a need for low-cost treatment options.

2. MATERIALS AND METHODS

2.1. Collection, Conditioning, and Proximate Analysis of *Moringa oleifera* Seeds

Moringa oleifera seeds were collected from agricultural fields in the La Yarada–Los Palos district. A total of 1 kg of seeds was gathered, and only those in suitable conditions for the study were selected. Seed conditioning was performed as described by Arango & Martinez (2022). *Moringa oleifera* seeds were manually dehusked, and the dry cotyledons were ground in a mortar, oven-dried at 105 °C for 60 min according to Cabrera et al. (2018), and finally sieved through a No. 70 mesh (0.21 mm). Dehusked *Moringa oleifera* seeds were subjected to proximate analysis at the Universidad Nacional del Altiplano de Puno, in the laboratories of the School of Biology.

2.2. Coagulant Extraction from *Moringa oleifera* Seeds

One L of 1 M sodium chloride (NaCl) saline solution was prepared with distilled water (electrical conductivity 5 $\mu\text{S}\cdot\text{cm}^{-1}$) to activate the seed components for the coagulation–flocculation process. Five grams of *Moringa oleifera* seed powder were weighed using a Taurus analytical balance and dispersed in 100 mL of 1 M NaCl. The mixture was vigorously agitated for 5 min to activate the coagulant with the prepared solution and allowed to stand for 3 min.

2.3. Jar Test

Jar tests were conducted following the method described by Feria et al. (2014), with modifications. In 2.0 L beakers containing Caplina Channel water, four doses of the natural coagulant obtained from *Moringa oleifera* seed powder (5% stock solution) were applied: 125, 250, 500, and 750 mg.L⁻¹. Each dose was evaluated in triplicate (n = 3), and in each test set, a blank (0 mg.L⁻¹) was run in parallel to estimate the percent improvement attributable to the coagulant according to the formula (relative to the initial value). The mixing

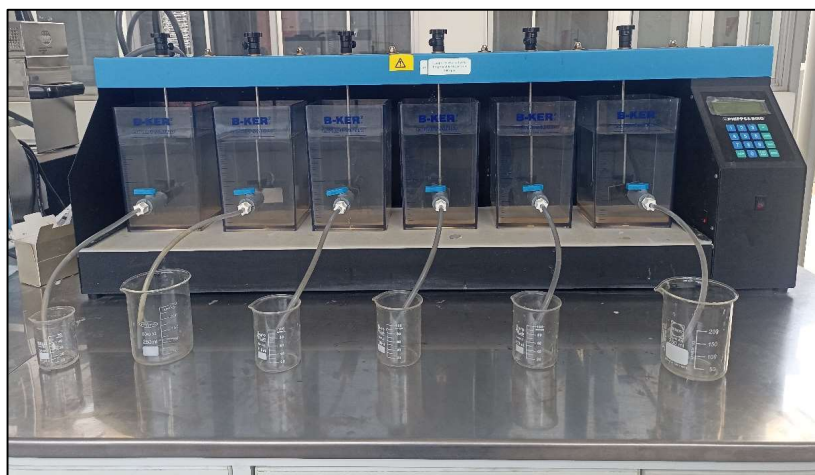


Fig. 1: Application of different doses of *Moringa oleifera* powder coagulant.

sequence was as follows: homogenization at 300 rpm for 2 min, rapid mixing at 250 rpm for 6 min, and slow mixing at 150 rpm for 6 min; sedimentation was then allowed for 90 min (Fig. 1).

The doses of the natural *Moringa oleifera* coagulant were determined using the following equation:

$$C_1V_1 = C_2V_2 \quad \dots(1)$$

Where:

C1 = Concentration of the stock coagulant solution 50,000 mg.L⁻¹

V1 = Volume extracted from the stock solution

C2 = Coagulant dose applied in the experimental procedure

V2 = Volume of Caplina River water to be treated (2 L)

Turbidity removal efficiency was determined according to Chales et al. (2022) using the equation:

$$\text{Removal (\%)} = \frac{\text{Initial turbidity} - \text{Final turbidity}}{\text{Initial turbidity}} \quad \dots(2)$$

2.4. Water Sampling and Analyses

A total of 88 L of water was collected from the Caplina River channel at coordinates E 374247, N 8016001 (UTM, WGS84), following procedures in the *National Protocol for Monitoring the Quality of Surface Water Resources*, approved by Resolution No. 010-2016-ANA (Autoridad Nacional del Agua [ANA] 2016). Analyses of water samples, before and after treatment, included turbidity (Turbidimeter Turbiquant® 1100 IR, MERCK), pH, electrical conductivity, and dissolved oxygen (multiparameter meter Hach HQ40D). Arsenic was determined by Standard Method 3114-C, APHA (atomic absorption spectrometry), while iron and copper were determined by Standard Method 3111-B, APHA (atomic absorption spectrometry).

2.5. Statistical Analysis

Variables with replication are reported as mean ± standard deviation (SD). When a variable had a single determination per treatment, the corresponding average was reported in the results. The coefficient of determination (R²) was calculated to explore the dose–response relationship for turbidity removal. For turbidity, electrical conductivity, and dissolved oxygen, comparisons among treatments and the initial values were performed using one-way analysis of variance (ANOVA), followed by Tukey's multiple comparison test with $\alpha = 0.05$ to identify significant differences (Pastrana-Pacho et al. 2023). In the table, superscript letters/symbols indicate homogeneous groups according to Tukey's test (same letters = not significantly different, different letters = significantly different).

Table 1: Proximate analysis results of *Moringa oleifera* seeds.

Proximate analysis	Unit	<i>Moringa oleifera</i> seeds ± SD
Moisture	%	17.23 ± 0.30
Protein	%	17.23 ± 0.30
Fat	%	32.92 ± 0.51
Carbohydrates	%	28.77 ± 0.08
Energy	kcal	480.28 ± 0.67
Ash	%	3.88 ± 0.46

3. RESULTS

The proximate analysis of *Moringa oleifera* seeds (Table 1) indicated a high fat content (32.92%) and protein content (17.23%).

The highest turbidity removal efficiency (99.73%) was obtained with 125 mg.L⁻¹ of *Moringa oleifera* seed powder (Fig. 2). In this study, doses between 125 and 750 mg.L⁻¹ were evaluated; within this range, the relationship between dose and turbidity removal was inversely proportional. Beyond this point, higher doses of *Moringa oleifera* powder increased the turbidity removal efficiency.

Fig. 2 also shows the influence of *Moringa oleifera* powder concentration (mg.L⁻¹) on the electrical conductivity (EC, $\mu\text{S.cm}^{-1}$) of Caplina Channel water, exhibiting a directly proportional relationship (R² = 0.9964): as the coagulant dose increased, EC also increased.

Table 2 indicates that all physicochemical parameters analyzed met the maximum permissible values for waters that can be made potable with conventional treatment (Peru's Environmental Quality Standards, ECA, Category 1 – A2).

Electrical conductivity (EC) increased with coagulant dose (R² ≈ 0.996), reflecting the higher ionic strength introduced by saline activation and the seed-derived ions. At the optimal dose, the final EC (936 $\mu\text{S.cm}^{-1}$) remained below the ECA-Agua Category 1–A2 threshold (1600 $\mu\text{S.cm}^{-1}$) and corresponded to TDS = 762 mg.L⁻¹, a range generally acceptable for palatability (< 1000 mg.L⁻¹, WHO). This supports practical acceptability while cautioning against the risk of overdose.

Dissolved oxygen (DO) increased from 4 to 7.24 mg.L⁻¹ after treatment, which may be attributed to re-aeration during mixing (increased gas–liquid interfacial area) and lower turbidity/organic load, which reduces oxygen demand and improves light penetration, thereby favoring oxygen transfer.

4. DISCUSSION

The moisture content of *Moringa oleifera* seeds was 17.23% (Table 1), which is higher than that reported by Silva et al.

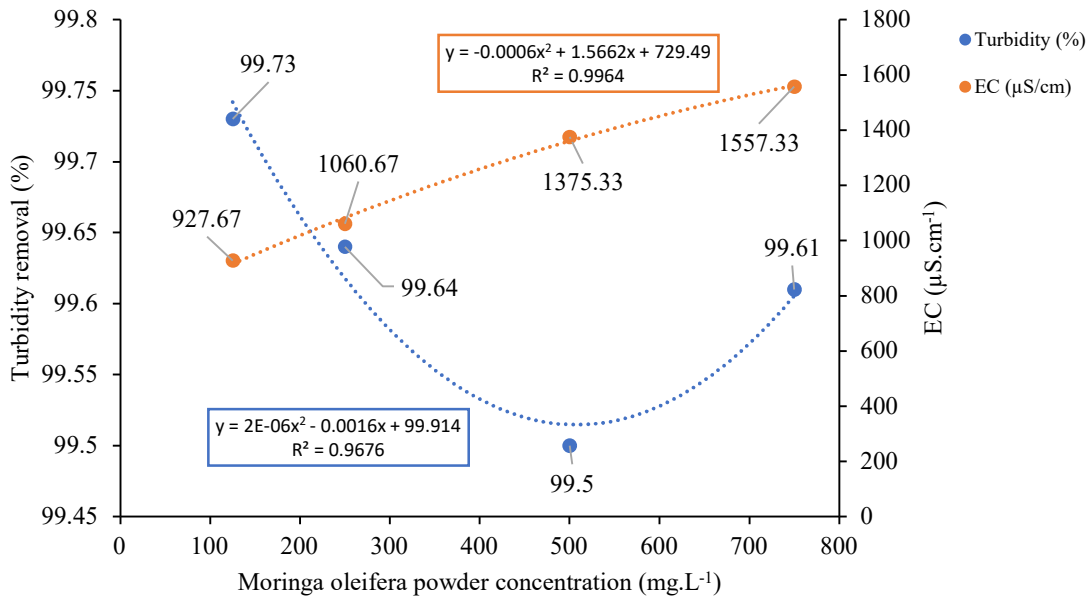


Fig. 2: Influence of *Moringa oleifera* seed-powder concentration (mg.L⁻¹) on turbidity removal (%) and electrical conductivity (µS.cm⁻¹) in Caplina Channel water.

Table 2: Comparison of water treated with *Moringa oleifera* against Peru's water ECA (Category 1 – A2).

Parameters	Caplina River water		Peruvian ECA for water, Category 1-A2 Waters that can be made potable with conventional treatment	The treated water meets the requirements (Yes / No)
	Initial water ± SD	Treated water ± SD		
Turbidity (NTU)	3350 ^a ±	9.045 ^b ±	100	Yes
pH	5.9 ^a ± 0.1	5.5 ^b ± 0.1	5.5 – 9.0	Yes
Electrical conductivity [µS.cm ⁻¹]	1423 ^a ± 4.6	936 ^b ± 5.3	1 600	Yes
Dissolved oxygen [mg.L ⁻¹]	±2.3	7.24 ± 1.2	≥ 5	Yes
Total dissolved solids [mg.L ⁻¹]	-	762 ± 2.1	1 000	Yes
Color (Pt/Co)	100 ± 0.1	<5	100	Yes
As [mg.L ⁻¹]	0.1 ± 0.01	<0.005	0.01	Yes
Cu [mg.L ⁻¹]	0.2 ± 0.01	<0.045	2	Yes
Fe [mg.L ⁻¹]	5 ± 0.01	<0.5	1	Yes

Note: One-way ANOVA, n = 3 per group: turbidity F(1,4)= 7.46×10³, pH F(1,4)= 267, EC F(1,4)= 2.45×10³, All with a < 0.05.

^{ab} Different letters indicate significant differences according to the Tukey multiple range test, p<0.05.

(2018) (5.59% in seed cake). This difference is consistent with the matrix type: defatted seed cake typically shows lower residual moisture due to pretreatment and oil removal, whereas the whole seed retains a higher water content.

The literature indicates that *Moringa oleifera* contains proteins, carbohydrates, and other components in proportions that vary with the matrix and processing (Del Toro et al. 2016). In this study, the seeds contained 17.23% protein.

Several reports show higher values: Silva et al. (2018) reported 32.57% in salt-treated cake, Rubio (2019), 30.2% in raw seed flour, and Almora-Hernández et al. (2022), 37.23% in cake. Such discrepancies are expected because defatting/extraction tends to concentrate the protein fraction in the cake relative to the whole seed, and because the reporting basis (wet vs. dry) and particle size also influence analytical outcomes.

The fat content in seeds was 32.92%, which is below that reported by Rubio (2019) (41.36% in raw flour) and slightly lower than that reported by López (2019) (35.1% in seeds). These variations align with differences in cultivar/origin, maturity stage, and the analytical conditions.

Seeds contained 28.77% carbohydrates, higher than reported by Rubio (2019) (14.74% in raw flour), López (2019) (16.2%), and Alvarez (2016) (21.02% in cake). It should be noted that, in proximate analysis, carbohydrates by difference accumulate the uncertainty of the other components (moisture, protein, fat, and ash); thus, differences in any of these (and in the reporting basis) can carry over to the “carbohydrates” fraction.

The energy calculated for *Moringa oleifera* was 480.28 kcal.100 g⁻¹, which is lower than that reported by López (2019) (533.5 kcal.100 g⁻¹ in seeds). This is consistent with the lower fat content observed here relative to that study, given that lipids contribute 9 kcal.g⁻¹ (vs. 4 kcal.g⁻¹ for protein and carbohydrates) and with the relatively higher moisture.

The ash content was 3.88%, similar to that reported by López (2019) (3.3%) and Alvarez (2016) (4.64% in cake). Other authors have reported higher values, for example, Almora-Hernández et al. (2022) (11.76%) and Silva et al. (2018) (7.11% in cake). These differences can be attributed to the matrix type (defatted cake can concentrate the relative mineral residue), geographical origin, and methodological variation.

Overall, the observed patterns are consistent with comparisons between whole seeds and cake/flour reported in the literature: defatting/extraction tends to increase protein and ash percentages and decrease fat relative to whole seeds, moisture and reporting basis conditions all fractions, and carbohydrates by difference reflect the accumulation of small variations in the other components (Silva et al. 2018, Del Toro et al. 2016, Rubio 2019, Almora-Hernández et al. 2022, López 2019, Alvarez 2016).

Turbidity quantifies the loss of water clarity due to suspended materials that attenuate light transmission (Marín-Velásquez & Arriojas-Tocuyo 2020). In this study, the 1 M NaCl-pretreated *Moringa oleifera* seed powder

coagulant achieved 99.50–99.73% turbidity removal across the evaluated dose range. The literature shows variable efficiencies attributable to matrix, pretreatment, and operating conditions: Zea et al. (2024) reported 85%, Carrillo et al. (2020) obtained 87.3% with 1 N NaCl and, after Soxhlet defatting, 97.8%, consistent with our values, Eichhorn et al. (2022) reported up to 93% using *Moringa* seeds as a natural coagulant, and Zacarías (2019) reported 89–96% in Shullcas River surface water. These differences are consistent with the influence of each water’s organic/colloidal load, biomass state (seed, flour, or defatted cake), saline activation, and variables such as pH, mixing regime, and settling time. In general, natural coagulants are regarded as options with lower direct toxicity and bioactive fractions (proteins, polysaccharides, and mucilages) (Castellanos & Martin 2020) and are proposed as alternatives to synthetic coagulants in specific contexts (Alva & Caballero 2022, Zea et al. 2024).

Mechanistically, cationic, water-soluble proteins from *Moringa* (pI > 10) promote charge neutralization and interparticle bridging, driving the formation of settleable flocs. This effect is activated by milling and dispersing the material in water (Arango et al. 2017, Castellanos & Martin 2020). Consistently, Hadadi et al. (2022) indicated that polysaccharides and proteins mediate bridging and neutralization, supporting turbidity removal. Saline extraction increases the availability of the active fraction, thereby increasing the coagulant potential for potabilization (Urrea-Florián & Torres-Benítez 2021). However, Garcia et al. (2022) noted that saline solutions can increase electrical conductivity and, at high doses, be associated with the cytotoxicity of the treated water; thus, it is advisable to delimit operational windows that maximize clarification without penalizing sensory or health quality. In our study, the minimum EC observed was 936 $\mu\text{S}\cdot\text{cm}^{-1}$ at 125 mg.L⁻¹, whereas Alvarez (2016) reported 1280 $\mu\text{S}\cdot\text{cm}^{-1}$ in a different matrix. This comparison suggests that the ionic contribution from activation and water composition governs the balance between efficiency and ionic strength.

Dissolved oxygen (DO) increased from 4 mg.L⁻¹ in Caplina Channel water to 7.24 mg.L⁻¹ after treatment with *Moringa oleifera*. This rise is consistent with mixing-induced re-aeration and reductions in turbidity and organic load, which decrease O₂ demand and improve transfer. In contrast, Muñoz et al. (2015) documented DO declines associated with pollution in the Zahuapan River, and contextualized that water quality and suspended/dissolved organics modulate DO behavior.

The total dissolved solids (TDS) content of the treated water was 762 mg.L⁻¹, which is higher than that reported

by Alvarez (2016) (511.33 mg.L^{-1}) for wastewater from passion fruit nectar production. This difference is reasonable, given the contrast in the matrices and ionic load. Dissolved organic matter spans a broad spectrum of species (from particles and colloids to macromolecules) that influence coagulation performance and global quality indicators (Fuentes et al. 2015). Additionally, Barrera-Escorcía and Namihira-Santillán (2004) observed associations between high bacterial concentrations, low salinity, and low DO in coastal waters, highlighting that physicochemical and biological conditions can co-vary. In our case, the increase in DO and reduction in turbidity after treatment were consistent with improved oxygen transfer in the short term.

The color in the channel water (100 Pt/Co) decreased to $< 5 \text{ Pt/Co}$ ($\approx 95\%$ removal). This performance exceeds that reported by Vivas et al. (2022), who used a cationic polyelectrolyte extracted from *moringa* seeds and obtained 6.67–25.67% color removal. It also exceeded that of Moreira-Colletti et al. (2016) (84.2–87.3% in lake water with added humic substances and 60 min reaction). These differences can be attributed to the matrix nature (surface vs. wastewater), extraction/activation strategy, dose, and settling time (90 min in this study), all of which affect the apparent color removal.

The presence of heavy metals in aquatic ecosystems is chiefly associated with anthropogenic industrial sources, with impacts on human health and biotic/abiotic compartments (water, biota, and soils) through incorporation into the trophic web via environmental discharges. In this context, the cationic polyelectrolyte derived from *Moringa oleifera* is considered an organic, biodegradable input with lower reported toxicity than certain synthetic coagulants, making its evaluation as a contaminant-removal agent in water relevant.

In the Caplina channel, the initial As concentration was 0.10 mg.L^{-1} , and after treatment with *Moringa oleifera* seed powder, a 95% removal (0.005 mg.L^{-1}) was observed. In previous studies, Esparza et al. (2023) reported a 51% reduction with *Moringa oleifera* Lam, while Hernández-Sánchez et al. (2018) reported 82.11% efficiency using *Moringa oleifera* Lam seed flour. Mendoza (2018) further noted that removal increased with dose and that this bioadsorbent could match the effectiveness of aluminum sulfate under certain conditions. For copper, the initial concentration (0.20 mg.L^{-1}) decreased to 0.045 mg.L^{-1} (77.5%), surpassing the performance of Elsergany (2023) with defatted *M. peregrina* extract at 200 mg.L^{-1} , which achieved a 66.5% reduction. For iron, the initial concentration (5 mg.L^{-1}) decreased to $< 0.30 \text{ mg.L}^{-1}$ (94%), exceeding the results of Lagos (2017) (90.4% with *Moringa oleifera* Lam). Collectively, the physicochemical parameters analyzed after treatment with *Moringa oleifera* seed powder

met the maximum limits for waters that can be made potable with conventional treatment (Category 1 – A2 of Peru's ECA for water).

The removal pathway is dual, integrating (i) adsorption/complexation and (ii) co-removal within organic flocs. Salt-activated *Moringa* concentrates contain cationic proteins ($\text{pI} = 10\text{--}11$, 6.5–30 kDa) that neutralize particles and negatively charged anions (e.g., arsenate), promoting aggregation via charge neutralization and bridging. At pH 6–8, the dominant As species are $\text{H}_2\text{AsO}_4^-/\text{HASO}_4^{2-}$ (anionic), so the cationic fraction of *Moringa* favors their capture. For Fe/Cu (cations), interactions occur at anionic sites of organic matter ($-\text{COO}^-$, $-\text{OH}$) and/or via co-precipitation within flocs, completing the dual mechanism. At elevated ionic strengths, Na^+ can compete with divalent cations for negative sites and compress the double layer, which could reduce the uptake of $\text{Cd}^{2+}/\text{Pb}^{2+}$; hence, it is reasonable to optimize the salt type/strength (NaCl vs. KCl), dose, and pH to maximize the removal of these metals without compromising clarification efficiency.

Extraction with 1 M NaCl is key to obtaining a protein-rich cationic extract of *Moringa oleifera*. The salting-in phenomenon increases the solubility and recovery of these proteins, enabling operation at moderate doses and achieving high turbidity removal efficiencies. As summarized in Fig. 3, coagulation/flocculation with the saline extract is primarily based on electrostatic adsorption; cationic proteins neutralize the colloid charge and facilitate sedimentation. Notably, excessive doses can restabilize the particles via positive overcharging. For heavy metals, adsorption and chelation occur simultaneously. Hydroxyl, carboxyl, and amine groups in the biomass (defatted seeds, husks, and leaves) complex/adsorb cations via ion exchange, electrostatic attraction, and surface coordination.

pH is a determining factor because it regulates functional group protonation and, consequently, metal affinity. In slightly acidic to neutral–mildly alkaline media (pH 6–8), carboxyls tend to ionize, favoring cation sorption. At highly alkaline pH values, metal-hydroxide precipitation increases and can compete with adsorption. Therefore, avoiding extreme pH and operating within windows that maximize complexation and stable floc formation are advisable.

In summary, the 1 M NaCl-activated *Moringa* coagulant/flocculant integrates electrostatic adsorption (cationic proteins) with adsorption/chelation of metal ions (hydroxyl, carboxyl, and amine groups), mechanisms that act complementarily to remove turbidity and metals and metalloids in water treatment.

Finally, Konkobo et al. (2024) indicated that under test conditions with biodegradable, low-toxicity organic extracts,

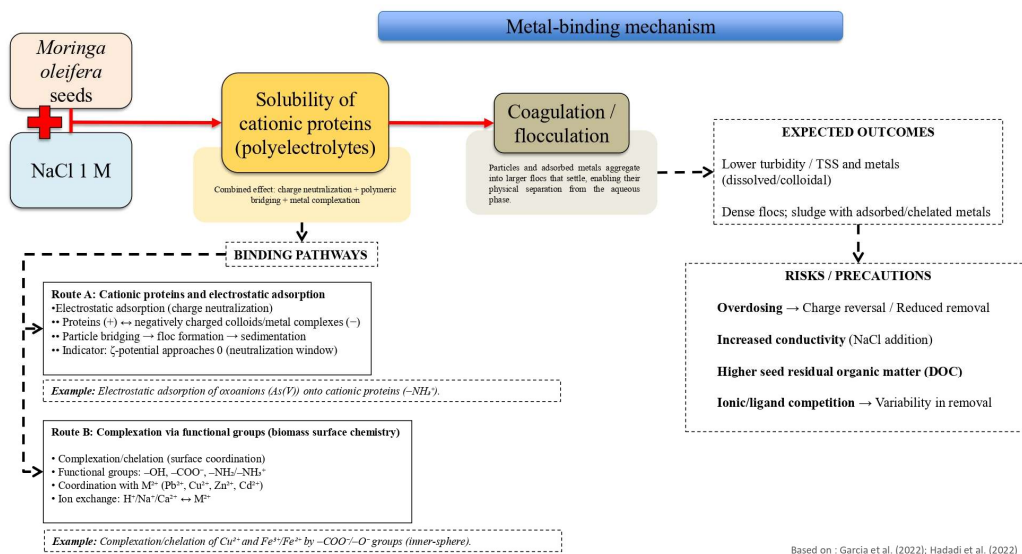


Fig. 3: Mechanism of metal binding by saline-extracted *Moringa oleifera* seed coagulant (1 M NaCl). Note. Saline extraction (“salting-in”) increases the solubility of cationic polyelectrolytes, enabling (Route A) electrostatic charge neutralization/bridging and (Route B) complexation/ion exchange at $-\text{OH}/-\text{COO}^-/-\text{NH}_2(-\text{NH}_3^+)$ sites, followed by flocculation and sedimentation.

the sanitary quality of treated water can meet physicochemical and microbiological parameters according to the WHO acceptability standards. While chemical coagulants such as aluminum sulfate effectively reduce turbidity, their use can be associated with costs and chemical residuals, as well as health and management considerations. In this study, 1 M NaCl was selected to enhance the extraction/activation of the cationic protein fraction (higher charge density), consistent with reports showing the better performance of saline *Moringa* extracts compared with water-extracted flours. In this framework, and as proposed by Zea et al. (2024), the use of organic products such as *Moringa oleifera* represents a bio-coagulation alternative for water treatment, particularly in contexts seeking to reduce colloidal load and metals while maintaining acceptability criteria and regulatory compliance of the treated water.

5. CONCLUSIONS

This study demonstrated that *Moringa oleifera* seed powder, as a natural coagulant-flocculant, has a high potential for removing turbidity and metals and metalloids from Caplina Canal water in Tacna, Peru.

Proximate analysis of *Moringa oleifera* seeds indicated that they contained 17.3% protein, 17.3% moisture, 32.92% fat, and 3.8% ash, making them suitable as a natural coagulant. Likewise, the Caplina canal water had a pH of 5.9, electrical conductivity of 1423 $\mu\text{S}\cdot\text{cm}^{-1}$, and turbidity of 3350 NTU.

The water treated with the natural coagulant-flocculant from *Moringa oleifera* had a final pH of 5.5, electrical conductivity of 936 $\mu\text{S}\cdot\text{cm}^{-1}$, dissolved oxygen of 7.24 $\text{mg}\cdot\text{L}^{-1}$, and turbidity of 9.045 NTU. Metals and metalloids such as arsenic (0.005 $\text{mg}\cdot\text{L}^{-1}$), copper (0.045 $\text{mg}\cdot\text{L}^{-1}$), and iron (< 0.3 $\text{mg}\cdot\text{L}^{-1}$) were also present. These values are within the Environmental Quality Standards for water in category 1 – A2, which can be made potable with conventional treatment.

6. ACKNOWLEDGMENTS

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