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Turbidity Removal using Moringa Oleifera Seeds Powder as a Bio-Coagulant

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Abstract

The ability and the effectiveness of Moringa Oleifera (MO) seeds powder as a bio-coagulant to remove turbidity in water was evaluated in this study. This sustainable and natural approach offers numerous advantages when compared to conventional chemical approaches, most notably the absence of chemical usage, cost-effectiveness, ease of use, and safety regarding human health. The investigation included the preparation of MO seeds powder solution (1%) and synthetic water samples by mixing pottery clay in tap water. Six turbidity ranges within 0-200 NTU designated as Range I to VI were constituted to examine the turbidity removal efficiency of MO seeds solution. The study showed the optimum MO dose as 15, 25, 25, 30, 35, and 35 mg/L for the turbidity ranges 0-25, 25-50, 50-75, 75-100, 100-150, and 150-200 NTU respectively. These observations clearly indicate that the turbidity removal efficiency of MO seeds solution increased with an increase in the dose. The study revealed the turbidity removal efficiency of MO seeds solution ranges from 81% to 94.06% while that of alum ranged from 76.7% to 93.8%. Also, the study showed that MO seeds solution's use as a natural bio-coagulant did not cause any substantial change in the pH of the water sample as done by alum (chemical coagulant).

Keywords

Bio-coagulants, Moringa Oleifera, Drinking water, Alum, Turbidity, Clay

1. Introduction

Access to clean and sufficient drinking water is a prominent worldwide concern. Unfortunately, a large number of people, roughly 785 million individuals, do not have access to the fundamental drinking water amenities. Among these, about 144 million people rely on surface water sources for their water needs [1]. Even in Nepal despite having abundant water resources, access to clean drinking water remains a significant challenge, particularly in rural regions. Although numerous water purification techniques are available, they are often inaccessible to the general population due to their high cost or the lack of technical expertise required to operate them. Therefore, in such a context MO, a plant rich in cationic protein and well adapted in tropical and sub-tropical countries, can be a reliable, alternative, natural coagulant for water treatment [2]. Studies have shown it to be effective, abundantly available, cheaper, with minimal generation of by-products, biodegradable, and non-toxic [2].

The use of MO in water treatment has the added advantage of being a safe biological solution over chemical coagulants as the plant is reported to be edible [3]. Throughout history, MO has been widely used to support health benefits. Further, MO can also be utilized as an effective source of fuel, fertilizer, water purification, and animal feed [4]. The constituents found in MO seeds are comprised of dimeric, cationic proteins that are soluble in water facilitating the coagulant activity [2]. The seeds in particular are considered a rich sources of bio-active components including albumin, globulin, prolamin, glutelin etc. responsible for the flocculation process [5]. The MO seeds contain non-toxic acrylamide monomers and the coagulation mechanism takes place by charge neutralization process [6]. Multiple coagulants, which can be divided into inorganic, synthetic organic polymer, and naturally occurring coagulants, are frequently utilized in conventional water treatment methods. Synthetic polyelectrolytes are commonly used as primary coagulants and coagulant aids. However many water treatment works in developing countries use arbitrary guidelines for chemical dosage and struggle with a shortage of trained personnel and insufficient laboratory facilities. Because of this in developing nations like ours, interest in natural coagulants for water treatment has immensely increased [7].

Inorganic chemical coagulants like aluminum and ferric salts and other charged organic polymers are highly effective at decreasing particulate and organic pollutants from water but they can be costly to produce, convey, and stockpile. Furthermore, they give rise to additional water-related health concerns including the presence of leftover iron and aluminum compounds and synthetic polymers that are harmful [8]. Not much investigation has been done in Nepal using MO in the form of a coagulant in water purification systems. Also, the expense associated with using this natural coagulant for water purification is expected to be lower than that of the conventional coagulant, alum. The natural coagulant is readily available in many rural areas of Nepal even where access to treated water is limited. Therefore, this study is conducted to evaluate how efficient the powder obtained from MO seeds is as a coagulant substance in water purification for decentralized household utilization, to provide a potentially low-cost and sustainable solution for improving access to safe drinking water in low-income locales.

2. Materials and methods

The overall schematic methodological framework of this study is shown in Figure 1.

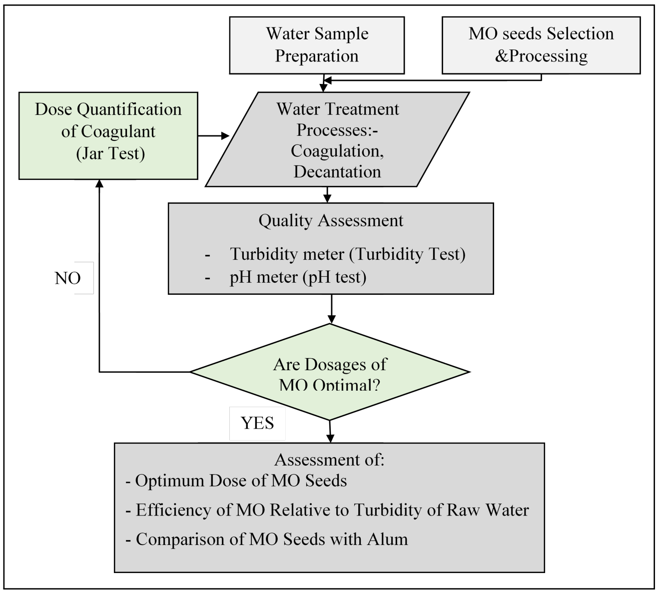

Figure 1: Methodological Framework

2.1 Preparation of Synthetic Turbid Water

Locally available pottery clay was ground into fine grain, passed through a 300-micron sieve, and mixed with tap water to prepare synthetic turbid water for coagulation study in each turbid sample as previously performed by AL-Sameraiy Mukheled in a study [9]. Preparation of different turbidities (0-200NTU) designated as Range I to VI as shown in Table 1 was done in Public health laboratory, Pulchowk Campus.

Table 1: Range of different turbidity values

Turbidity Value (NTU)	Range
0-25	I
25-50	II
50-75	III
75-100	IV
100-150	V
150-200	VI

The turbidity of raw water often experienced at the source ranges from 0 to 100 NTU. Hence, four ranges with a closer range value of 25 NTU are implied in the study. In rainy seasons, the turbidity increases at the sources and reaches up to 200 NTU but the occurrence is within a short period. Hence, the ranges from 100-200 NTU have been divided into only two ranges.

2.2 Preparation of MO Seeds Powder

Fresh and ripe MO seeds were arranged from Nepal Agro Forestry Seed Cooperative Limited (NAFSCOL), Balkumari, Kathmandu, Nepal. Seeds free from damage were selected and dried at 40°C for about two days to remove any moisture present. The outer shells surrounding the seed kernels were dehusked using a knife. The inner kernels were ground into a fine powder using a grinder for 30 seconds to 1 minute. The powder was sieved through 600 microns to obtain a fine powder.

2.3 Preparation of Coagulant Solution

Five grams of MO seeds powder of size lesser than 600 microns were mixed with 500ml of distilled water to prepare a coagulant solution of 1% concentration. Doses of prepared coagulant solution, ranging from 5ml to 40ml in increments of 5ml, were applied based on the specific needs of different levels of turbidity in synthetic water to assess the effectiveness of turbidity removal. Similarly, 1 gm of alum was mixed with 100 ml of distilled water to prepare a coagulant solution of 1% concentration. Varying doses of it were then used on varying turbidities of synthetic water to know its efficiency in removing turbidity.

2.4 Evaluation of MO seeds powder through jar test

The effectiveness of the MO seeds as coagulant was determined through the jar test (ESICO International, MODEL 1926), by means of exploratory tests in a range of doses 5ml to 40ml of MO solution of 1% concentration. Rapid mixing was done for 3 minutes and a slow mixing at 40 rpm for 20 minutes. The process was completed with the sedimentation phase, in which the water was allowed to stand for thirty minutes. After the sedimentation period, a sample of supernatant was collected at a point approximately 2 cm below the top of the liquid level of each beaker. Physiochemical parameters like Turbidity and pH were determined by turbidimeter (Max Electronics, Model No. 988) and pH meter (HANNA instruments, Code: HI2002-02) respectively and analyzed. The procedure was repeated three times on each water sample and average values of turbidity for the same retention times were recorded. The exploratory tests were carried out in synthetic turbid water samples with different values of initial turbidity in the range as indicated in table 1.

3. Results and Discussion

3.1 Turbidity removal efficiency of MO seeds powder

The turbidity removal efficiency of MO seeds solution for varying turbidity Ranges I, II, III, IV, V and VI is shown in Figure 2 and Figure 3. The graph shows the optimal dose estimated in each range was 15 ml, 25ml, 25ml, 30ml, 35ml, and 35ml reducing the turbidity up to 2.33 NTU, 6.33 NTU, 7.33 NTU, 9.67 NTU, 9.67 NTU, and 9.67 NTU from the turbidity Ranges I, II, III, IV, V and VI respectively. This also indicates higher turbidity range requires a higher dose of MO coagulant for turbidity removal up to the permissible limit as per NDWQS i.e. less than 10 NTU. The turbidity removal efficiency was calculated to be 82.93%, 81.00%, 88.94%, 88.72%, 92.12%, and 94.06% for Ranges I, II, III, IV, V and VI respectively. This clearly indicates the better performance of MO seeds in high turbid water. Moringa's coagulation activity is more pronounced in high turbidity water since there are more particles for the cationic proteins to interact aiding the formation of floc which are clusters of particles that come together, leading to improved water clarification and purification. It highlights the importance of optimizing the coagulant dose to the specific characteristics of the water source indicating that higher turbidity levels necessitate a higher coagulant dose to achieve the desired reduction. By optimizing the MO coagulant dose based on the initial turbidity levels, water treatment facilities can achieve efficient turbidity reduction, ensuring compliance with water quality standards.

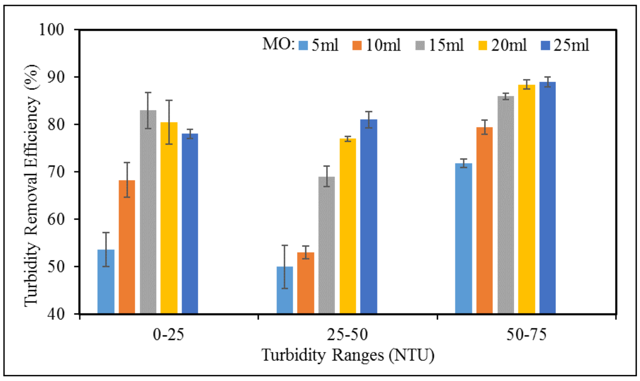

Figure 2: Efficiency of MO in turbid water sample of Range I, II and III

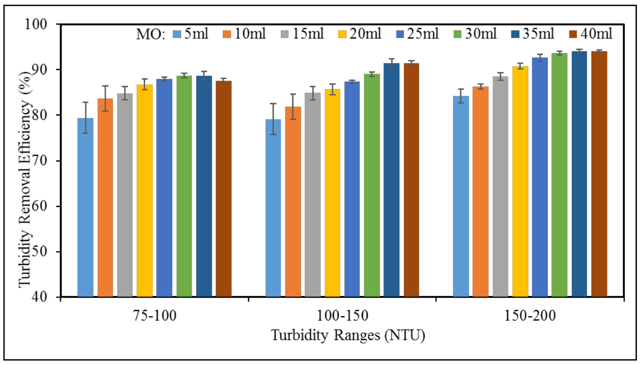

Figure 3: Efficiency of MO in turbid water sample of Range IV, V and VI

3.2 Comparison of Optimal Efficiency of MO with Alum

In order to show the effectiveness of MO seeds, we compared its efficiency of turbidity removal with that of conventional chemical coagulant alum. Among the various synthetic turbid water prepared from clay soil, the MO seeds powder was found to be more or less similar to that of alum in the medium and higher turbid ranges i.e. Range III to VI as shown in Table 2 and Figure 4. However, the efficiency of MO seeds was slightly higher in lower turbid ranges i.e. Range I and II. This performance illustrates that MO seeds can be a viable alternative for water treatment when chemical coagulants like alum are not readily available or are less desirable due to cost or environmental concerns. The reliable coagulation properties of MO seeds position them as a promising solution for water treatment in diverse settings, particularly when the feasibility of conventional coagulants poses challenges.

Table 2: Efficiency of alum vs MO in turbid water sample

Turbidity Range	Optimal Efficiency (%)	
	Alum	MO
I	81.00	82.93
II	76.70	81.00
III	88.50	88.94
IV	88.24	88.72
V	92.06	92.12
VI	93.89	94.06

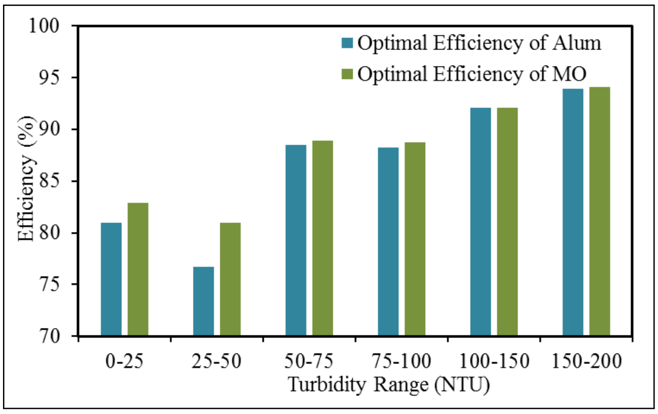

Figure 4: Efficiency of alum vs MO in turbid water sample

3.3 pH variation after water treatment with MO and alum

Treatment of turbid water sample with seed powder of MO experienced only a slight variation of pH while treatment with alum showed a higher decrease of pH in comparison to that of the initial state as shown in Table 3 and Figure 5. pH can impact taste, mineral solubility, and corrosion in distribution pipes, crucially affecting overall water quality and suitability. Therefore, the milder pH variation observed with MO seeds powder suggests that it offers a practical and effective means of enhancing water quality without introducing significant alterations in pH, thereby contributing to the overall suitability of the treated water.

Table 3: pH effect of MO & alum in synthetic water sample

Turbidity Range	Initial pH	Final pH	
		with Mo	with Alum
I	7.39	7.37	7.15
II	7.45	7.43	7.13
III	7.53	7.51	7.05
IV	7.58	7.57	6.99
V	7.61	7.60	6.90
VI	7.64	7.62	6.88

4. Conclusions

The research findings demonstrate the effectiveness of MO seeds powder as a bio-coagulant for water treatment, particularly in varying turbidity conditions. From this research work, it has been found that in low turbid water i.e. Range I, MO seeds powder achieved the residual turbidity level of <5 NTU and in medium to high turbid water i.e. Range II to VI the residual turbidity level was <10 NTU which are all within the permissible limit of Nepal Drinking Water Quality

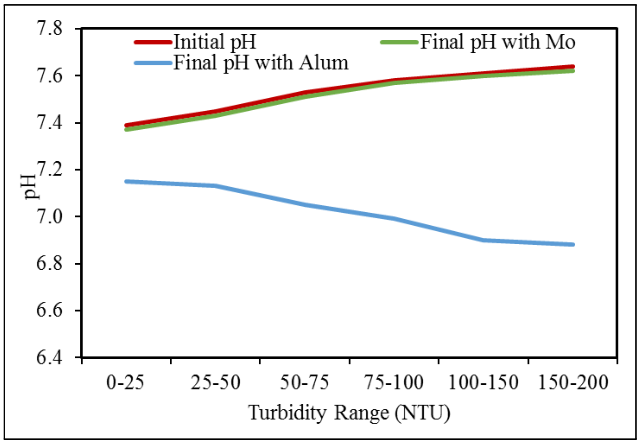

Figure 5: pH effect of MO & alum in synthetic water sample

Standards (NDWQS). The turbidity removal efficiency of MO was highest for higher turbidity range i.e. 94.03% for Range VI. The experimental results confirmed the turbidity removal efficiency of MO was better and in consistent with that of alum in terms of residual turbidity for pottery clay synthetic water. Also, MO showed almost no variation in pH while alum showed a marked variation in the pH of water causing it to be more acidic than its initial state. Therefore, it is reasonable to consider MO as a bio-coagulant for its advantageous effect and properties in treated water which can be better implied for point-of-use household purposes in rural settings. Its advantageous effects, coupled with its better performance across different turbidity ranges and pH stability, make MO a practical and sustainable choice for addressing water treatment needs in resource-constrained environments. Refinement methods to enhance the turbidity removal efficiency of MO seeds and the influence of variables like storage conditions and the effect of temperature on MO powder can be further studied.

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