

Optimizing Rural Water Quality Using Indigenous Plant-Based Coagulants: A Comparative Analysis

Moulik Jain

The Wisdom Global School, Haridwar, Uttarakhand, India

Abstract

Access to potable water is a basic human right and remains a critical challenge, particularly in regions where the river water isn't clean. This study presents a comparative analysis of four seed-based natural coagulants—*Moringa*, *Vigna mungo* (urad), *Vigna unguiculata* (cowpea), and *Zea mays* (corn)—combined with a consistent natural filter for purifying rural tap water. Recent research has highlighted the potential of low-cost, naturally occurring materials as effective solution for rural water purification. This study addresses the gap in existing literature by testing multiple coagulants under consistent filtration conditions to determine which is the best-performing coagulant.

To test this, a consistent multilayer natural filtration prototype was used, with a single source of rural municipal tap water sample, which was first treated with each of the four coagulants and then passed through the filter. Turbidity, TDS, pH, sulphate, chlorine, chloride, alkalinity, and total hardness were measured for the sampled water, after the coagulation stage and after filtration, to assess the performance of the coagulants. The results showed that *Moringa oleifera* consistently outperformed other coagulants, achieving the greatest reductions in TDS (Total Dissolved Solids), turbidity, and hardness while maintaining pH stability. Cowpea was found to be effective for the reduction in turbidity, and corn extract showed moderate TDS reduction. Urad exhibited average performance in all tested parameters. All treated samples, except for corn in the case of turbidity and cowpea in the case of TDS, met the WHO (World Health Organization) guidelines for safe drinking water.

Keywords: natural coagulants, rural water purification, *Moringa oleifera*, water filtration, turbidity reduction, total dissolved solids (TDS), water science, water resources management

Corresponding email: moulikjain903@gmail.com



1. Introduction

Access to clean drinking water remains a huge challenge, especially in many rural areas where getting an expensive filter isn't feasible. In many regions of developing countries, sewage systems are dysfunctional for example according to a recent studies, rivers like the Yamuna in India, which serve as water sources for millions, are severely polluted due to untreated sewage, industrial effluents, and agricultural runoff, resulting in high BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) levels, low dissolved oxygen, and unsafe microbial contamination (Srivastava et al., 2025). Considering the poor quality of sewage treatment and the large population without access to safe water, it becomes crucial to develop a cheap and do-it-yourself (DIY) method for water purification.

Filtration works in two steps: first, particles move towards the filter (transportation), and then they attach to the filter surface (attachment). Particles move through the water using processes like diffusion, interception, or settling, depending on their size (O'Melia & Stumm, 1967). Small particles are best removed by diffusion, while larger particles settle or get caught as they pass through the filter (Yao et al., 1971). These particles need to be treated chemically, using coagulants. This helps them form larger chunks of impurities, called coagulates, which makes them easier to trap in the filter and remove from the water (Ntibrey et al., 2020), as shown in Figure 1.

This is central to understanding how different coagulants like *Moringa oleifera* affect the properties of the water after it is filtered. This study compares natural coagulants by first coagulating a consistent sample of raw water taken from a tap in a rural region and then filtering the same water through a consistent multi-stage natural filter.

Water quality is defined by a range of physicochemical parameters that determine its suitability for human consumption and ecological balance. In this study, vital parameters like Total Dissolved Solids (TDS), pH, turbidity, sulphates, chlorine, chloride, alkalinity, and total hardness were tested. Total Dissolved Solids (TDS) indicate the concentration of inorganic salts and directly affect taste and potability. pH reflects the acidity or alkalinity of water, with extreme deviations harming health. Turbidity measures suspended particles, which can shield microorganisms from disinfection and signal pollution. Sulphates, chlorine, and chloride, while permissible in small amounts, may cause gastrointestinal discomfort, corrosivity, or unpleasant taste when elevated. Alkalinity governs the buffering capacity of water against pH fluctuations, and total hardness, driven by calcium and magnesium levels, influences scaling, taste, and potential health effects. In this study, changes in these parameters were systematically examined.

These coagulants aggregate suspended impurities in water, which makes it easier to remove them during the filtration process. This is the reason why both turbidity and TDS are reduced after coagulation, as noted in Sirbadgi et al. (2024). The process also stabilized pH levels, neutralizing acidic or basic components to bring the water closer to neutral conditions, as demonstrated with *Moringa oleifera* seed powder. The process of coagulation reduces the quantum of harmful contaminants like chloride and sulphates, and improves hardness and alkalinity (Nzeyimana & Mary, 2024). The process of coagulation followed by filtration is an effective procedure to make water safer for drinking.

Several studies have explored the development of low-cost filtration systems for rural communities. They often use simple, affordable materials such as sand, activated charcoal, ceramic discs, and rice husk ash (Lakhote et al., 2016; Henry Michael et al., 2013). While most focus on physical or adsorptive filtration, only a smaller set of researchers has incorporated naturally available coagulants to enhance performance. Chauhan et al. (2015) reported the significant coagulation and antimicrobial



properties of *Moringa oleifera*, *Vigna mungo*, *Vigna unguiculata*, and *Zea mays*. It showed up to 92% microbial count reduction.

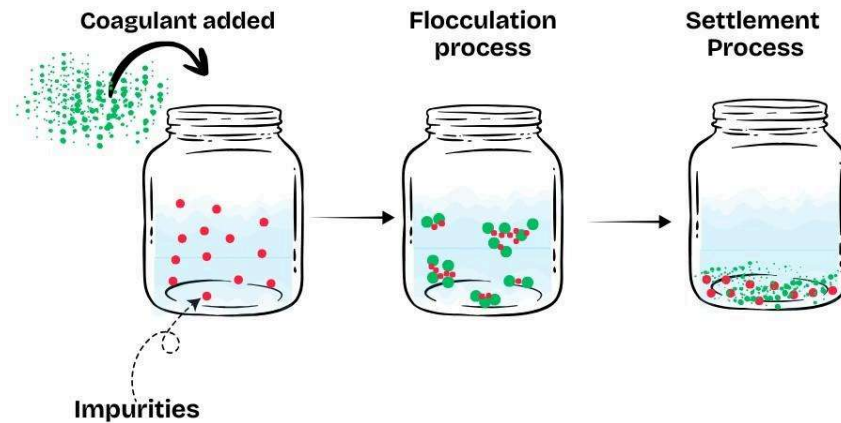


Figure 1: Formation of larger chunks of impurities during the coagulation process. Adapted from: Beyene et al (2016).

Despite these promising results, there remains a lack of comparative studies evaluating different natural coagulants under consistent filtration setups. This study addresses that gap by testing four seed-based coagulants—*Moringa oleifera*, urad, cowpea, and corn—under identical experimental conditions, paired with a single multi-stage filter made from natural materials.

The objective of the study is to identify which of the natural coagulants—*Moringa oleifera*, urad, cowpea, or corn—performs best in improving water quality. The raw water sample was coagulated and filtered. The filtered water was tested for total dissolved solids (TDS), pH, turbidity, sulphate (AE 209), chlorine (AE 246), chloride (AE 213), alkalinity (AE 214), and total hardness (AE 211). These tests were performed on raw water, on water after coagulation, and on final filtered water to determine the effect of each process and assess the effectiveness of each coagulant.

This paper is structured as follows: Section 2 describes the experimental setup, materials, and methodology. Section 3 depicts the results of each coagulant. Section 4 concludes the study and depicts the main findings, limitations of our study, and future research directions.

2. Materials

2.1. Coagulant Pretreatment

Before filtration, raw water was treated with one of the four natural coagulants: *Moringa oleifera*, urad (*Vigna mungo*), cowpea (*Vigna unguiculata*), and corn (*Zea mays*) seed extracts. These plant-based substances act as flocculants, helping suspended particles and microorganisms clump together (Madsen et al., 1987). The study evaluates which of these coagulants is the most

efficient. The coagulants were chosen as they were easily available, farmed locally, and cost-effective. The seeds were ground using a household mixer grinder to achieve a fine powder, as depicted in Figure 2.

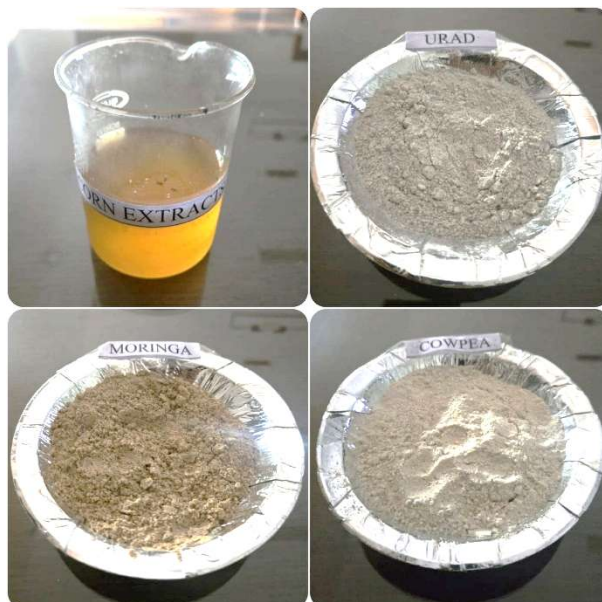


Figure 2: Four coagulants used for the coagulation. Corn extract, urad, *Moringa oleifera*, and cowpea.

2.2 Filter Structures

After coagulant pretreatment, water passes through the following layers, arranged from top to bottom (as shown in Fig. 3).

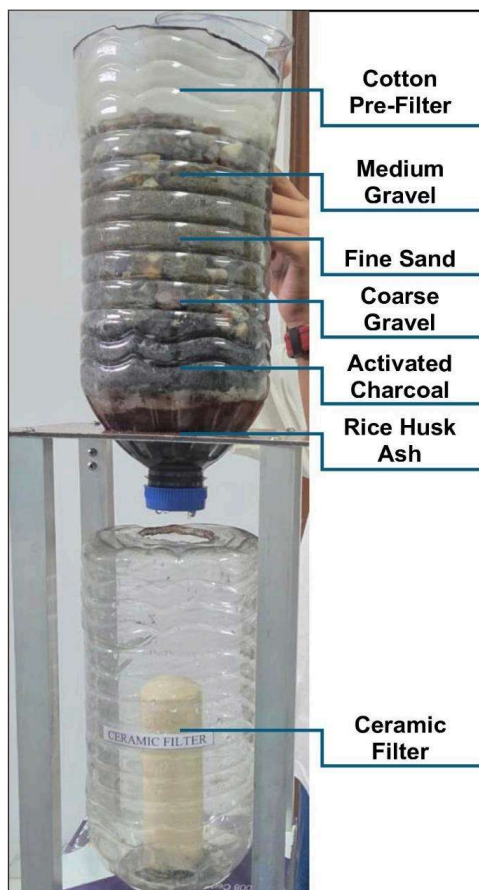


Figure 3: A consistent, natural, multi-layered DIY filter was used to compare the water after coagulation.

1. Cotton pre-filter: A clean cloth layer was used to trap coarse sediment and large debris before water entered the main system. While not effective for microbial removal on its own, it plays a vital role in reducing turbidity. Cloth filters have been shown to significantly reduce microbial load by capturing carriers of waterborne pathogens and to lower cholera incidence in areas where boiling water is not possible (Colwell et al., 2003).
2. Sand-gravel filter: The mechanical filtration stage includes:
3. Medium gravel: Distributes water evenly across the layer.
4. Fine sand: Traps dirt and suspended particles.
5. Coarse gravel: Supports the filter structure and aids drainage.

This configuration removes most visible impurities and reduces turbidity before water passes into finer filtration layers. Its effectiveness depends on the grain size (Lakhote et al., 2016).

6. Activated Charcoal Filter: Activated charcoal was included for its ability to trap pollutants and remove odours, colours, and synthetic impurities from water. (Ajaybhaskar Reddy et al., 2023).
7. Rice Husk Ash Layer: Produced from finely burned and sifted rice husks, this layer is rich in amorphous silica. Modified rice husk ash has been shown to remove up to 98% of arsenic from contaminated water (Javed et al., 2022).
8. Ceramic Filter Unit: A ceramic filter was used as the final filter media, serving as a fine-pore barrier capable of reducing turbidity and removing 77–96% of *E. coli* from water (Bulta & Michael, 2019).

2.3. Testing Parameters

For raw water, coagulated water, and final filtered water, the following parameters were measured: turbidity, total dissolved solids (TDS), pH, sulphate (AE 209), chlorine (AE 246), chloride (AE 213), alkalinity (AE 214), and total hardness (AE 201 and AE 211). The equipment used to test various parameters included:

- pH: Demeteries pH testing kit.
- TDS: KENT Digital TDS Meter.
- Chlorine (AE 246): Aquasol.
- Turbidity: Demeteries turbidity testing kit.
- Total Hardness (AE 211): Aquasol.
- Sulphates (AE 209): Aquasol.
- Alkalinity (AE 214): Aquasol.
- Chloride (AE 213): Aquasol.

The apparatus used for coagulation and mixing was a Remi RQ-140/DE Homogenizer.

3. Methods

3.1. Sampling

The water sample was collected from a small village named Dadupur in Haridwar district in India, sourced from the municipal tap supply. It was selected as it reflects the general water quality available in most rural areas and is considered to have higher contamination levels.

The procedure was as follows:

3.2. Coagulation

For each trial, the water sample was placed in a clean container and treated with the powdered form of the assigned coagulant at a concentration of 2g/l. The dosage of 2 g/L was selected based on prior studies where similar natural coagulant concentrations demonstrated effective turbidity and contaminant reduction while maintaining water safety (Ntibrey et al., 2020). The mixture was stirred continuously for 60 minutes using a homogenizer mixer to ensure an effective coagulation process. It was then left undisturbed for 30 minutes to allow floc (aggregate of impurities) formation and sedimentation. Following the settling period, it was carefully passed through the multi-stage filtration unit.



3.3. Filtration

After the coagulation, the clear supernatant was passed through the multistage filtration unit described in the materials section above. The filtration was conducted without any external force and only under gravitational flow; the average processing time for each sample was about 30 minutes. Between trials, the filtration unit was rinsed with distilled water to avoid any cross-contamination.

3.4. Testing

The tests for all the parameters were performed on the raw water sample, on the water after coagulation, and on the water after filtration. The filtered raw water without coagulation was also tested. All the tests were repeated three times, and the average figures were recorded. All tests were carried out according to the guidelines provided in the respective testing kits and performed under controlled laboratory conditions.

For this study, WHO benchmarks for all parameters were used to determine the suitability of the water quality as The World Health Organization (WHO) drinking water quality standards provide globally recognized limits for safe and acceptable water, covering key parameters such as TDS, pH, turbidity, sulphates, chloride, and hardness. Since these guidelines are widely applicable across regions where national or regional standards may not directly apply, they serve as the primary reference point in this study for assessing the suitability of water for human consumption.

4. Results & Discussion

4.1. pH

The World Health Organization (WHO) recommends that the pH of drinking water should be between 6.5 to 8.0. The values outside this range can cause corrosion, scaling, or unwanted taste (WHO, 2008). The water with pH values below 4 or above 11 causes corrosive injury to the mouth, throat, and digestive tract; it can also be acutely toxic.

The results in this study indicated a pH of 6.4 for tap water, which is just below the acceptable minimum. After filtration without any coagulation process, the pH increased to 7.6, indicating that the multilayer filtration process itself helps neutralize the slight acidity.

A slight increase in pH was also observed in the filtrate of the coagulated water. These are plotted against the acceptable range in Figure 4.

These results show that the leguminous seed-based coagulants (*Moringa oleifera*, urad, and cowpea) mildly increase the pH, due to the presence of basic organic compounds like proteins and alkaloids in the seed extracts. Most importantly, all pH values remained within the WHO guidelines, making the water safe for drinking.



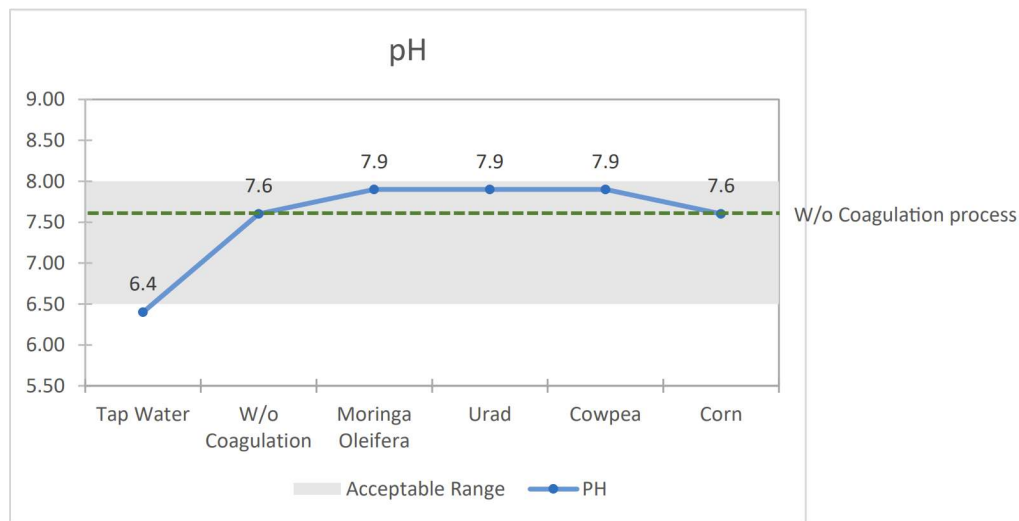


Figure 4: Observed pH, plotted for each of the coagulants after the filtration process. The highlighted area shows the acceptable range.

4.2. TDS

The WHO guidelines recommend that the TDS be below 300ppm for drinking water (WHO, 2008). Values above this affect taste gravely and thus are not suitable for human consumption. Values above this also signal that the water sample contains salts, minerals, or harmful contaminants like nitrates, arsenic, and lead, which can have adverse health effects. Salinity, which is also signalled by high TDS, can lead to severe diseases like cardiovascular disease, inflammation, and infection.

The water sample collected in the study showed a TDS of 335 before any treatment, which is marginally above the WHO limit. After basic filtration without coagulants, the TDS decreased only slightly to 314 ppm, indicating a limited impact from filtration alone.

These are plotted against the acceptable range in Figure 5.

The biggest improvement was shown by *Moringa oleifera*, which reduced the TDS to well below the acceptable threshold. This indicates the usefulness of *Moringa oleifera* in reducing TDS. Corn extracts were also extremely useful in lowering TDS. Urad and cowpea, on the other hand, did not indicate a satisfactory level of TDS.

In this study, the TDS was measured using a conductivity-based meter, which estimates TDS by calculating the electrical conductivity of the water and then multiplying it by a factor of 0.5-0.7. This method doesn't differentiate between truly dissolved ionic solids and weakly charged colloids or organics (it is worth noting that weakly charged colloids or organics can also pose a harm to our health). As such, an EC-based TDS meter may overestimate TDS in the presence of weakly charged colloids or organics, and underestimate it when the water contains many uncharged dissolved solids (Rusydi, 2018). In

contrast, the gravimetric method involves evaporating a known volume of water and weighing the dry residue, thus measuring only truly dissolved solids.

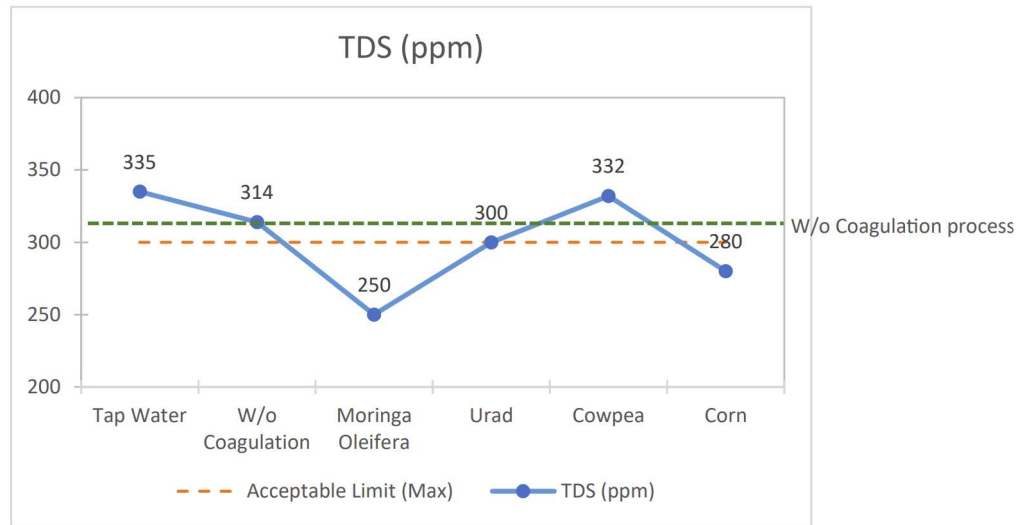


Figure 5: Observed TDS (ppm), plotted for each of the coagulants after the filtration process. The dotted line is the maximum acceptable limit.

While the accuracy limitations of EC-based TDS meters are well recognized in scientific literature, in practice, especially in fieldwork and community-level testing, these devices are widely used because of their speed, portability, low cost, and reliability for relative comparisons (WHO, 2017; Rusydi, 2018). The gravimetric method is extremely tedious and requires days and perfect laboratory conditions to measure it, which was not possible. In the context of our study, this reliance on EC-based TDS measurements represents a limitation, as it may not fully reflect the true changes in dissolved solids following coagulation and filtration. But still, it does indicate the removal of potentially harmful weakly charged colloids or organics, indicating the usefulness of coagulants like *Moringa oleifera*.

The TDS reduction observed in our study is attributed to the coagulants' ability to neutralize and bind charged colloidal or weakly dissolved organic matter, forming flocs which are then removed by sedimentation and filtration. These flocs no longer contribute to conductivity, leading to lower EC and thus lower TDS readings on the meter. This is supported by Sirbadgi et al. (2024), who observed up to 69.2% TDS reduction using plant-based coagulant.

Thus, while true ionic TDS (gravimetric) may remain partially unaffected, the reduction seen on a TDS meter (EC-based) is real and relevant, especially when considering the perceived quality and operational safety of drinking water. A significant reduction of TDS was seen after the filtration process, as it was reduced from 335ppm to 250ppm using *Moringa oleifera* as a coagulant, which is also consistent with the reduction seen in literature. In sum, natural coagulants, especially *Moringa oleifera* and corn extract, display a vast reduction in TDS because of their ability to flocculate (cause fine suspended particles to clump together into aggregates or flocs, thus making them easier to remove) semi-dissolved and colloidal impurities. While they may not be considered truly dissolved, salts can be detected by gravimetric analysis; their effect on the water

quality remains significant. The distinction between EC-based and gravimetric TDS should be recognized in both research and practical applications.

4.3. Chlorine

The WHO guidelines recommend that the Chlorines in potable water should be between 0.2-5.0 ppm. Chlorine was not detected in the original water sample, indicating that it is not present in the municipal tap water (in the area where the study was conducted). It was also not found in the water samples tested after coagulation and after filtration, signifying that coagulation doesn't lead to the addition of chlorine to the water.

4.4. Turbidity

The WHO recommends that the turbidity of potable water be below 5 NTU (Nephelometric Turbidity Unit). Anything above this value promotes the growth of microorganisms, which could be dangerous to health. Turbidity above 5 NTU also indicates that the water sample contains the presence of suspended solids and harmful pathogens that can be agents for diseases. (WHO, 2017).

In this study, the turbidity of the original tap water sample was observed at 14 NTU, which exceeds the WHO guideline and indicates a high level of harmful particulate matter. Filtration without coagulation reduced turbidity to 1 NTU, which showed the effectiveness of the multilayer filtration media in removing suspended solids.

These are plotted against the acceptable range in Figure 6.

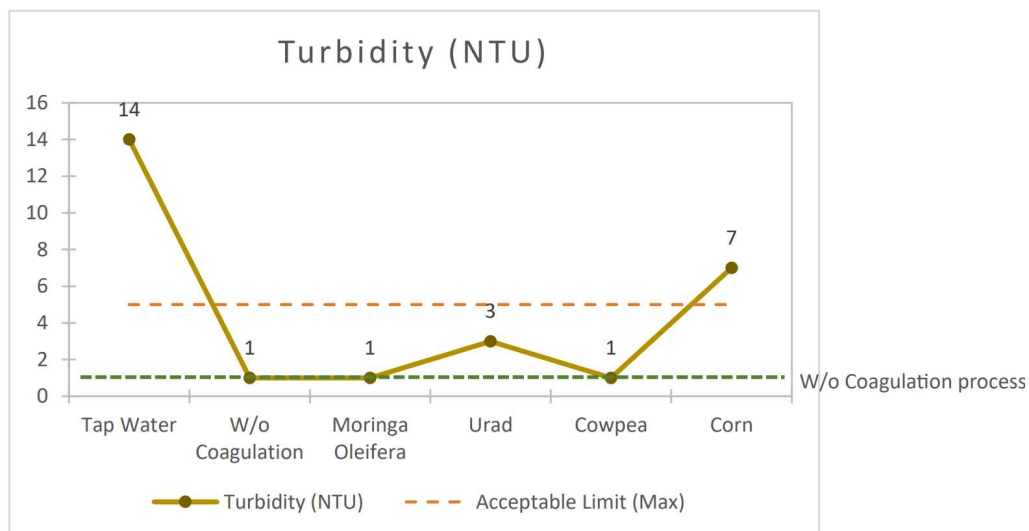


Figure 6: Observed Turbidity (NTU), plotted for each of the coagulants after the filtration process. The dotted line is the maximum acceptable limit.

These results indicate that amongst all four coagulants used for filtration, *Moringa oleifera*, and cowpea were the most effective, as both displayed a turbidity of 1 NTU. The other two coagulants, urad and corn, displayed the turbidity values of 3 and 7 NTU, respectively. Urad was within the WHO guidelines, but the turbidity of corn exceeds the WHO limit and therefore indicates incomplete removal of suspended matter.

These findings are consistent with the results of Mangale et al. (2012), who reported that *Moringa oleifera* seed extract reduced turbidity by over 90% in surface water samples, outperforming several other plant-based coagulants tested under similar conditions.

4.5. Total Hardness

The World Health Organization (WHO) recommends that the total hardness of drinking water should be below 500 ppm as calcium carbonate, as higher levels can cause scaling in pipes, affect soap lathering, and contribute to taste changes (WHO, 2017). While hardness is not considered a direct health hazard, very high levels have been associated with, in extreme cases, kidney stone formation. (WHO, 2017)

In this study, the hardness of the tap water sample was found to be 250 ppm, which is below the acceptable limit. The hardness values appeared to increase after filtration without coagulation. This can likely be attributed to mineral leaching from the sand, gravel, or ceramic media, which may have released calcium and magnesium ions into the treated water. Making this process explicit highlights the importance of combining filtration with coagulation to prevent such unintended side effects.

These are plotted against the acceptable range in Figure 7.

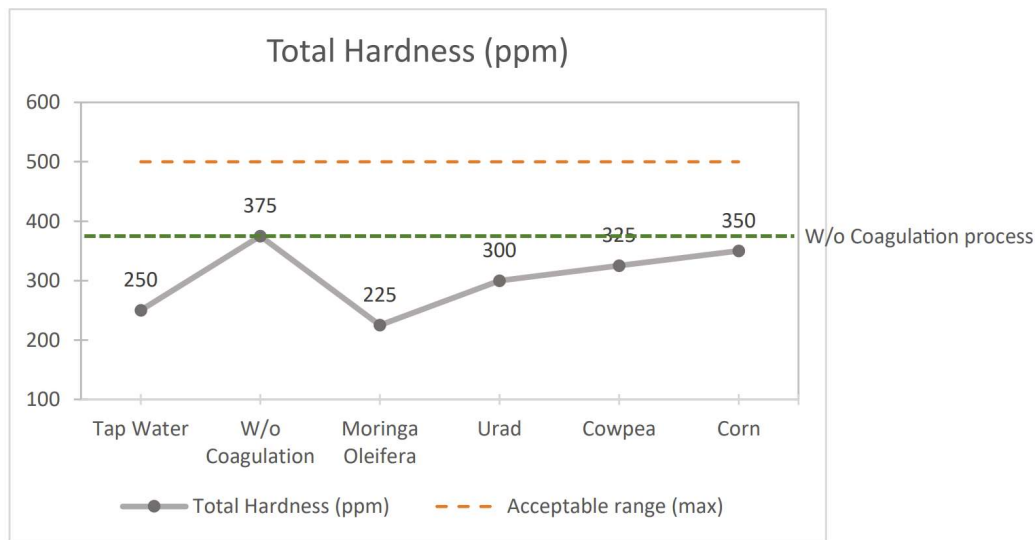


Figure 7: Observed Total Hardness (ppm), plotted for each of the coagulates after the filtration process. The dotted line is the max acceptable limit.

The results of this study show that *Moringa oleifera* was the best in reducing the total hardness of water. Urad and cowpea were also effective for this purpose. Corn was the least effective for this purpose. It is important to note that all values remained below the WHO limit and thus are safe for human consumption in the total hardness parameter.

4.6. Sulphate, Alkalinity, and Chloride

Sulphate ion concentration in drinking water is recommended to be less than 500 ppm, as anything beyond that can cause a bitter taste and gastrointestinal discomfort (WHO, 2017). The tap water contained 120 ppm, which increased to 160 ppm after filtration without coagulation, likely due to mineral leaching from the filter media. After coagulation, *Moringa oleifera* and cowpea showed higher sulphate levels at 180 ppm, whereas urad and corn maintained the original concentration at 120 ppm. All recorded sulphate levels were well below the WHO guideline value.

The recommended alkalinity range for potable water by the WHO is 20–200 ppm as CaCO₃, as it helps buffer pH and prevents rapid changes in acidity and alkalinity (WHO, 2017). The tap water sample measured well within this range at 75 ppm, remaining the same without coagulation after filtration. *Moringa oleifera* and urad both reduced it to 25 ppm, and cowpea increased it to 100 ppm, and corn reduced it to 50 ppm. All the results observed were in the acceptable range.

The WHO recommends that the chloride in water should be less than 250 ppm, as it can cause issues with taste (WHO, 2017). In this study, the original tap water had a chloride level of 8 ppm, which is well below the acceptable limit. Filtration with coagulants didn't change this much. Among the coagulants, *Moringa oleifera* showed an increase to 20 ppm, while urad reduced it to 6 ppm. In comparison, cowpea and corn both resulted in 8 ppm, showing minimal changes in chloride content across most treatments, and showing that neither tap water nor water after coagulation contains any concerning amounts of chloride.

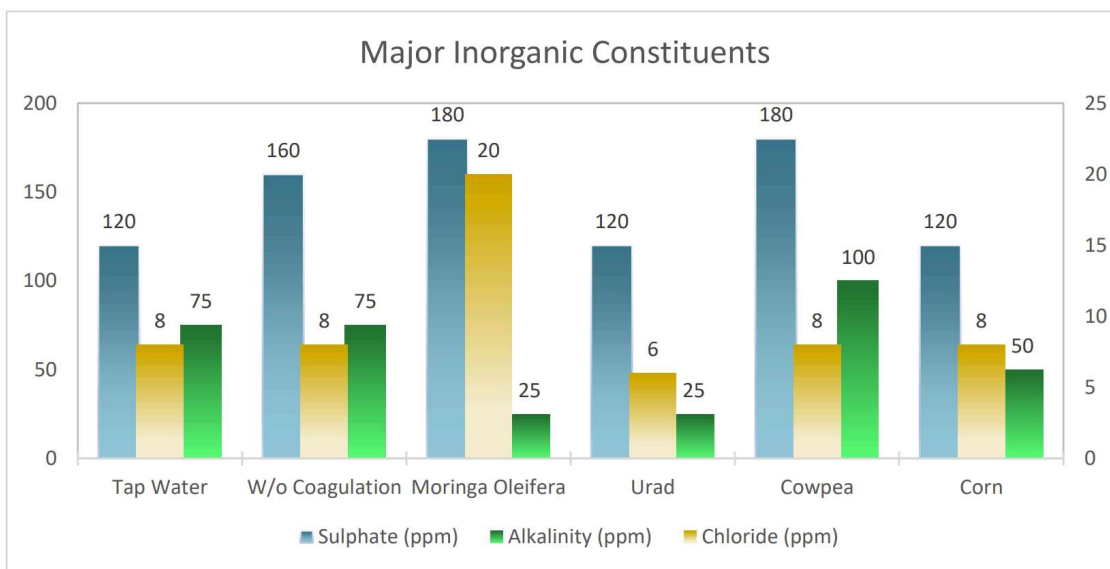


Figure 8: Observed Sulphates (ppm) and Alkalinity (ppm), plotted on left y-axis, and Chlorides (ppm), plotted on right y-axis, for each of the coagulants after the filtration process.

Overall, the samples before and after the filtration of water were safe for human consumption on the parameters of chloride, alkalinity, and sulphate. Observed chlorides, alkalinity, and sulphates are plotted in Figure 8.

5. Conclusion

This study evaluated the performance of four seed-based coagulants—*Moringa oleifera*, *Vigna mungo* (urad), *Vigna unguiculata* (cowpea), and *Zea mays* (corn)—when paired with a consistent DIY natural filtration system in improving the quality of rural tap water. It was tested across parameters, which included pH, TDS, turbidity, total hardness, chloride, alkalinity, and sulphate. All the tested samples, after filtration and coagulation, were within the guidelines recommended by WHO, apart from cowpea for TDS and corn for Turbidity, which both exceeded the limits.

Moringa oleifera was shown to be the best across all parameters, as it consistently outperformed the other coagulants tested. It achieved the highest reduction in TDS, turbidity, and hardness, while maintaining pH stability. The superior performance of *Moringa oleifera* compared to other natural coagulants can be explained by its unique water-soluble cationic proteins. These proteins neutralize negatively charged colloidal particles more efficiently, leading to faster flocculation and improved turbidity and contaminant reduction.

Cowpea also achieved strong turbidity removal but showed less improvement in TDS. Corn extract was moderately effective for TDS but underperformed in turbidity reduction. Urad provided balanced but less pronounced improvements across all the parameters.

The study shows that combining natural coagulants and a multi-layered natural filter can significantly improve water quality, offering a solution to the communities that lack centralized treatment infrastructure.

6. Future Research

While the results of this paper are promising, several aspects need to be explored further to improve the practicality and scalability of this approach.

- Scalability of the System: future work needs to focus on making this design into a household modular design that can be capable of treating single household requirement of water per day.
- Fast and less tedious coagulation: the current method requires stirring for more than 60 minutes, which is impractical for large-scale or household use. "Future research should investigate the effect of reducing stirring time to 30 minutes or adding a mineral catalyst to accelerate floc formation.
- Testing Across Diverse Water Sources: This study sampled water from a rural North Indian municipal tap supply. Additional trials should be conducted on various other types of water, like water near the sea, which would have more chloride content, water from downstream areas, or a highly turbid pond, and test which coagulants perform best in those waters.
- Pathogen removal assessment: The source of the water used in this study is municipal tap water, which comes from the river Ganga. Ganga water contains Bacteriophage, which removes bacteria and pathogens (Bahera et al., 2022). A



key next step is to spike water samples with known concentrations of *E. coli* to quantitatively assess the log-reduction in bacterial count achieved by each coagulant..

Future research on these areas could help transition this approach from theory to practical, low-cost solutions. This could lead to a solution to the problem of unsafe water and lead to a world where all people realize their right to clean and potable water.

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Author Biography

Moulik Jain is a student at The Wisdom Global School, Haridwar, India. Moulik is extremely passionate about the environment. Living near the Ganga River, he has witnessed firsthand how people struggle to get clean drinking water because of pollution. This inspired him to make a low-cost filtration system using natural seed-based coagulants (*Moringa oleifera*, urad, cowpea, and corn). The results of his study aligned with the WHO guidelines. This research was conducted with mentorship from Dr. Devin Carroll (University of Pennsylvania) and Mr. Kieran Tait (University of Bristol), with laboratory support in Haridwar.

Beyond the research, Moulik is engaged in academics as well as extracurricular activities. He was part of the senior committee that organized the first MUN in his city, as well as being the president of the Youth club, where he regularly organizes medical awareness camps, climate action workshops, and Ganga cleanup drives. He is also a debater, pianist, and chess player, having represented his school at various national competitions, winning various awards at prestigious institutions like IIT Bombay, BITS Pilani, NMIMS Indore, and KIIT.

In the future, Moulik wants to pursue environmental engineering, focusing on finding sustainable technologies and water resource management. He hopes to combine scientific research with community action to develop scalable solutions that address global challenges such as climate change, resource sustainability, and universal access to clean drinking water.

Mentor Contribution Statement

This manuscript was completed under the mentorship of **Dr. Devin Carroll** and **Mr. Kieran Tait**, whose continuous support and guidance were instrumental throughout the research and writing process. Both mentors played a crucial role in shaping the conceptual framework, refining the methodology, and ensuring that the study met high standards of academic rigour and clarity.

During office hours and regular feedback sessions, Dr. Carroll provided in-depth technical and conceptual guidance—particularly in experimental design, data interpretation, and the theoretical grounding of the filtration mechanisms. His insights helped strengthen the scientific basis of the research and ensured that each measured parameter (pH, TDS, turbidity, etc.) was analysed in accordance with established environmental engineering principles.

Mr. Tait offered detailed editorial and structural feedback, helping refine the argument flow and improve the precision of academic writing. His mentorship during writing consultations and office hours significantly enhanced the manuscript's readability, coherence, and adherence to scholarly standards.

Both mentors encouraged critical thinking, independent problem-solving, and scientific integrity, fostering a learning environment that combined technical excellence with creativity. Their patient explanations, prompt feedback, and open-door availability made the research and revision process both insightful and rewarding.

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Appendix

Table 1: Results of Water Quality Parameters Before and After Coagulation Treatment

	WHO Guidelines	Tap Water	W/o Coagulation	<i>Moringa oleifera</i>	Urad	Cowpea	Corn
pH	6.5-8.0	6.4	7.6	7.9	7.9	7.9	7.6
TDS (ppm)	<300	335	314	250	300	332	280
Chlorine (ppm)	0.2-5.0	ND	ND	ND	ND	ND	ND
Turbidity (NTU)	<5	14	1	1	3	1	7
Total Hardness (ppm)	<500	250	375	225	300	325	350
Sulphate (ppm)	<500	120	160	180	120	180	120
Alkalinity (ppm)	20-200	75	75	25	25	100	50
Chloride (ppm)	<250	8	8	20	6	8	8
ND: Not detected							

Note: This table summarizes the results observed for the tested parameters of raw water and the filtrates after the coagulation process. The corresponding WHO guidelines are also provided for a better understanding of the improvements in the water quality achieved.

