

Preparation and Assessment of Hardgone Water Softener

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Abstract: *Hard water, containing excess minerals like calcium and magnesium, can cause skin irritation, dryness, and rough hair. Traditional water softeners, often reliant on harsh chemicals, can exacerbate these issues, especially for sensitive skin. To address this, we developed an eco-friendly, botanical-based water softener that includes natural extracts, essential oils, and chelating agents. The formulation aims to reduce water hardness while offering hydration and nourishment for skin and hair. Key ingredients like moringa extract, aloe vera, lavender essential oil, blue pea flower infusion, and sandalwood essential oil were selected for their antioxidant, moisturizing, and soothing properties. Ethylene diamine tetraacetic acid(EDTA) was incorporated as a chelating agent to bind calcium and magnesium ions, while Apple Cider Vinegar (ACV) balanced the pH and enhanced conditioning. The formulation was tested for pH stability, chelation efficiency, and sensory qualities. The results showed effective softening, stability, and no irritation, confirming the formulation as a gentle, eco-friendly, and cost-efficient solution.*

Keywords: Water softener, water hardness, Hardgone brand, EDTA, ACV

I. INTRODUCTION

1.1 Overview of water hardness

Water hardness is among one of the major issues caused by high levels of dissolved minerals, mainly calcium and magnesium, in water. Although it does not pose a health risk, hard water can lead to several complications, including scale accumulation in pipes and household appliances, decreased soap lathering efficiency, skin irritation and hair loss(1). A water softener is a specialized system which removes these minerals using ion exchange or other treatment techniques and effectively transforms hard water into soft water. By preventing mineral buildup, water softeners expand the lifespan of appliances, improve water quality for cleaning and bathing, and contribute to long-term cost savings. Due to the persistent problem of water hardness in many areas, water softening systems have become an important tool for both residential and industrial applications. This study examines the efficiency and advantages of newly formulated water softening solution. This system helps prevent scale formation in pipes and appliances, enhances the effectiveness of soaps and detergents, and improves overall water quality for domestic and industrial purposes, assuring the efficient operation and longevity of various systems(2).

The main cause of water hardness is the presence of dissolved calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in water. These minerals are naturally introduced into the water supply as it moves through rock formations like limestone, chalk, and gypsum, which contain large concentrations of these elements. Groundwater possess higher hardness levels than surface water as it remains in contact with mineral-rich rocks for extended time periods. Also, industrial activities and agricultural runoff contribute to water hardness by depositing minerals into water sources(3). On the basis of geological makeup of a region, municipal water supplies may distribute hard water. Although not hazardous to human health, hard water can lead to scale buildup in plumbing systems, reduce the efficiency of soaps and detergents, and increase energy consumption due to the reduced performance of water-heating appliances. Effective treatment methods, such as water softening systems, are necessary to eradicate these issues. The adverse effects of hard water on human health and daily activities originates due to high mineral content(3, 4). Hard water also tends to leave residue on skin and hair, potentially causing dryness and irritation. Addressing water hardness with suitable treatment methods, such as

water softeners, ensures improved water quality for household and industrial applications, leading to better efficiency, cost savings, and prolonged heating appliance durability.

1.2 Importance of water softening

Calcium and magnesium minerals can lead to limescale buildup in plumbing systems and appliances, reducing their efficiency and lifespan. By eradicating these hardness-causing minerals through processes such as ion exchange, water softeners prevent scale formation, thereby enhancing the performance and durability of household appliances like water heaters, dishwashers, and washing machines. This leads to energy savings along with reduction in maintenance costs. Water softeners also improve the effectiveness of soaps and detergents. Soft water reacts more favorably with cleaning agents, producing better lather and cleaning results(4). This means cleaner dishes, softer laundry, and reduced soap scum in bathrooms. Bathing in soft water can benefit personal care, as it is helpful in maintaining the skin's natural oils, decreasing the dryness and irritation. Hair washed in soft water feels softer and more manageable. Beyond household benefits, the use of water softeners can have positive environmental impacts. By enhancing appliance efficiency and reducing the need for harsh cleaning agents, they contribute to lower energy consumption and decreased chemical runoff into the environment leading to environmental sustainability(4).

II. INTRODUCTION TO HARDGONE WATER SOFTENER

Our Natural Water Softener named as “HARDGONE” is specifically formulated to counteract the harsh effects caused by the mineral present in water by decreasing water hardness with the use of beneficial botanical extracts and essential oils for nourishment and hydration. This unique formulation include the composition of blue pea flower, moringa, aloe vera, and vitamin E, all of which provide deep hydration, antioxidant protection, and gentle conditioning for both skin and hair. EDTA is incorporated to chelate excess calcium and magnesium, preventing mineral buildup and ensuring a softer water experience. ACV plays a crucial role in balancing the water’s pH, making it gentle on the skin. Infused with the soothing aroma of lavender oil, this water softener also offers a refreshing and calming sensory experience. Unlike conventional softeners depends on harsh chemicals, this formulation prioritizes natural ingredients to provide a safe and effective solution suitable for all skin types. It softens hard water, enhances hydration, balances pH levels, and delivers the benefits of aromatherapy. Free from sulfates, parabens, and artificial additives, this 200 mL softener can be used in multiple ways—as a final rinse for hair, a facial mist, or an additive in bathwater. Transform hard water into a skin-friendly solution and enjoy the benefits of softer skin, healthier hair, and a refreshing bath experience.

III. OBJECTIVES OF THE FORMULATION

3.1 Purpose of using “Hardgone” water softener

A “Hardgone” water softener is designed to treat hard water, which is characterized by high concentrations of minerals like calcium and magnesium. These minerals, are harmful to skin and hair, and can cause a range of problems in households and industries that rely on water for various tasks. The primary purpose of using a “Hardgone” water softener is to remove these hardness-causing minerals, thereby "softening" the water.

One of the main benefits of using this formulation is the prevention of scale buildup. Hard water tends to leave mineral deposits in pipes, appliances, and water heaters, that leads to inefficiencies and potentially costly repairs. By softening the water, a “Hardgone” softener helps prevent these deposits, prolonging the lifespan of plumbing systems and appliances. Another significant advantage is the improved effectiveness of soaps and detergents. Hard water can make it more difficult for soaps to lather, which means more soap is required to clean effectively. With softened water, soaps and detergents work with high efficiency, decreasing the amount needed and improving cleaning results. Softened water also has benefits for skin and hair health. Hard water can leave a residue on the skin, making it feel dry or irritated, and it can make hair look dull. With softened water, skin feels smoother and hair becomes shinier and more manageable.

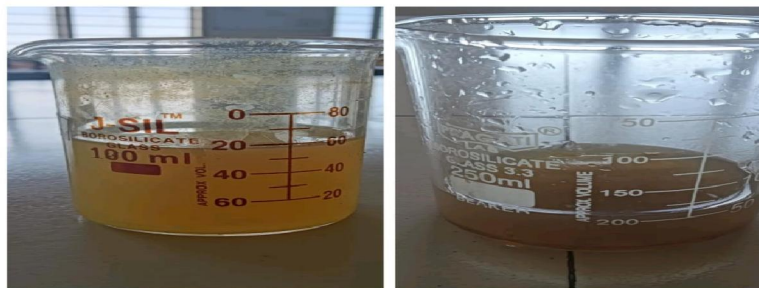
3.2 Expected benefits

Using a water softener infused with lavender oil, aloe vera extract, moringa extract, blue pea flower, ACV, EDTA, and vitamin E provides vast range of benefits for both skin and hair. Lavender oil is well known for its soothing and anti-

inflammatory properties, which help calm skin irritations and promote a healthier complexion(5). Aloe vera extract, known for its hydrating and healing qualities, moisturizes the skin, removes dryness, and soothes scalp conditions, decreasing dandruff and itchiness(6). Moringa extract acts as a natural water-softening agent, minimizing water hardness, which results in softer skin and more manageable hair(7). Rich in antioxidants, blue pea flower extract helps protect against oxidative stress, supporting skin elasticity and improving hair strength(8). ACV plays a crucial role in balancing the pH levels of water, making it more compatible with the skin's natural barrier and developing hair shine and smoothness. EDTA is a chelating agent that binds the metal ions in hard water and softens it. Vitamin E is a potent antioxidant that nourishes and protects the skin and hair from environmental damage, thereby promoting overall health and appearance. The combination of these carefully selected ingredients not only softens water but also improves skin and hair health by addressing the challenges associated with hard water while delivering essential nourishment.

IV. AN APPROACH THAT FAILED TO GIVE GOOD RESULTS

Turmeric (*Curcuma longa*) is a bright yellow spice widely used in cooking, medicine, and skincare. It contains curcumin, a powerful antioxidant and anti-inflammatory compound known for its health benefits. Traditionally used in Ayurvedic practices, turmeric has detoxifying properties and can help purify water by reducing bacterial contamination. Its antioxidant properties may also help neutralize certain impurities. But turmeric is susceptible to degradation when exposed to light and air, leading to a loss of its potency(9). Oranges (*Citrus sinensis*) are juicy citrus fruits comprised of vitamin C, fiber, and antioxidants. They highly strengthen immunity, enhance skin health, and support heart function. Oranges contain citric acid, which can help break down mineral deposits in hard water, reducing calcium and magnesium buildup. They do not function as conventional water softeners but their natural acidity can aid in mild descaling processes(10). Despite these benefits, oranges are highly unstable due to oxidation, losing their potency when exposed to air and high temperatures. Amla (Indian gooseberry) is a superfood known for its high vitamin C content, which boosts immunity, enhances skin glow, and improves hair health. Amla's natural acidity helps break down mineral deposits in hard water, contributing to its purification. It also possesses antibacterial properties that can help reduce impurities(11). However, amla is highly unstable, degrading quickly due to oxidation and heat exposure, which reduces its effectiveness. Lemon (*Citrus limon*) is rich in vitamin C, antioxidants, and antibacterial properties. It is an effective natural descaler, breaking down calcium and magnesium deposits in hard water and improving taste. Lemon water also detoxifies the body and boosts metabolism(10). However, its citric acid content makes it highly sensitive to oxidation, causing fast nutrient degradation when exposed to air and heat. Vitamin E capsules are known for their powerful antioxidant properties, promoting skin repair and improving hair health. While they do not chemically soften water, they help counteract the drying effects of hard water on the skin by retaining moisture. Moringa (*Moringaoleifera*) is a nutrient-dense plant with medicinal properties, improving immunity and regulating blood sugar levels. Its seeds have natural coagulant properties that bind with impurities, making the water clearer and improving overall quality(7). This method is widely used in rural areas as an alternative to chemical water treatment. However, moringa leaves and seeds degrade if not stored properly, losing essential nutrients due to air exposure. Mogra (*Jasminumsambac*) is a fragrant white flower with calming and therapeutic properties. While not a conventional water softener, mogra essential oils and extracts counteract the drying effects of hard water, providing skin and hair benefits(12). However, mogra flowers are delicate and wilt quickly, making their essential oils volatile and prone to evaporation. Fenugreek (*Trigonellafoenum-graecum*) is a herb with medicinal uses. Its seeds contain mucilage, a gel-like substance that can condition water and make it gentler on the skin. While not a direct water softener, fenugreek can be used in hair rinses or bathwater to reduce the drying effects of hard water(13). However, due to their oil content, fenugreek seeds are prone to rancidity if stored in humid conditions. Aloe vera is a succulent plant known for its hydrating and healing properties(14). Figure 1 shows the appearance of formulation on preparation and after 48 hours storage. Figure 2 shows the materials and methods used. Table 1 shows the composition of the ingredients in the formulation.



On preparation **After storage**
Fig. 1 Formulation appearance on preparation and after storage



Fig. 2 Materials and methods used in the procedure

Table 1: Composition of the below ingredients in the formulation

Sr.no	Ingredients	Common name	For 200 ml	For 1000 ml	Role in formulation	Drawback	Reference no.
1.	Indian gooseberry	Amla	20 ml	100 ml	Natural acidity break down mineral deposits in water	Unstable and degrade quickly due to environmental factors	(11)
2.	Citrus limon	Lemon	16 ml	80 ml	Natural acidity break down mineral deposits in water	Unstable and degrade quickly due to environmental factors	(10)
3.	Citrus sinensis	Orange	16 ml	80 ml	Natural acidity break down mineral deposits in	Unstable and degrade quickly due to	(15)

					water	environmental factors	
4.	Aloe barbadensis	Aloe	10 ml	50 ml	Hydration	-	(14)
5.	Moringaoleifera	Drumstick tree	14 ml	70 ml	Natural coagulant	-	(16)
6.	Trigonellafoenum-graecum	Fenugreek	8 ml	40 ml	Hydrophobic part of saponins bind with nonpolar residues of the metal ions and hydrophilic part attaches to water making a stable complex	Develops rancidity due to high oil content	(13)
7.	Curcuma longa	Turmeric	4 ml	20 ml	Coloring agent and natural preservative	Unstable, becomes dark brown in color on storage	(17)
8.	Jasminumbac	Mogra	6 ml	30 ml	Flavoring agent for odour	Prone to evaporation, no long lasting smell	(12)
9.	Tocopherol	Vitamin e	1 capsule	5 capsules	Retain moisture	-	(18)
10.	Purified water	-	Upto200 ml	Upto 1000 ml	Vehicle	-	-

V. COMPOSITION OF HARDGONE WATER SOFTENER – AN APPROACH THAT WORKED

5.1 Moringaoleifera

Moringaoleifera, also known as the drumstick tree or horseradish tree, is a fast-growing, drought-resistant tree native to northern India. Belongs to the family Moringaceae, it is widely cultivated across tropical and subtropical regions for its nutritional and medicinal properties. Different parts of the tree—including leaves, seeds, pods, and flowers—are used in conventional medicine and culinary applications(16). The leaves of Moringaoleifera are particularly rich in essential nutrients such as vitamins A and C, calcium, potassium, and protein. They contain potent antioxidants such as quercetin and kaempferol, which help to overcome oxidative stress. Studies indicate that moringa aid in regulating blood sugar levels, potentially benefiting individuals with diabetes. Also its anti-inflammatory properties have been analyzed for reducing inflammation and supporting heart health. The seeds yield an oil high in behenic acid, used in cooking and cosmetics, and includes water-purifying capabilities due to their coagulating properties. Overall, Moringaoleifera offers a range of therapeutic benefits, making it a valuable resource in promoting health and well-being(16).

Moringaoleifera seeds have been recognized for their potential in water treatment, particularly in reducing hardness caused by calcium and magnesium ions. The active agents responsible for this property are water-soluble cationic proteins, which carry a positive charge. When introduced into water, these proteins interact with negatively charged particles and hardness-causing ions(7). The main mechanism involves adsorption and charge neutralization, where the

cationic proteins bind to anionic species, leading to the formation of flocs that can be removed through sedimentation. Different studies have shown that Moringa seed extracts can reduce water hardness by 50-70%, which depends on initial concentrations and dosages used. This natural coagulant offers an eco-friendly and cost-effective alternative for water softening, especially in regions where conventional treatments are inaccessible(16).

5.2 Lavendulaangustifolia

Lavender oil is an essential oil extracted from the flowers of the *Lavendulaangustifolia* plant and is commonly known as English lavender. This oil is renowned for its calming properties and is widely used in aromatherapy to deal with anxiety and promote relaxation. Studies have indicated that inhaling lavender oil may help to reduce anxiety levels, particularly in high-stress environments(19). It also possesses antimicrobial and anti-inflammatory properties, making it beneficial for minor skin irritations and wound healing. Here in the formulation lavender oil is used as a flavoring agent due its long lasting and mesmerizing odour. The chemicals of the plant also not react with any other ingredient of the formulation hence, not affects the stability(19).

5.3 Aloe barbadensis

Aloe vera extract is derived from the leaves of *Aloe barbadensis miller*. It is a succulent plant known for medicinal properties. The gel-like composition found inside the leaves is rich in bioactive compounds, including vitamins, enzymes, minerals, and polysaccharides, which contribute to its therapeutic effects. Aloe vera is mainly recognized for its skin-healing properties. It is widely used to treat burns, wounds, and various skin conditions due to its anti-inflammatory, antimicrobial, and hydrating effects. The gel helps to aid wounds as it possess wound healing properties by promoting collagen synthesis and reducing oxidative stress(20). Also its cooling effect provides relief from sunburns and minor skin irritations. Aloe vera has applications in digestive health. It possess compounds that support gut health by soothing the digestive tract and relieving symptoms of acid reflux and irritable bowel syndrome. Aloe vera extract is also known for its potential in regulating blood sugar levels, making it a subject of research for diabetes management. It has immunomodulatory properties that may help to improve the body's defense mechanisms(20).

Aloe vera extract has natural coagulant property in water treatment due to its rich content of polysaccharides, such as acemannan. These high-molecular-weight compounds possess multiple charge sites, enabling them to neutralize the negative charges on colloidal particles in water. This mechanism of neutralization reduces repulsive forces, facilitating the aggregation of particles into larger flocs that can be removed through sedimentation or filtration(21). Studies have demonstrated that Aloe vera extract can effectively reduce water turbidity, with liquid extracts achieving up to 87.84% turbidity reduction at natural pH levels. However, it's important to note that while Aloe vera extract effectively reduces turbidity, it does not significantly impact water hardness, as its mechanism targets suspended particles rather than dissolved minerals like calcium and magnesium. Therefore, Aloe vera serves as a natural coagulant to improve water(21).

5.4 Clitoriaternatea

The blue pea flower (*Clitoriaternatea*) also known as butterfly pea, is a native plant to tropical Asia and belongs to the Fabaceae family. This vibrant blue flower is rich in anthocyanins, flavonoids, and peptides, that contributes to its numerous medicinal benefits(22). Conventionally used in Ayurvedic and traditional Chinese medicine, blue pea flower is known for its antioxidant properties, which helps to deal with oxidative stress and slow aging. It supports brain health by enhancing memory and cognitive function, making it beneficial for neurological conditions. The flower also exhibits anti-inflammatory, anti-microbial, and anti-diabetic properties(22). Blue pea flower is also valued for its calming effects, helping to reduce stress and anxiety. Its adaptogenic properties helpsin relaxation and overall well-being. Consumed as a tea or extract, it aids as a natural remedy for multiple health concerns.

Here in the formulation blue pea is used as a coloring agent due its long lasting and stable blue shade color. The chemicals of the plant also not react with any other ingredient of the formulation hence, not affects the stability(8).

5.5 Malusdomestica

ACV is a fermented liquid derived from crushed apples (*Malusdomestica*), containing acetic acid, beneficial enzymes and polyphenols. It is produced through a two-step fermentation process, in which sugars in apples are converted into alcohol and then fermented into vinegar by *Acetobacter* bacteria. It is widely recognized for its therapeutic benefits, mainly in digestive health(23). It promotes gut health by supporting beneficial gut bacteria and helping in digestion. Its acetic acid content helps regulate blood sugar levels, making it beneficial for individuals with insulin resistance or type 2 diabetes mellitus. ACV is known to support weight management by promoting satiety and reducing appetite. The antimicrobial properties of ACV make it effective for topical use in treating minor skin infections and dandruff. It also exhibits anti-inflammatory effects, which remove sore throats and support heart health by improving cholesterol levels. ACV contains acetic acid as its primary component, which imparts a low pH to the solution. ACV is effective in removing hard water stains and limescale deposits due to its acidic nature. In the formulation, ACV acts as pH adjuster(23).

5.6 EDTA

EDTA is a synthetic chelating agent derived from formaldehyde, ethylenediamine, and sodium cyanide. It is widely used in medicine due to its strong ability to bind metal ions. It is commonly used in chelation therapy to treat heavy metal poisoning, such as lead or mercury toxicity, by binding to these metals and facilitating their excretion. It is also used in dealing hypercalcemia and certain cardiovascular conditions by reducing calcium buildup in blood vessels. EDTA is used as an anticoagulant in blood sample preservation, preventing clotting by binding to calcium ions essential for coagulation(24).

EDTA is a hexadentate ligand that means it has six sites capable of binding to metal ions. In water softening, it therefore efficaciously reduces hardness by forming stable, water-soluble complexes with Ca^{2+} and Mg^{2+} ions, which are primarily responsible for water hardness. The chelation process is done by EDTA's four carboxylate groups and two amino groups donating electron pairs to the metal ions thereby creating a cage-like structure that sequesters these ions. This prevents them from interacting with other substances such as soaps and detergents and removing issues like soap scum formation and scale buildup(24).

5.7 Vitamin E

Vitamin E capsules are derived from both natural and synthetic sources. Natural source of vitamin E are plant-based oils such as sunflower, soyabean, and wheat germ oil with d-alpha-tocopherol being the most bioavailable form. Synthetic vitamin E is labeled as dl-alpha-tocopherol and is produced through chemical synthesis(18). Therapeutically, vitamin E functions as a powerful antioxidant, protecting cells from oxidative stress and supporting immune function.



Fig 3 Materials used in the HARDGONE water softener

It plays a crucial role in skin health by promoting wound healing and reducing inflammation. It also supports cardiovascular health by preventing LDL cholesterol oxidation. It also aid in neurological function and eye health. Vitamin E offers numerous benefits, including skin hydration and protection against oxidative stress(18).Figure 3 shows the materials used in “HARDGONE” water softener. Table 2 shows the composition of the ingredients in the formulation.

Table 2: Composition of the formulation

SR. NO.	Ingredients	Common name	For 200 ml	For 1000 ml	Role in formulation	Reference no.
1.	Moringaoleifera extracts	Drumstick tree	10ml	50ml	Adsorber and neutralizer of cations	(7)
2.	Purified water	Water	Upto 200ml	Upto 1000ml	Vehicle	
3.	Lavendulaangustifolia	Lavender	10 drops	50 drops	Flavoring agent	(5)
4.	Aloe barbadensis	Musabbar, kumara, aloe	20 ml	100ml	Neutralizer of colloidal particles present, stabilizer	(6)
5.	Clitoriaternatea	Blue pea	10 drops	50 drops	Coloring agent	(8)
6.	MalusDomestica	Apple cider vinegar (ACV)	10 ml	50ml	pH adjuster	(25)
7.	EDTA	-	5gm	20gm	Chelating agent	
8.	Tocopherols	Vitamin e	1 capsule	5 capsules	Protection against oxidative stress	(18)

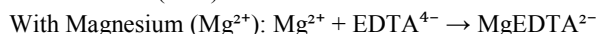
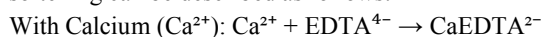
VI. WORKING PRINCIPLE OF WATER SOFTENER

6.1 Principle role of ingredients used in Formulation

A water softener is a system formulated to remove hardness-causing minerals from water, primarily calcium and magnesium ions. These minerals contribute to scale buildup in pipes, reduce soap efficiency, and cause skin dryness. The working principle of a water softener are the chemical reactions that alter the water's composition, making it softer and more suitable for household and industrial use. This document explores the chemical reactions and the impact of various components such as EDTA, lavender oil, aloe vera, purified water, moringa, vitamin E, ACV, and blue pea flower in the water softening process.

6.1.1. EDTA

EDTA is a powerful chelating agent vastly used in water softeners due to its ability to bind with divalent metal ions like calcium and magnesium. It contains four carboxyl groups and two amine groups that are capable of forming stable, water-soluble complexes with these minerals. This prevents the formation of insoluble compounds, such as calcium carbonate, which would otherwise precipitate and cause scale buildup(24). The chemical reactions of EDTA in water softening can be described as follows:



By binding to these ions, EDTA successfully reduces water hardness, allowing for better cleaning efficiency and preventing scale formation(24).

6.1.2. Lavender Oil (*Lavandula angustifolia*)

Lavender oil is an essential oil known for its calming aroma and antibacterial properties. It contains compounds like linalool and linalyl acetate that provide therapeutic effects. It imparts a pleasant fragrance and can inhibit microbial growth, enhancing the hygiene and sensory quality of softened water. In the formulation lavender oil is used as a flavouring agent due to its aroma(19).

6.1.3. Aloe Vera (*Aloe barbadensis miller*)

Aloe vera is rich in bioactive compounds such as vitamins, minerals, polysaccharides, and enzymes. Although it does not chemically react with hardness ions, it plays a crucial role in reducing the effects of hard water on the skin. Polysaccharides present in aloe form a protective layer on the skin which helps in moisturization and prevent dryness caused by hard water. In a water softener formulation, aloe vera can also function as a stabilizer or emulsifier, ensuring the even distribution of other active ingredients within the solution(21).

6.1.4. Purified Water

Purified water acts as a vehicle for dissolving and combining the active components of the water softener. It is free from impurities and extraneous minerals, which helps prevent interference with the softening process. By using purified water, the formulation remains consistent, and no additional hardness is introduced to the treated water.

6.1.5. Moringa (*Moringa oleifera*)

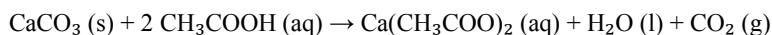
Moringa contains various bioactive compounds such as proteins which have coagulant properties. Although it does not chemically bind calcium or magnesium ions like EDTA, moringa can help decrease water turbidity by coagulating suspended particles and impurities. The antioxidants and nutrients in moringa may also contribute to skin health by reducing oxidative stress and supporting the skin's natural protective barrier when exposed to softened water(7).

6.1.6. Vitamin E (Tocopherol)

Vitamin E is a fat-soluble antioxidant which shields cells from oxidative stress. In the context of a water softener, vitamin E provides protective and moisturizing benefits. It does not engage in chemical reactions with hardness ions but helps in counteracting the drying effects of hard water on the skin. By incorporating vitamin E, the water softener formulation enhances skin hydration and provides a soothing effect(18).

6.1.7. Apple Cider Vinegar (ACV)

ACV contains acetic acid that is a weak organic acid. In a water softener, ACV can help dissolve some mineral deposits, especially calcium carbonate, by lowering the pH of the water(23). This enhances the chelation process by making calcium and magnesium ions more accessible for EDTA binding. The chemical reaction between acetic acid and calcium carbonate is as follows:



By promoting the breakdown of these deposits, ACV complements EDTA in reducing water hardness(23).

6.1.8. Blue Aprajita or blue pea flower (*Clitoria ternatea*)

Blue aprajita also known as butterfly pea flower is composed of anthocyanins responsible for giving it a distinctive blue color. It adds a visually appealing blue hue to the water, enhancing the aesthetic experience(22).

When combined in a water softener formulation, these ingredients work synergistically to create an efficient and multifunctional solution. EDTA acts as a chelating agent, binding calcium and magnesium ions to prevent scale deposits, while ACV lowers the pH, helping in the dissolution of calcium carbonate and enhancing EDTA's chelation efficiency. Aloe vera and lavender oil contribute to emulsification and stabilization, improving the solubility of soaps in softened water. Vitamin E, moringa, and blue pea flower provide antioxidant protection, shielding the skin from oxidative stress caused by hard water exposure. To improve the sensory experience, lavender oil and blue aprajita add a pleasant fragrance and a visually appealing color, making the water softener both effective and enjoyable to use.

6.2 Impact of softener on hard water

EDTA, when used in hard water, acts as a chelating agent, binding with calcium and magnesium ions, thus softening the water. Lavender oil gives aesthetic vibrant blue color. Aloe Vera and Moringa, both natural purifiers, aid in detoxifying and neutralizing impurities. Vitamin E, known for its antioxidant properties, supports skin protection against hard water exposure. ACV can help in dissolving mineral deposits, improving water quality. Blue pea flower (butterfly pea) has antioxidant properties, possibly enhancing the overall water treatment. Altogether these ingredients work synergistically to reduce the negative effects of hard water.

VII. METHODOLOGY

To formulate a 200 mL water softener, we started by preparing a blue pea flower infusion by boiling 50 mL of distilled water and adding 5–10 dried blue pea flowers. Let the mixture steep for 10–15 minutes until the water turns a deep blue, then allow it to cool. In a separate beaker, take 100 mL of distilled water and dissolve 0.5–1 gram of EDTA, ensuring it is fully mixed. In another small bowl, blend 10 mL of aloe vera extract with 5–10 mL of ACV, stirring until the consistency is even. This mixture should then be combined with the EDTA solution. Next, incorporate 5–10 mL of moringa extract into the liquid and mix thoroughly before adding the cooled blue pea flower infusion. For improved nourishment, take one or two vitamin E capsules, pierce them, and squeeze the contents into the formulation, stirring well to evenly distribute the oil. In a separate bowl, combine 5–10 drops of lavender oil with a small amount of water to aid dispersion. Slowly and gradually introduce this essential oil blend into the main solution while stirring continuously. Finally, add enough distilled water to bring the total volume up to 200 mL, assuring all ingredients are well mixed. Transfer the completed formulation into a clean spray bottle or storage container. This water softener can be used as a final rinse for hair, a facial mist for hydration, or as an additive to bathwater for a soothing effect.

7.1 Materials and Requirements

In the formulation of water softeners, using high-quality apparatus ensures the accuracy, efficiency, and safety of the process. Essential equipment includes a beaker, glass rod, funnel, hot plate, dropper, and filter paper. These tools when crafted from high-quality materials like glass, are crucial for producing a high-grade water softener that meets specific standards(26).

The beaker is most vital pieces of equipment used in the water softener formulation process. A high-quality glass beaker promotes accurate measurements and mixing of liquids. Glass is preferred for this purpose because it is chemically inert, therefore it will not react with the substances in the water softener formula and ensures the purity of the solution. A glass beaker also allows easy observation of the chemical reactions and changes during the process as it is transparent providing a clear view of the progress. This transparency is a major benefit for accurate monitoring and timing in the formulation(26).

A glass rod is key tool used in the process. It is used for stirring the solution to ensure uniform and homogenous distribution of the chemical agents. Glass rods are ideal because they are non-reactive and does not introduce any contamination or unwanted reactions into the mixture. Their smooth surface decreases the risk of scratching or damaging other equipment during mixing which is a major concern when using less durable materials like plastic. The rigidity and precision of the glass rod allow for efficient control during the stirring process(26).

The funnel plays an important role in transferring liquids from one container to another preventing the spillage. A high-quality glass funnel is useful as it can withstand various chemicals without degradation. Glass funnels offer superior control over the pouring process, which is important for accurate measurement when working with concentrated chemicals. The smooth surface of glass ensures that the liquid flows easily without sticking to the sides, resulting in minimal loss of material(26).

A hot plate or an induction is used to heat the water or chemical mixtures. In the formulation of water softeners, some reactions may require gentle heating to accelerate the dissolution of chemicals or improve their efficiency. A high-quality glass apparatus, when used with a hot plate, is excellent for ensuring controlled heating. Glass has the advantage of being able to resist many chemicals and provide consistent heat distribution. Moreover, glass is a non-reactive material, so there's no risk of contamination or chemical alteration due to the heat process(27).

A dropper is important for precisely adding small amounts of chemicals or reagents to the formulation. High-quality glass droppers are precise, easy to clean, and non-reactive with most substances used in water softener preparation. The ability to control the volume of liquid dispensed is an important measure for ensuring the correct chemical balance in the formulation, which is vital for achieving the aimed softening effect(27).

Finally, filter paper is used to separate any solid impurities or precipitates or agglomerates from the water softener solution. High-quality filter paper allows filtration process to be efficient, removing the smallest unwanted particles. This is a critical parameter in the final product's purity and effectiveness. Using glass apparatus with such filtration ensures that no contaminants are introduced during handling or mixing(27).

Testing the pH is a pivotal step in deciding the effectiveness and stability of water softeners. When formulating a high-quality agent for water softening, the pH plays a significant role as it impacts the ion exchange process and the overall efficiency of the system. Proper pH testing is necessary to decide that the water softener works optimally by maintaining the correct chemical environment required for ion exchange to occur(28). The pH range for water softening typically lies between 6 and 8.5, ensuring that the hardness-causing ions like calcium and magnesium are effectively removed without affecting the performance of the softening agent. Stability testing ensures that the agents will maintain their effectiveness over time and under varying environmental conditions. This helps manufacturers provide high-quality water softeners that consistently perform well(28).

7.2 Steps for using “HARDGONE” water softener

To use the water softener, begin by preparing a bucket of water for your intended purpose. For bathing, fill a bucket with water and add an adequate amount of the softener in few drops form, ensure even distribution by stirring gently. Softened water allows soap to lather more properly, so use a smaller amount of soap or shampoo than usual. After cleansing, rinse thoroughly to experience softer skin and smoother hair. It can also be used as a facial mist.

For washing clothes, add the softener to a bucket of water before mixing in detergent. Since softened water enhances the detergent's effectiveness, only a less amount is needed to achieve a deep clean. Soak clothes in the prepared solution then wash as usual. This method not only removes dirt more efficiently but also helps maintain softness of the fabric and prevents detergent buildup.

When using the softener for general cleaning, mix it into a bucket of water and use this solution to wipe surfaces, mop floors, or clean glass. The reduced mineral content prevents residue buildup, leaving surfaces shinier and easier to maintain. Using softened water reduces soap usage while improving cleaning efficiency, making household chores more effective and effortless.

VIII. EXPERIMENTAL ANALYSIS

Testing and analysis of a water softener product is essential to analyze its effectiveness, safety, and overall performance. A well-formulated water softener should efficiently decrease water hardness along with maintaining skin-friendly properties. This analysis aims to evaluate the product's ability to complex with mineral ions, improve water quality, and enhance user benefits such as hydration, pH balance, and overall usability. The testing process involves various parameters, including hardness reduction, pH balance, solubility, stability, and sensory attributes such as texture and fragrance. Also, the presence of beneficial ingredients like aloe vera, moringa, vitamin E, and essential oils will be assessed to ensure their effectiveness in nourishing the skin and hair. Performance testing will also include user trials to determine satisfaction levels and any skin sensitivities. By conducting a comprehensive evaluation, this analysis will provide valuable insights into the efficiency of the water softener, ensuring it meets quality standards and delivers the intended benefits.

8.1 Physical parameter testing

8.1.1 Odour - The water softener possesses a mild, refreshing aroma primarily obtained from lavender oil and other botanical extracts. The fragrance is pleasant, enhancing the user experience without being overpowering. The absence of artificial fragrances ensures that the product remains gentle on sensitive skin and suitable for daily use.

8.1.2 Appearance and Colour - The final formulation presents a clear to slightly tinted liquid, depending on the concentration of botanical ingredients such as blue pea flower infusion and moringa extract. The colour is vibrant light blue reflecting the natural composition of the product. The liquid maintains a smooth consistency without visible separation or sedimentation, ensuring uniformity in every use.

8.1.3 Viscosity - The water softener has a viscosity similar to that of water permitting it to mix effortlessly with bathwater, rinse water, or other liquid mediums. Its lightweight consistency allows even distribution, making it easy to use without leaving any residue.

8.1.4 Stability at Room Temperature - Stability testing confirms that the water softener remains well-formulated at room temperature without any noticeable changes in texture, colour, or odour over time. No phase separation, precipitation, or microbial growth observed, this shows excellent formulation stability. The product retains its effectiveness and freshness, ensuring a long shelf life when stored in a cool, dry place away from direct sunlight. The overall assessment of the physical parameters suggests that the water softener meets quality expectations, maintaining its sensory and functional properties while delivering optimal performance.

8.2 Soap suds test

The soap suds test is a qualitative method used to evaluate water hardness by observing the lathering ability of soap in a water sample. Hard water contains dissolved minerals such as calcium and magnesium that reacts with soap to form scum, reducing the formation of foam. In contrast, soft water allows soap to lather easily, producing stable suds(29).

Interpretation of Results - The image shows a test tube with a liquid forming foam at the top and a relatively clear solution below. This indicates that the water has undergone treatment with a water softener. The presence of significant foam at the superficial part suggests that the water has low concentrations of calcium and magnesium ions, allowing the soap to lather efficiently. The clear solution at the bottom further supports the absence of excessive hardness. Figure 4 below shows the results of soap suds test.



Fig 4 result of soap suds test

8.3 Stability or Phase separation test

The phase separation test is an essential method to analyze the stability of a water softener formulation over time. It helps to determine that whether the components remain uniformly mixed or separate into distinct layers, which could indicate poor solubility, ingredient incompatibility, or degradation. In this test, the water softener product was stored for 48 hours under controlled conditions and then shaken to assess its homogeneity. The results showed no phase separation thereby confirming that the formulation remained stable throughout the storage period. There was absence of visible layers, sediment, or precipitation indicates that all ingredients are well-blended and maintain their consistency.

This stability assures that the product delivers uniform performance, remains easy to use, and has a prolonged shelf life without requiring frequent agitation before application. If phase separation had occurred, it might have led to uneven distribution of active ingredients, reducing the product's effectiveness in softening water. Since no such issues were observed, the formulation shows excellent storage stability, making it reliable for long-term use in water softening applications. Figure 5 below shows the results of phase separation test.

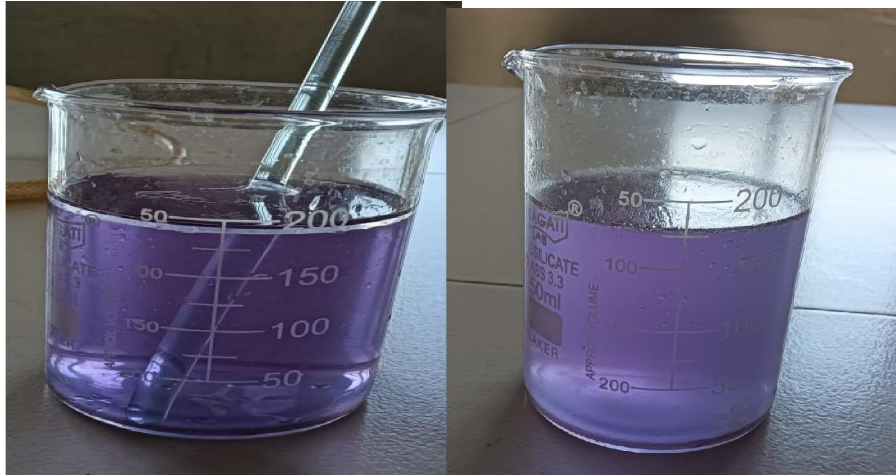


Fig 5 results of phase separation test

8.4 Cations test

Before adding the Hardgone water softener, the presence of calcium and magnesium ions in the water was confirmed through chemical tests, including the flame test. When subjected to a flame test, the water sample exhibited characteristic colors—calcium produced an orange-red flame. The observations indicated the presence of hard water, which can cause scaling and reduce the effectiveness of detergents. After treating the water with the Hardgone softener, the flame test was repeated, and no characteristic color for calcium was observed, indicating its removal. Similarly, tests for magnesium showed that its ions were no longer present. The absence of these cations confirmed that the water had been effectively softened. The Hardgone water softener successfully removed calcium and magnesium, improving water quality and making it more suitable for household and industrial use.

8.5 pH test

The pH test is essential for evaluating the acidity or alkalinity of a water softener formulation, ensuring it remains within an optimal range for effective performance(28). The test was conducted, and the pH was found to be 5.5 to 7, indicating a mildly acidic to neutral formulation. This range ensures that the softener works efficiently without causing corrosion in plumbing systems or scaling in appliances, thereby extending their lifespan. Additionally, maintaining the correct pH in softened water benefits skin and hair, preventing dryness or irritation that can result from overly hard or acidic water. If the pH were too low, it could increase the risk of corrosion, while a higher pH might reduce the product's effectiveness. Since the measured pH falls within the appropriate range, the water softener is confirmed to be stable, reliable, and suitable for long-term use in water treatment applications. Figure 6 below shows the results of pH test.



Fig 6 results of pH test

8.6 TDS meter test

A Total Dissolved Solids (TDS) meter is an essential tool for measuring the effectiveness of a water softener by detecting the concentration of dissolved minerals and salts in water. To assess our water softener's performance, we conducted a TDS test by measuring the water quality before and after softening(30).

Without using the water softener, the TDS reading was 406 ppm, indicating a high concentration of dissolved minerals like calcium and magnesium that are majorly responsible for water hardness. After passing through the softener, the TDS level dropped significantly to 197 ppm, showing a substantial reduction in mineral content. This test confirms that our water softener effectively removes hardness-causing minerals, improving water quality. While TDS levels may not drop drastically due to sodium ion exchange, the reduction demonstrates the system's efficiency in preventing scale buildup and ensuring softer water. Figure 7 below shows the TDS meter test results. Table 3 comprises testing and results of water softener formulation.

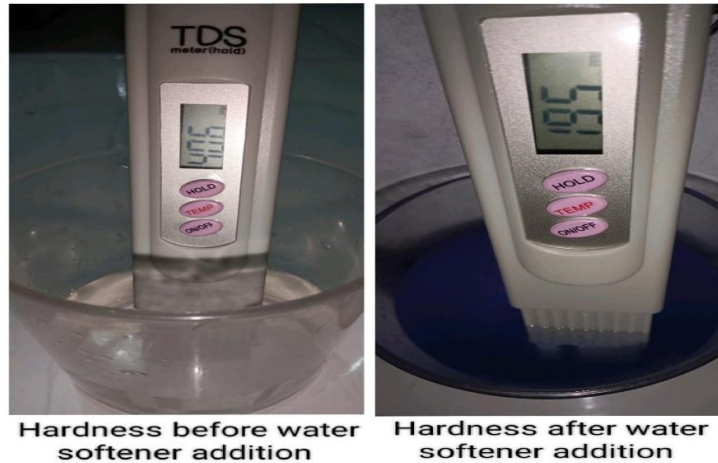


Fig 7 TDS meter test results

Table 3: testing and results of water softener formulation

Sr.no	Tests	Observation and Results
1.	Physical properties	
1.1	Odour	Pleasant and refreshing odour
1.2	Appearance and colour	Homogenous and vibrant blue
1.3	Viscosity	Similar to water and effortlessly miscible
1.4	Stability at room temperature	Stable at room temperature
2.	Soap Suds test	Formation of foam above the formulation indicates that the

		formulation is effective
3.	Stability or phase separation test	No phase separation after 100 shakings on storage of 48 hours
4.	Cations test	No presence of calcium and magnesium
5.	pH	5.5 to 7
6.	TDS meter test	Before addition of water softener – 406 ppm After addition of water softener – 195 ppm

IX. APPLICATIONS AND BENEFITS

Water softeners are essential devices used to reduce the hardness of water by removing minerals such as calcium and magnesium. The benefits of using a water softener extend far beyond just improving water quality—they have various practical, economic, and health-related advantages. In this essay, we will explore the numerous benefits of water softeners, particularly their impact on skin and hair health, appliance longevity, energy efficiency, environmental sustainability, and economic applications(31).

9.1 Improved Water Quality and Skin Health

Hard water contains high levels of dissolved minerals that leave residues on the skin and hair. These mineral deposits strip away natural oils, leading to dryness, irritation, and discomfort. This is particularly concerning for individuals with sensitive skin or conditions such as eczema and psoriasis. By using a water softener, the concentration of these minerals is significantly reduced, making the water gentler on the skin. People who use softened water often experience softer, smoother skin with reduced irritation and fewer flare-ups of skin conditions. Additionally, softened water prevents clogged pores and breakouts, ensuring healthier skin overall.

9.2 Healthier, More Manageable Hair

The effects of hard water on hair are equally problematic. The excess minerals in hard water interact with hair care products, making shampoos and conditioners less effective. This can result in dry, brittle hair that lacks shine and volume. Hard water also causes mineral build-up on the scalp, leading to dandruff, itchiness, and even hair thinning. Using a water softener ensures that hair retains its natural moisture, remains soft, and is easier to manage. It also enhances the effectiveness of hair care products, allowing them to properly cleanse and nourish the hair.

9.3 Increased Lifespan of Appliances

One of the most significant advantages of a water softener is its ability to protect household appliances from scale buildup. Hard water leads to mineral deposits inside dishwashers, washing machines, water heaters, and coffee makers, reducing their efficiency and causing frequent breakdowns. These deposits clog pipes and reduce water flow, ultimately leading to costly repairs or replacements. Softened water prevents these issues by eliminating mineral accumulation, thereby extending the lifespan of appliances and reducing maintenance costs.

9.4 Energy Efficiency and Cost Savings

Water heaters are particularly affected by hard water. When minerals accumulate inside the heating elements, they form an insulating layer that reduces heat transfer. This forces the heater to work harder to maintain the desired water temperature, resulting in increased energy consumption and higher utility bills. By using a water softener, homeowners can improve the efficiency of their water heaters, leading to lower electricity or gas consumption and significant cost savings over time.

9.5 Better Cleaning and Increase Soap Efficiency

Hard water reduces the effectiveness of soap and detergents due to the presence of calcium and magnesium ions. These minerals react with soap molecules, creating soap scum instead of a rich lather. As a result, people need to use more soap for bathing, laundry, and dishwashing, leading to increased expenses. Softened water, on the other hand, allows

soap to lather more easily, requiring less detergent while producing better cleaning results. Clothes washed in soft water feel softer and last longer, as there is no mineral buildup that can make fabrics stiff and dull.

9.6 Environmental Benefits

Water softeners contribute to environmental sustainability in several ways. Since soft water improves the efficiency of cleaning products, less soap and detergent are required, reducing the amount of chemical waste that enters water systems. Additionally, softened water decreases the need for harsh chemical descalers, which can be harmful to the environment. By extending the lifespan of appliances and plumbing systems, water softeners also help reduce electronic and plastic waste, further minimizing their environmental impact.

9.7 Economic Advantages for Businesses

Water softeners provide substantial economic benefits in industrial and commercial settings. Factories, hotels, hospitals, and laundromat often experience problems due to hard water, such as clogged pipes, boiler inefficiencies, and increased equipment maintenance costs. By installing water softeners, businesses can significantly reduce these issues, leading to improved operational efficiency and lower repair expenses. Industries that rely on consistent water quality—such as car washes and food production—benefit from softened water by ensuring cleaner results and reducing the need for excess detergents or chemicals.

9.8 Reduced Maintenance of Plumbing Systems

Hard water deposits minerals inside pipes, leading to blockages, reduced water pressure, and corrosion. Over time, this can result in expensive plumbing repairs and replacements. Softened water prevents scale buildup, ensuring that pipes and fixtures remain free from mineral deposits. This reduces maintenance costs and increases the longevity of plumbing systems, benefiting both homeowners and businesses alike.

X. COMPARATIVE STUDY

Water softeners play a crucial role in addressing the challenges caused by hard water, including skin dryness, hair damage, and mineral buildup in appliances. Various commercial water softeners are available in the market, each differing in formulation, cost, and effectiveness. This study compares Hardgone Water Softener with other marketed products to highlight its cost-effectiveness and benefits. Hardgone Water Softener is primarily composed of natural ingredients such as Moringa, Aloe, ACV, Blue Pea, and Lavender, with minimal use of synthetic chelators like EDTA. In contrast, most marketed water softeners rely on chemical-based formulations, including EDTA, citric acid, phosphates, and synthetic surfactants, which can sometimes lead to skin dryness and irritation. The plant-based components in Hardgone make it a safer and more skin-friendly alternative, reducing water hardness while also nourishing and protecting the skin and hair. Additionally, it is biodegradable and environmentally friendly, unlike some synthetic water softeners that contain non-biodegradable phosphates, which may negatively impact water systems. In terms of cost-effectiveness, Hardgone Water Softener is highly affordable, priced between ₹250-₹270 for 200ml, whereas other liquid softeners in the market typically range from ₹300 to ₹500 for the same quantity. More advanced solutions, such as salt-based water softening systems, require a high initial investment of ₹5000 or more, along with ongoing maintenance costs. This makes Hardgone a cost-effective solution for individuals seeking an affordable yet effective water softener for personal use. Regarding overall effectiveness and user benefits, Hardgone effectively softens water and prevents mineral buildup while ensuring that hair and skin retain their natural moisture. Unlike some marketed softeners that can leave behind soap scum or chemical residues, Hardgone's gentle, natural formulation ensures a residue-free and non-irritating bathing experience. Additionally, it serves multiple purposes, being suitable for bathing, washing clothes, and other household uses, whereas most marketed softeners are formulated exclusively for bathing. Hardgone Water Softener offers a more natural, affordable, and effective alternative to conventional marketed formulations. It provides comparable or even superior benefits in terms of softening water, protecting hair and skin, and being environmentally safe, all at a significantly lower cost. For consumers seeking a budget-friendly,

eco-conscious, and skin-friendly solution, Hardgone Water Softener emerges as an excellent choice over traditional chemical-based water softeners.

XI. ENVIRONMENTAL AND HEALTH ASPECTS

Hardgone Water Softener is a natural, eco-friendly alternative to conventional water softeners, designed to effectively reduce water hardness while ensuring safety for both human health and the environment. Unlike traditional softeners that rely on synthetic chelating agents and harsh chemicals, Hardgone incorporates plant-based ingredients such as Moringa, Aloe Vera, Blue Pea, ACV, and Lavender, making it a safer option for skin and hair. Hard water often causes dryness, irritation, and buildup, but Hardgone's natural formulation helps retain moisture, reducing the risk of itchiness, eczema, or allergic reactions. Aloe Vera and Moringa nourish the skin and scalp, preventing the stripping of natural oils that is common with chemical-based softeners. While many commercial softeners contain phosphates and other non-biodegradable substances that contribute to water pollution and harm aquatic life, Hardgone's biodegradable ingredients ensure minimal environmental impact. The product contains a controlled amount of EDTA, a common chelating agent, ensuring safe and effective mineral removal without introducing excessive chemicals into wastewater. Additionally, Hardgone enhances soap efficiency, reducing the need for detergents and minimizing chemical waste in water systems. Traditional water softeners often increase sodium levels in water, which can have adverse effects on soil and plants, whereas Hardgone's formulation avoids excessive sodium buildup, making it a more sustainable option for households. The absence of harsh surfactants and toxic additives makes it non-toxic and safe for individuals with sensitive skin, ensuring that it does not cause irritation or long-term health concerns. By preventing scale buildup in plumbing and appliances, it also reduces the need for chemical descaling agents, further lowering environmental pollution. Hardgone's formulation aligns with sustainable living by offering an efficient, natural, and biodegradable water-softening solution that protects both personal health and the ecosystem. As a result, it provides an effective and responsible alternative to conventional softeners, ensuring clean, softened water without compromising environmental safety or human well-being.

XII. CONCLUSION

Hardgone Water Softener stands out as a natural, effective, and eco-friendly solution for addressing water hardness while prioritizing health and environmental sustainability. Through its unique formulation comprising Moringa, Aloe Vera, Blue Pea, ACV, and Lavender, it effectively reduces mineral buildup without the harmful effects associated with conventional chemical-based softeners. The product not only enhances water quality but also provides notable benefits for skin, hair, and overall hygiene, preventing dryness, irritation, and clogged pores. Unlike traditional softeners that rely on synthetic chelating agents and excess sodium, Hardgone minimizes chemical exposure, ensuring safe usage for individuals with sensitive skin and reducing environmental pollution. Its biodegradable composition supports sustainable living by preventing soil and water contamination, making it a responsible choice for households and businesses alike. The product also improves soap efficiency, reducing detergent consumption and minimizing chemical waste. The findings from the comparative analysis suggest that Hardgone is a cost-effective and sustainable alternative to marketed water softeners, offering similar or superior performance without the associated environmental risks. It effectively prevents scale buildup in appliances and plumbing systems, prolonging their lifespan and reducing maintenance costs. Moreover, its natural ingredients ensure a gentle yet efficient softening process, making it safe for everyday use.

Looking ahead, the future scope of Hardgone Water Softener includes expanding its application beyond household use to industrial and commercial sectors, where eco-friendly alternatives are in high demand. Further research can be conducted to enhance its formulation, exploring additional plant-based ingredients that may improve its efficiency while maintaining its sustainability. Additionally, packaging innovations using biodegradable or refillable containers can further reinforce the product's environmental commitment. Recommendations for future development include increasing public awareness about the benefits of natural water softeners, collaborating with sustainability-focused organizations, and conducting extensive real-world testing to gather user feedback and improve the formulation. By continually innovating and promoting the use of eco-friendly water softeners, Hardgone has the potential to become a

leader in the sustainable water treatment industry, providing a long-term solution for healthier water while preserving environmental integrity.

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