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Assessing natural coagulants as potential substitutes for water treatment - A sustainable approach to raw water

ABSTRACT

Natural raw water's quality has decreased as a result of several health and environmental risks brought on by industrialization, urbanization, demographic change, etc. Natural-based coagulants are used frequently to remove pollutants since they are accessible, affordable, eco-friendly, and quickly biodegrade as compared to inorganic-based coagulants. This natural-based coagulant is employed in this study to minimize raw water turbidity and boost drinking water quality. The raw water is taken from the Kalyani dam, Tirupati, Andhra Pradesh, and the coagulants such as Strychnospotatorum (SP), Ocimum sanctum (OS), and Citrus sinensis (CS) are used in this research. These natural coagulants are first cleaned, rinsed with tap water, dried, crushed, and then finely sieved to produce a powder. The turbidity achieved the best removal efficiency for Strychnospotatorum, Ocimum sanctum, and Citrus sinensis is 89%, 78%, and 72%, respectively. Other water quality measures, including alkalinity, hardness, pH, and total dissolved solids, are also evaluated to determine the coagulant's performance in the treatment of drinking water. The outcomes demonstrated that natural coagulants performed consistently well concerning water parameters. Thus, natural coagulants are excellent alternatives to chemical coagulants or coagulant aids, particularly in developing areas.
Keywords: *Coagulation, efficiency, Strychnospotatorum, Ocimum sanctum, Citrus sinensis*

1. INTRODUCTION

About 71 percent of the world's surface is made up of water, although freshwater makes up only 2.5% of that total. Water resources are depleting on a global scale due to ongoing population expansion, rising living standards, climate change, industrialization, agriculture, and urbanization [1]. A percentage of the remaining water sources may be sufficiently contaminated to make them dangerous for direct consumption. Raw water pollution may result from human activity, geopogenic causes (water-rock interaction), or regional climate conditions [2]. As a result, proper water treatment and sanitation are necessary to get rid of turbidity, pollutants, and other pathogenic germs. These processes can be aided by adding coagulants. Moreover, excessive turbidity poses a significant problem for water treatment [3].

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Coagulation and flocculation are the most often used methods to make turbid water more palatable and more aesthetically pleasing due to their simplicity and efficiency [4]. By using this method, colloidal particles are destabilized, which leads to an increase in particle size for simpler sedimentation. Chemical-based (inorganic and synthetic organic) coagulants as well as naturally occurring coagulants can be used to achieve coagulation and flocculation [5]. The usage of chemical-based coagulants has generated controversy among these two, due to their toxicity to living things. Chemical coagulants are used more frequently in wastewater treatment procedures due to their low cost, simple processing, storage, and high availability. The most popular coagulants include aluminium, iron salts, and synthetic organic polymers like (poly aluminium chloride(PACl) [6]. Some research suggested that Alzheimer's disease might be brought on by the aluminium that remains in water after using alum and PACl [7]. The low temperature also has an impact on the coagulation kinetics and hurts the floc aggregation rate, making metal salts less effective in the water below 10 °C [8]. In addition to tending to accumulate in food chains, high amounts of chemical coagulants like aluminium tend to lower water's pH [9]. Groundwater and soil are polluted by the inappropriate disposal of hazardous sludge. Aquatic creatures and plant species suffer when toxic sludge, such as aluminium, iron, etc., builds up in natural water bodies [9]. Therefore, the effective use of natural coagulants is required for the treatment of water and wastewater.

According to this perspective, using plant-based or natural coagulants constitutes a significant development in environmentally sustainable technology. Being a viable substitute at the moment, they have several advantages over chemical coagulants, including being recyclable, non-toxic, and creating sludge in smaller amounts and with lesser metal content, in addition to being widely distributed in nature, affordable, and multifunctional. Benefits for human health safety include biodegradability, lower dose requirements, less sludge generation, as well as the absence of any residual heavy metals [10]. As a result, it might be a better alternative technique for purifying drinking water. Natural coagulants obtained from plants may have positive economic effects since local residents would have additional employment prospects as a result of plant cultivation as another source of income. Numerous studies on natural coagulants have been conducted, including those on the following plants: Moringaoleifera [11], Cactus [12], Hibiscus rosa-sinensis [13], Acorn [14], Alyssum seeds [15], Citrus fruit peel [16], Fava bean [17], Cassia obtusifolia seed gum [18], Dolichos lablab [19], Lens culinaris [20], Descurainia Sophia [21], Strychnospotatorum [22,23], Cassava Peels Starch [24]. These organic coagulants are typically derived from plant barks, stems, roots, leaves, peels, seedpods, and flowers, as well as from animal bones, shells, clam scales, and naturally occurring minerals in the soil. Out of these, the plant coagulants are the most commonly available, affordable, degradable, safe for the environment and carbon-neutral, naturally regenerating, simple to prepare, and easy to handle of all the nature-based coagulants [22]. Many experts are highly concerned about turbidity removal for water quality when it comes to natural coagulants. To confirm their changes in water treatment, it is crucial to examine the other important physical and chemical parameters. A novel aspect of this research is to analyze the various water quality indicators for treated water to ascertain the stability and desired limitations.

To access the effectiveness of natural coagulants, the five water characteristics were taken into account: turbidity, hardness, alkalinity, pH, and total dissolved solids level for destabilizing colloidal particles. The purpose of this essay is to look into the possibilities of Strychnospotatorum, Ocimum sanctum, and Citrus sinensis as coagulants for the purification of drinking water. This natural substance was chosen since it is widely accessible and more effective in the treatment process.

1.1. Natural plant-based coagulants and coagulation mechanisms

Insoluble flocs are produced as a result of coagulation between the coagulant applied, the contaminants, and the water's alkalinity. Flocs are clumps of colloidal, dissolved, and suspended particle matter from the water that has been adsorbent by these reaction products. Untreated reservoir water contains both organic and inorganic pollutants, including silt, rotting material, alga, bacteria, etc. Therefore, coagulation is a crucial phase in the purification of water. Furthermore, coagulants form suspensions in water to collect and minimize turbidity [25]. Three pillars support the coagulation of organic coagulants: the properties of the coagulant used, the qualities of the water to be treated, and the features of the mixing process [26, 5, 10]. The concentration of colloidal particles, the molecular weight of the coagulant, the equipment and reagents used, the physical and chemical characteristics of the pollutants, such as zeta potential, colour, and the presence or absence of impurities such as trace elements and dissolved salts (ions and chemicals), all have an impact on the coagulation process [10, 27, 28, 26, 29, 30, 31]. Additionally, the subsequent phases of treatment are similarly impacted by coagulation. According to Kumar et al. [10], a productive and efficient coagulation process improves the end product's microbiological quality and lengthens the filter's useful life, lowering the overall cost of treated water. Some of the benefits of natural coagulants are shown in Fig. 1. Natural coagulants are made up of protein, carbohydrates, and lipids. In addition, polymers made of polysaccharides and amino acids constitute the main building blocks.

Previous studies have shown that charge neutralization and polymer bridging are the primary processes regulating coagulation activity. Strychnospotatorum, Ocimum sanctum, and Citrus sinensis are three different plant-based coagulants studied in this study. Strychnospotatorum (nirmali) are medium size tree that is used mostly as a traditional medicinal extract, is located in central and southern India, Burma, Nepal, and Sri Lanka [32]. Strychnospotatorum seed extracts are naturally anionic polyelectrolytes. It has a reticulated structure and is extremely permeable.

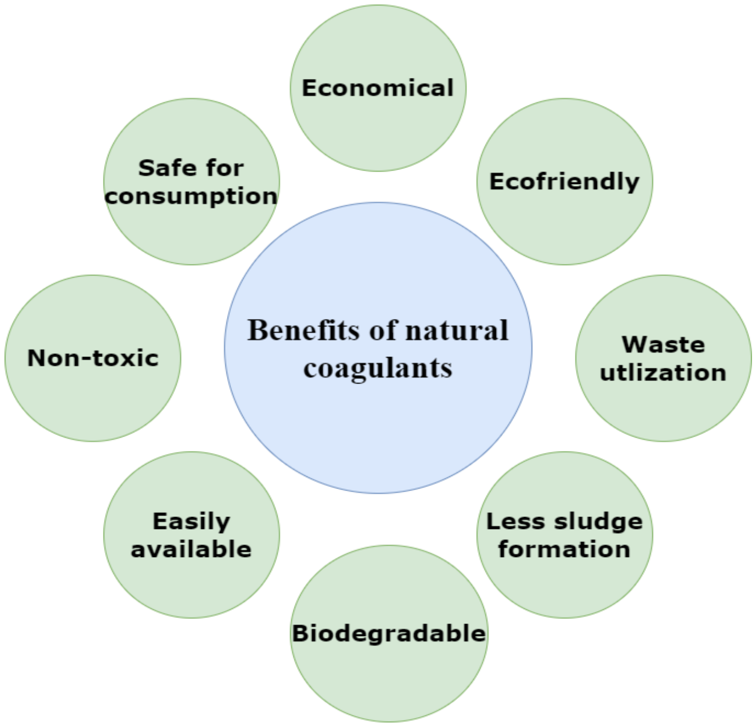

Figure 1. Benefits of natural coagulants

Chemical connections between individual particles can destabilize the water's particles. -COOH and free-OH surface groups boost the coagulation competency, while hydroxyl groups in the polymer chain provide adsorption sites for creating chemical bridges [33]. Alkaloids, lipids, and carbohydrates are additional components of the seed extract. Using polysaccharides derived from the seeds of Strychnospotatorum, [34] found that turbidity may be reduced by up to 80%. On the other hand, Ocimum sanctum, also called sacred tulsi or Indian holy basil, has been used for a very long time in Ayurvedic medical systems in the Indian subcontinent and is believed to have anticancer, antibacterial, antioxidant, and hypolipidemic properties. In the research study of [35], the Ocimum sanctum contains active ingredients like ursolic acid and eugenol. Additionally, the Citrus sinensis is a member of the Rutaceae family, and it is noted that the flavonoids and vitamins present in Citrus sinensis have potent anti-inflammatory and antioxidant activities. It has a functional group of CH, CH_2, CH_3, C=O, COOH, and M(RCOO)n, and its structure is porous [26]. Furthermore, Citrus sinensis also contains polyphenol chemicals [36].

2. MATERIALS AND METHODS

2.1. Water sample

The sample was taken from the research water source, the Kalyani dam in Tirupati. The methodology of the research is shown in Fig. 2. A typical raw water sample taken from the dam has the following characteristics are shown in Table 1. The samples were taken as grab samples in duplicate in pre-cleaned containers and then processed with nitric acid (2%). The samples were transferred to the laboratory in a cool box. Using Standard Methods, the dam water's physical and chemical characteristics were determined.

Table 1. Physical and chemical parameters for untreated waters

Sl.no	Parameters	Method used	Untreated	WHO standards
1.	Turbidity (NTU)	Meter	13.8	< 10
2.	pH	Meter	8.2	6.5 – 9.2
3.	TDS (mg/l)	Meter	963	< 1000
4.	Alkalinity (mg/l)	Titration	331	< 600
5.	Hardness (mg/l)	Titration	234	< 600

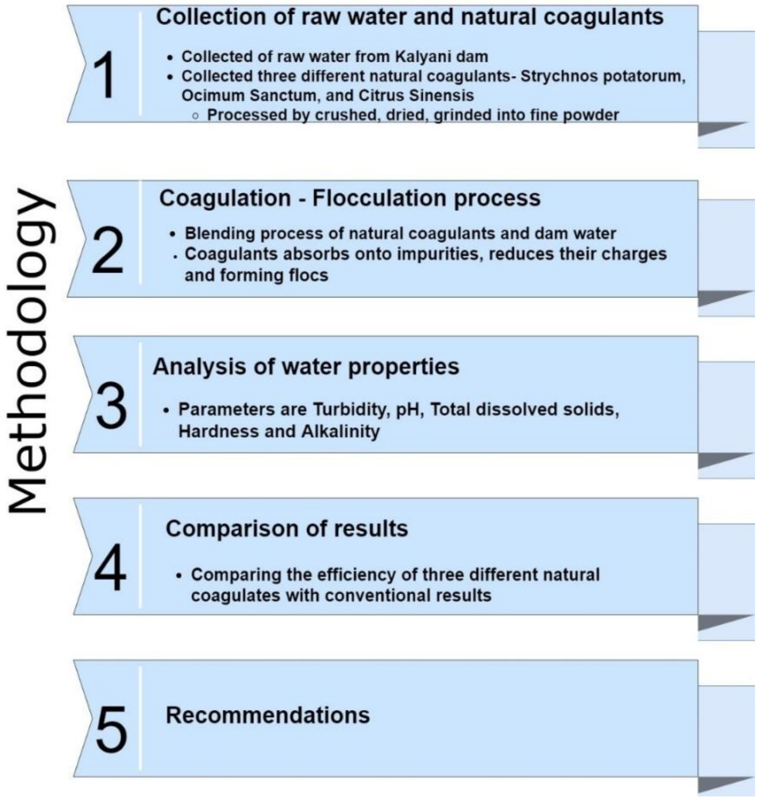

Figure 2. Methodology used in the study

2.2. Strychnospotatorum (Nirmali)

Seeds of Strychnospotatorum were bought from the market. The seeds from the pod were both oven- and sun-dried in the current investigation. The dry kernels were crushed and ground to the minimum possible size in a domestic mixer. 100 mL of distilled water and one gram of ground-up seed were combined, and the mixture was blended in the mixer at the highest speed for 60 seconds. As a 1% stock solution, the suspension was filtered and utilized. As and when it was necessary, the fresh stock solution was made.

2.3. Ocimum sanctum

Ocimum sanctum leaves were gathered in and around Tirupati, Andhra Pradesh, India. Fresh and mature leaves were washed in distilled water and allowed to dry naturally in the shade. Then, in a domestic mixer, it is broken down and pulverized to the smallest possible powder. This powder was employed in the extraction process. To improve the water extraction of the coagulant, 100 mL of distilled water and 1 gram of leaf powder were combined and quickly stirred for 20 minutes using a magnetic stirrer. The resultant solution was passed through a 0.45-micron filter paper employed as a 1% stock solution to create a homogenous solution free of suspended materials. When needed, the fresh stock solution was freshly made.

2.4. Citrus Sinensis

Key orange peels were gathered in Tirupati markets. After being washed, the peels were dried for two to three days in the hot sun to remove any remaining moisture. The semi-dried peels were then air-dried for about two hours at 105°C until the moisture content was reduced by about 95%, which improved the peels' capacity to grind into a fine powder because the presence of moisture inside the peels would limit their ability to break apart into small pieces. To get the smaller solids with a diameter of less than 1.25 mm, the ground peels were sieved into a fine powder. These smaller solids were then combined with distilled water in a ratio of 1 g: 30 ml [37]. The mixture was then agitated for a further 20 minutes to ensure that the distilled water and peel solution was thoroughly combined. The solution was then given a 30-minute rest period to allow the residual solids to settle. The mixed solution was filtered through 110 mm filter paper to eliminate small residue inside the solution while retaining its active components (crude extracts). The filtrate's supernatant was applied as a natural coagulant [30]. The Citrus sinensis liquid was kept at room temperature in an airtight bottle until it was needed. The details of natural coagulants are shown in Table 2.

Table 2. Selection of plant materials

Plant name	Part of the plant used	Collection site
Strychnospotatorum (Nirmali) Family: Strychnaceae (Loganiaceae)	Seeds	Directly collected seeds from the local market, Tirupati
Ocimum sanctum Family: Lamiaceae	Leaves	SrinivasaMangapuram and A.Rangampeta village, Tirupati
Citrus sinensis Family:Rutaceae	Peel/skin	Fruit market, Tirupati

2.5. Analytical Methods

Using a turbidity meter (µC Turbidity meter 135, Systronics instruments), the scattering properties of light were measured and expressed in Nephelometric turbidity units (NTU). Turbidity impairs aesthetics as a result of hazy water. The turbidity value will be high if the intensity of dispersed light is high. A multi-parameter device (Conductivity/TDS meter 308, Systronics instruments) was used to measure the total dissolved solids (TDS). The total dissolved solids (TDS) concentration is the result of adding the cations (positively charged) and anions (negatively charged) ions in the water. Similar to this, the pH was determined using a pH meter (PH system 361, Systronics instruments) to determine the concentration of hydrogen ions. The microcontroller-based approach was applied to all three meters. Titrimetric standards were used to determine the hardness content and overall alkalinity.

2.6. Planning of experiment

The experiments were intended to: (1) assess raw turbid water; (2) study coagulation using Citrus Sinensis, Ocimum sanctum, and Strychnospotatorum; and (3) analyze turbidity, pH, total dissolved solids, hardness, and alkalinity utilizing dam water. All experiments are conducted under approved standard procedures. The coagulant dose range for Strychnospotatorum and Citrus sinensis was 100–200 mg/L and for Ocimum sanctum 500–600 mg/L, respectively. These dosages were established through experiments and a literature review. To effectively remove turbidity, the ideal pH was also identified. To compare the outcomes with raw water, coagulation tests were employed as a standard. So, a number of studies including Strychnospotatorum, Ocimum sanctum, and Citrus sinensis were planned. To measure the effectiveness of treatment, five trials were done for each dosage, and the average of these data was used for discussion.

3. RESULT AND DISCUSSION

3.1. Turbidity effects on natural coagulants

The physicochemical parameters of the treated water revealed that applying various dosages of Ocimum sanctum, Strychnospotatorum, and Citrus sinensis at pH 7-8 resulted in a reduction in turbidity shown in Figure 3. The highest percentage reduction for turbidity was 89% at a dose of 100 mg/L, followed by 84.5% at a dose of 200 mg/L for Strychnospotatorum shown in Fig. 3(a). Other natural coagulants including Ocimum sanctum and Citrus sinensis also exhibited removal efficiencies of turbidity of 72% and 78%, respectively displayed in Figure 3b, 3c. This demonstrates unequivocally that turbidity greatly lowers when natural coagulant concentrations rise. Dollah et al. [16] state that when turbidity reduction efficiency is just above 70% (like the results from this study) with natural coagulants, it confirms WHO accepted limits This coagulant extract effect lowers the turbidity of the water, indicating that the suspension can clear due to the bioactive component that is already present. These bioactive substances might also be positively charged proteins that are water soluble and connect to or interact with the primarily negatively charged contaminants in the water samples. Clearwater is typically regarded as a sign of healthy water. Since the total solids themselves remain in suspension, the use of natural coagulants at a larger dose will result in less turbidity removal. When compared to Ocimum sanctum and Citrus sinensis, the Strychnospotatorum had a more effective elimination efficiency. Similar to this, several researchers investigated the possibility that the low turbidity removal in all-natural coagulants may be caused by a low amount of turbidity and a high pH.

3.2. pH effects on natural coagulants

pH is a significant physical parameter to consider because coagulants are frequently connected with electric charges. Fig. 3 depicts how the dosage of the coagulant affects the pH of the water. The research demonstrates that pH was seen to dramatically fall at all extract concentrations. When various coagulants are applied to water, the pH will slightly change. This finding can be attributed to the organic character of the bio-coagulants. According to the data, Citrus sinensis, Strychnospotatorum, and Ocimum sanctum each had a pH reduction of 85%, 79%, and 72%, respectively.

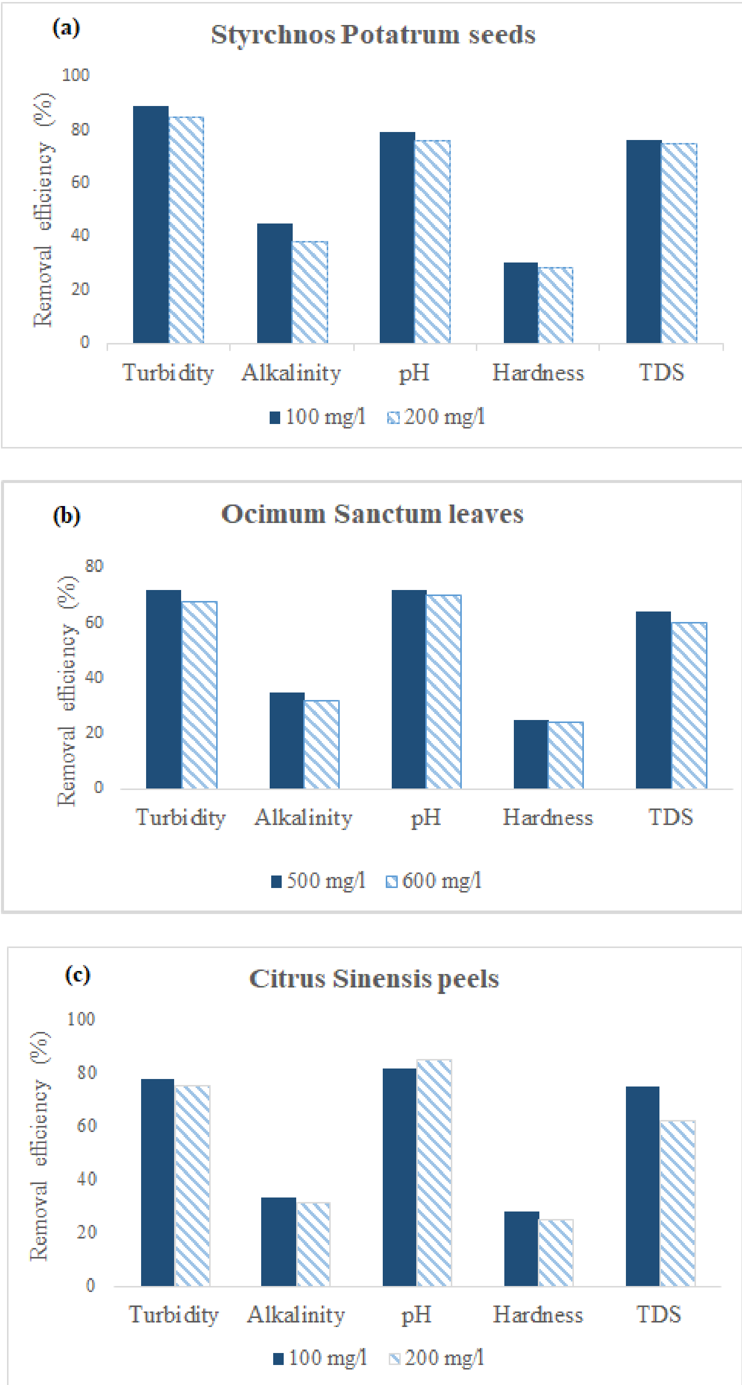

Figure 3. Effectiveness of natural coagulants using (a) Strychnospotatorum, (b) Ocimum sanctum, and (c) Citrus Sinensis

Fruit peel waste typically contains bioactive substances such as phenolics, ascorbic, citric acids, and carotenoids that could affect the reduction in the pH removal process. The effect of pH affects the removal effectiveness when utilizing organic coagulants, according to research by [38, 39]. The lengthy chain of proteins included in the molecules of natural coagulants is thought to be the cause of their action, which results in the aggregation of pollutants and the creation of flocs, according to a variety of literature. In the case of metal-based coagulants hydrolyze in water and release H^+ ions, resulting in a pH fall. On the other hand, sewage output and aerobic respiration can also induce pH decreases. Additionally, lower pH levels led to enhanced removal effectiveness because the concentration of positive charges in natural coagulants was larger and was able to destabilize the negative colloids in the effluent. At pH 6.5 and 8, all the coagulants utilized in this investigation showed improved coagulation efficacy. The pH of dissolved Citrus sinensis extracts allows for greater coagulation, according to our research. Thus, increasing the acidity of the Citrus sinensis extracts assures a lower pH, which enhances its coagulating properties.

3.3. Alkalinity effects on natural coagulants

With an increase in coagulant dose, total alkalinity for the coagulants Strychnospotatorum, Ocimum sanctum, and Citrus sinensis exhibited a modest decrease. For Strychnospotatorum, Ocimum sanctum, and Citrus sinensis, the highest clearance efficiencies were, respectively, 45%, 35%, and 33%, (see Fig. 3). The highest permitted alkalinity for drinkable water, according to WHO recommendations are 200 mg/L; however, the alkalinity obtained while applying all three coagulants was still within the acceptable range. Alkalinity did not change statistically significantly across the range of doses used for samples treated with extracts from the seeds of Strychnospotatorum, the leaves of Ocimum sanctum, and the peel of Citrus Sinensis. The daily pH levels are also significantly influenced by the alkalinity of the water. pH levels rise as a result of hydrogen usage during photosynthesis by algae and plants. Similar to respiration, decomposition can cause pH levels to decrease. Most bodies of water are alkaline, they can buffer these changes, which makes it challenging to identify small or localized oscillations. Because the use of natural coagulant extracts alters the pH and alkalinity of dam water rather than adding chemicals, there is no need to condition the water to buffer the acidity created by iron or aluminium salts in the treatment process. The alkalinity of the water, which is predominantly provided by bicarbonate ions (HCO_3^-) in naturally occurring waters, affects the water's ability to buffer and control hydrogen ion concentration. Water with extremely low levels of alkalinity corrodes distribution systems, which are leached and shield microorganisms from disinfectants, posing a clear danger to the general population. Even though the dose of natural coagulant was increased, the pH and alkalinity remained constant at about 8 and 200 mg/l, respectively. This outcome is comparable to Hoa and Hue's [40] study on MoringaOleifiera seeds.

3.4. TDS effects on natural coagulants

Natural coagulants improve the TDS removal of a given water sample, according to numerous studies. However, the removal of TDS is reduced when the amount of natural polymer added increases past the optimal point, and this situation may be prone to surface saturation by an immense accumulation of polymer particles, which leads to particle stability. The inclusion of Strychnospotatorum, Ocimum sanctum, and Citrus sinensis coagulants effectively enhanced the TDS removal up to 76% at a pH of 7.2 at a reduced dosage ratio, as shown in Fig. 3. This observation may be the result of the reduced surface area coverage required for the establishment of polymer bridging. TDS is primarily composed of inorganic salts, with a trace quantity of organic material. Inorganic salts that are frequently found in water include the cations such as calcium, magnesium, potash, and sodium as well as anions are carbonates, nitrate, bicarbonates, chlorides, and sulphates. TDS can impact the flavor of water and frequently denotes high alkalinity or hardness. Individual coagulants had a positive removal efficiency for total dissolved solids. The elimination of total dissolved solids was observed to range between 60% and 76%. As a result, the reduction was stable. The removal of TDS is improved by the use of all three coagulants. This will also neutralize the charge without changing pH and remove the forces that hold colloidal particles in place, causing the particles to float in the water.

3.5. Hardness effects on natural coagulants

Total hardness was carried out by three natural coagulants such as Strychnospotatorum, Ocimum sanctum, and Citrus sinensis. Magnesium (Mg^{2+}) and calcium (Ca^{2+}) ion equivalent concentrations are added to determine the overall hardness. Such a value was essentially unrelated to the dosage of the coagulant. But among the many divalent salts, calcium and magnesium are thought to be the main causes of water hardness. This outcome is caused by the lack of any interaction between the utilized bio-coagulant and the ions (Ca^{2+} and Mg^{2+}) responsible for the total hardness. According to the data, Strychnospotatorum had the best removal effectiveness for the hardness from the dam water, with a removal efficiency of 30% at pH 7.2 and 100 mg/L (see Fig. 3a). These seeds are readily available, cost-effective, and can be used to remove hardness. Hardness removal is not significantly influenced by the coagulant dosage in any substantial way. It is reasonable to assume that natural coagulants are polyelectrolytes, they eliminate water hardness by interparticle bridging and adsorption. Second, the formation of light, slowly settling solids or flocks and the precipitation reaction that changed the soluble ions responsible for hardness into insoluble compounds would both be good indicators of the reaction mechanism. The greater result for groundwater and surface water samples is due to hardness caused by calcium, magnesium, as well as other hardness-causing chemicals. Soft water has a low pH, while hard water has a high pH. Reduced levels of $CaCO_3$ hardness were found in Ocimum sanctum and Citrus sinensis, providing a consistent indicator of lower calcium content. It is important to have more hardness, which may not be due to more calcium but may instead be owing to high magnesium concentrations, either with or without calcium. In Fig. 4, three independent natural coagulants' overall efficacy is replicated. The effectiveness of various parameters is seen to be stable, and the results are within desirable norms.

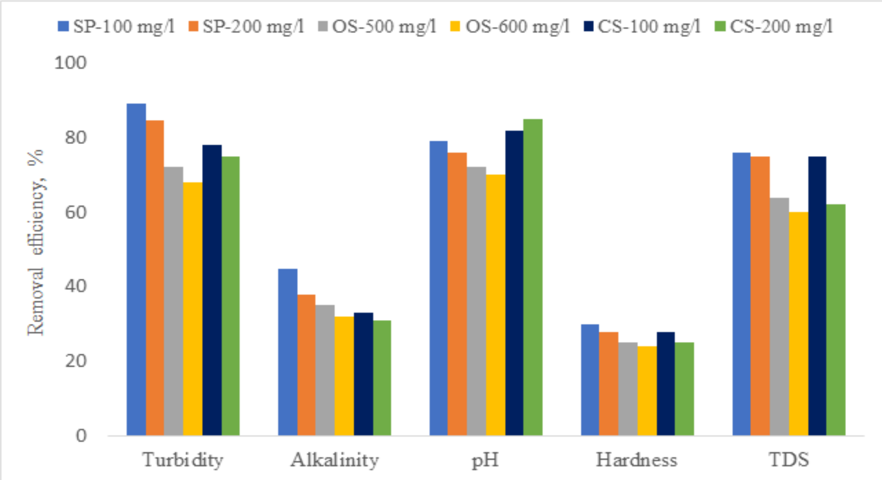

Figure 4. Results of three independent natural coagulants on various parameters

4. CONCLUSION

All three of the investigated coagulants are significantly steady in the treated water. The turbidity of the raw water was significantly decreased by each of the three coagulants under examination. The applied dosage of the evaluated natural coagulants demonstrated better removal efficiency percentages without noticeably changing the pH and alkalinity of treated water. This has an advantage over synthetic/chemical coagulants since it eliminates the need to add buffering agents to change the pH. In the treatment of raw water, extracts of Strychnospotatorum, Ocimum sanctum, and Citrus sinensis showed excellent coagulating capability. Strychnospotatorum seed extract could only lessen the turbidity by up to 5.2 NTU, while the treated water's colour exhibited lower values by Indian norms. In comparison to the other two natural coagulants, the seed extract performs removal efficiency more effectively in terms of alkalinity (45%), total hardness (30%), and total dissolved solids (76%) According to our findings, Citrus sinensis extracts' higher acidity ensures a lower pH by strengthening its coagulating characteristics, which in turn allows for stronger coagulation. Because these compounds are derived from natural sources, they can develop value-added products, offering themselves as a new source of profit. Nevertheless, despite all the advantages, natural coagulants and polymers should only be used on a small scale for the process of water clarity after undergoing studies that confirm their biodegradability, non-toxicity, and viability. To ascertain the conditions necessary to retain the coagulants in good condition for use in water treatment applications, more research should be done on the formulation, extraction, preservation, and shelf-life of Strychnospotatorum, Ocimum sanctum, and Citrus sinensis extract.

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IZVOD

PROCENA PRIRODNIH KOAGULANATA KAO POTENCIJALNIH ZAMENA ZA TRETMAN VODE - ODRŽIVI PRISTUP SIROVOJ VODI

Kvalitet prirodne sirove vode je smanjen kao rezultat nekoliko zdravstvenih i ekoloških rizika izazvanih industrijalizacijom, urbanizacijom, demografskim promenama itd. Koagulansi na prirodnoj bazi se često koriste za uklanjanje zagađivača jer su pristupačni, pristupačni, ekološki prihvatljivi i brzo se biorazgrađuju u poređenju sa koagulantima na neorganskoj bazi. Ovaj koagulant na prirodnoj bazi se koristi u ovoj studiji kako bi se smanjila zamućenost sirove vode i poboljšao kvalitet vode za piće. Sirova voda se uzima iz brane Kaljani, Tirupati, Andra Pradeš, a koagulanti kao što su Strychnospotatorum (SP), Ocimum sanctum (OS) i Citrus sinensis (CS) koriste se u ovom istraživanju. Ovi prirodni koagulansi se prvo čiste, ispiraju vodom iz slavine, suše, drobe, a zatim fino prosejavaju da bi se dobio prah. Najbolju efikasnost uklanjanja mutnoće postigli su Strychnospotatorum, Ocimum sanctum i Citrus sinensis, što je 89%, 78% i 72%, respektivno. Ostale mere kvaliteta vode, uključujući alkalnost, tvrdoću, pH vrednost i ukupne rastvorene čvrste materije, takođe su procenjene kako bi se utvrdilo dejstvo koagulanta u tretmanu vode za piće. Rezultati su pokazali da prirodni koagulanti konstantno dobro funkcionišu u pogledu parametara vode. Stoga su prirodni koagulanti odlične alternative hemijskim koagulantima ili pomoćnim sredstvima za koagulaciju, posebno u područjima u razvoju.
Ključne reči: *Koagulacija, efikasnost, Strychnospotatorum, Ocimum sanctum, Citrus sinensis*

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