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A review on "Removal Of Water Turbidity By Natural Coagulants Obtained From ProsopisJuliflora and Cactus Opuntia"

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ABSTRACT

Natural coagulants have been increasingly popular in the past few years due to its benefits and the fact that it resolves most of the associated problems when using chemical coagulants. Plant-based natural coagulants perform coagulation either by polymer bridging or charge neutralization, it can be extracted from various plant components. Concerted research and development efforts have been conducted in discovering new plant species and constituents that can be used as natural coagulants, which further boosting the effectiveness of existing plant-based natural coagulants. The objective of this paper is to provide a mini review on studies done over the span of ten years regarding plant-based natural coagulants. This review also includes advantages and disadvantages of natural coagulants prior to identify several potential research gaps to provide platform towards the need of further study.

KEYWORDS: Natural Coagulants, Turbidity, ProsopisJuliflora, Cactus Opuntia, Wastewater, Lake

1. INTRODUCTION

Water is undoubtedly the most vital element among the natural resources. In many developing countries, access to clean and safe water is a crucial issue. More than six million people die because of diarrhea which is caused by polluted water. Developing countries pay a high cost to import chemicals for water treatment [1]. Natural waterways are contaminated due to industrialization, urbanization, population growth etc., degrading their quality. Contaminated waterways cause numerous health and environmental hazards. Therefore, it is imperative to remove contaminants. Coagulation is one of the efficient primary chemical treatment methods that could be used to treat such contaminants. Natural coagulants have gained popularity in the water and wastewater treatment industry due to their advantage over chemical coagulants. Natural coagulants are derived from either plants, animals, or microorganisms. This study has elaborated on the nature and mechanisms, and types of natural coagulants. In this review work, many studies have proposed several types of natural coagulants. However, plant-based natural coagulants

extracted from different plant components have been extensively discussed and compared based on their application and efficiency in water and waste treatment. The primary purpose of this review is to refine the knowledge on the potential use and optimization of the effectiveness of eco-friendly and sustainable natural coagulants. Besides, the development efforts and the barriers reported by recent findings for the commercialization of natural coagulants are also discussed.

1.1 Advantages and Disadvantages of Natural Coagulant

Natural coagulant gains the advantage over chemical coagulant due to various reasons. One of the reasons are natural coagulant are safer than chemical coagulant. When using coagulant for water treatment, there will be possibilities of residue coagulant present in the water after the treatment. Chemical coagulant residue such as alum is harmful because it can cause Alzheimer disease if consumed. On the other hand, if natural coagulant was used, the residual coagulant would not be harmful. Likewise, natural coagulant is much cheaper compared to chemical coagulant. Chemical coagulant such as alum, need coagulant aid to effectively treat high turbidity water, thus making it more expensive and difficult to be used in poor countries. Whereas natural coagulants are much cheaper and can be extracted from various plant wastes which greatly reduce the treatment cost. Nevertheless, an abundance and locally available resource must be met to use natural coagulant commercially. Natural coagulant also has some disadvantages. Using natural coagulant will increase the organic matter present in the water, thus increasing microbial activity. Consequently, additional chlorine should be used to sanitize the treated water. Besides that, natural coagulant such as Moringaoleifera need longer sedimentation time than chemical coagulant and although some coagulant has antibacterial property that can treat E. coli infested water, the removal efficiency is not complete, thus secondary bacterial growth risk could occur.

2. SCOPE AND OBJECRIVE OF THE STUDY

- To reduce the level of turbidity and bacteriological contaminants from water using locally available natural coagulants like Cactus Opuntia, Prosopisjuliflora.
- To make the water treatment process easier and environmental friendly for household applications.
- Water is undoubtedly the most vital element among the natural resources.
- In many developing countries, access to clean and safe water is a crucial issue.
- Developing countries pay a high cost to import chemicals for water treatment.
- In most of the cases, these are expensive since they are required in higher dose.
- Many of the chemicals are also associated with human health and environmental problems.
- So natural coagulants can be used for water treatment as they do not causes any problems which occur due to the use of chemical coagulants.

3. LITERATURE REVIEW

Water is the fundamental requirement for all human activities and biological activities. It is the main component in the hydrological cycle. The water resources are continuously decreasing around the world due to various environmental degradation activities, climate change (Konapala et al., 2020), population growth (Zubaidi et al., 2020), and increasing standards of living and urbanization (Wu et al., 2013). Rapid population growth and haphazard waste disposal have resulted in the impending water crisis. In order to sustain the water requirements, various processes and technologies are being researched to improve the quality of water(Ullah et al., 2020). These technologies fall into three main categories, namely physical, chemical, and biological treatment methods. Physical methods include settling, media, and membrane filtration (OboteyEzugbe and Rathilal, 2020), adsorption (Ali and Gupta, 2006), and UV processes (O'Malley et al., 2020). Coagulation (Alibeigi-Beni et al., 2021), disinfection (Collivignarelli et al., 2017), ion exchange (Ergunova et al., 2017), catalytic reduction (Guo et al., 2020; Sivakumar, 2015), oxidation (Gogate and Pandit, 2004), and softening processes (Brastad and He, 2013) are some of the chemical methods used in the wastewater treatment. Biological methods include microbial biodegradation (Huang et al., 2018), phytoremediation (Hu et al., 2020), bioreactor processes (Neoh et al., 2016), constructed wetlands (Wu et al., 2015) etc. Moreover, some processes are combined with others

to improve efficiency (Ang and Mohammad, 2020). One of the most widely used processes in water and wastewater's primary treatment is coagulation for removing suspended particulate matter and colloids in wastewater(Staicu et al., 2015). Coagulation is considered one of the simple methods to remove suspended solids and impurities in water efficiently. Successful coagulation can be attained by using either chemical-based (inorganic and synthetic organic) coagulants or natural coagulants (de Paula et al., 2018). Natural coagulants have been recognized for their traditional local water purification (Choy et al., 2014; Dorea, 2006). Naturally occurring coagulants are sustainable, environmentally friendly, and less toxic than chemical coagulants (Teh et al., 2014). Natural coagulants have grasped the scientific community's attention in the past decades due to their significant health and environmental benefits, and it solves most of the common problems associated with chemical coagulants. Natural coagulants are produced or extracted from different sources such as microorganisms, animals, or plants (non-plant-based and plant-based). Now, several effective coagulants which have plant origin are being identified. Some of the common ones include Hibiscus sabdariffa (Roselle seeds) (Mohd-Esa et al., 2010), Dolichos lablab (Hyacinth bean) (Daverey et al., 2019), Moringaoliefera (Nonfodji et al., 2020), Nirmali seeds (Prabhakaran et al., 2020) watermelon seeds (Bhattacharjee et al., 2020) and cactus species (Rebah and Siddeeg, 2017). The drawbacks of chemical coagulants have resulted in the search for eco-friendly and sustainable natural coagulants in their usage and production. The main advantages of natural coagulants are renewability, biodegradability, nontoxicity, and cost-effectiveness. These studies have already proved the effectiveness of natural coagulants in wastewater treatment applications (Choy et al., 2014; Yin, 2010). However, the industrial usage of natural coagulants in wastewater treatment applications is limited. This is mainly due to the processing cost and the performance consistency of the extracted compounds from natural sources. Due to this, researchers tend to focus on modifying natural coagulants to get the maximum benefits (Muruganandam et al., 2017; Ahmed et al., 2016). This study aims to identify potential research gaps to refine the knowledge on natural coagulants and summarize the optimization methods for coagulants for improving their efficiency in water and wastewater treatment. This study also showcases the application of these coagulants for large-scale commercial usages and may assist in future studies. These will be discussed in sections as follows: the need for natural coagulants, mechanisms of natural coagulants, types of natural coagulants, barriers in the commercialization of natural coagulants, and examples of modified or blended natural coagulants. This study has been carried out in Colombo, Sri Lanka, in 2021.

Need for natural coagulants-

Chemical coagulant used has raised controversial issues due to its toxic nature for living organisms and can be categorized into three types: hydrolyzing metallic salts, pre-hydrolyzing metallic salts, and synthetic cationic polymers(Freitas et al., 2018; Verma et al., 2012). Due to the low cost, easy handling, storage, and high availability, chemical coagulants are more prevalent in wastewater treatment processes. Al2 (SO4) 3 , Fe2 (SO4) 3 , AlCl3, and FeCl3 are the most commonly used coagulant salts (Freitas et al., 2018; Matilainen et al., 2010; Sher et al., 2013). Despite the availability, low cost etc.; chemical coagulants are far behind in green chemistry due to high residual concentrations of aluminum found in treated wastewater (Freitas et al., 2018; Matilainen et al., 2010). According to Freitas et al., 2018; McLachlan 1995; Polizzi et al. 2002, Alzheimer's disease is linked with the neurotoxicity of aluminum. Synthetic polymer coagulants form hazardous secondary products such as acrylamide which is carcinogenic and neurotoxic, and also synthetic polymers have low biodegradability (Freitas et al., 2018; Kurniawan et al., 2020). Excessive concentrations of chemical coagulants such as aluminum reduce the pH of water tends and also, they can be accumulated to food chains (Kurniawan et al., 2020). Improper disposal of toxic sludge pollutes the groundwater and soil. Accumulation of toxic sludge, such as aluminum, iron etc., in natural water bodies causes adverse effects on aquatic organisms and plant species (Kurniawan et al., 2020). Hence there is a need for the efficient utilization of natural coagulants for water and wastewater treatment.

Mechanism of coagulation by natural coagulants-

Coagulation occurs between the coagulant added, the impurities, and the alkalinity of the water, resulting in

the formation of insoluble flocs. Flocs are the agglomerations of particulate suspended matter in the raw water, reaction products of the added chemicals, colloidal and dissolved matter from the water adsorbed by these reaction products. Unprocessed water from the reservoir contains organic and inorganic impurities, such as silt, rotten substance, alga, bacterium, etc. Hence coagulation is the essential step in water purification. In addition, coagulants make suspensions in water to gather and reduce the turbidity of water (Z. Song et al., 2009). The successful coagulation of natural coagulants (Ang et al., 2020) stands on these three pillars: characteristics of coagulant used, characteristics of water to be treated, characteristics of mixing process (Ang et al., 2020; Kumar et al., 2017). As Fig. 1 shows, these coagulation factors play a significant role in determining the most efficient coagulant required for the treatment. Coagulants' molecular weight (Ang et al., 2020; Gautam and Saini, 2020), types of equipment and reagents used, chemical and physical properties of the pollutants such as zeta potential (Ang et al., 2020), color, the concentration of the colloidal particles, the presence or absence of impurities (trace elements and dissolved salts (ions and chemicals) also affect the coagulation process (Ang et al., 2020; Kumar et al., 2017; Muruganandam et al., 2017). If the natural coagulant contain positive surface charge, its coagulation activity against negatively charged suspended particles will be higher and vice versa for negatively charged natural coagulants with positively charged suspended particles. Functional groups also contribute to surface charge (Ang et al., 2020). Molecular weight of natural coagulant is very important in particle bridging. If the molecular weight of natural coagulant is higher, it can form strong bridges with the particles and it leads to the formation of strong flocs and improve settling (Ang et al., 2020). Mixing is another critical step in the coagulation process. Fast mixing increases the interactions between coagulants and suspended particles and forms micro flocs. Slow mixing leads to the aggregation of micro flocs into large flocs (Kurniawan et al., 2020). Coagulation also affects the other steps of the treatment process. An efficient and effective coagulation process favors the microbiological quality (Kumar et al., 2017) of the end product and increases the lifetime of filters (Kumar et al., 2017), reducing the total cost of treated water. Natural coagulants are composed of carbohydrates, protein, and lipids. The primary building blocks are the polymer of polysaccharides and amino acids. According to the previous research, the main mechanisms governing coagulation activity are charge neutralization and polymer bridging. Polymer bridging is preceded by polymer adsorption. Because of the affinity between long-chain polymers and colloidal particles, long-chained polymers can attach to the colloidal particle's surface. A part of the polymer is attached to the particle while the other parts form loops and tails. These loops and tails are the main structure of polymer bridging loops, and tails allow attaching to other colloidal particles and form larger flocs. The basis of charge neutralization is known as the electrostatic patch mechanism. The patches of positive and negative regions on the particle's surface cause the additional attraction between particles. Ionizable polymer (polyelectrolytes) is used as a coagulant in the charge neutralization mechanism. It stabilizes the negatively charged colloidal particles. Polycation is used to stabilize the particles, gaining near to zero zeta potential. The optimum dosage of polyelectrolyte needed will be determined by the charge density of the polyelectrolyte (Amran et al., 2018; Yin, 2010). Natural coagulants have varied mechanisms of action. Let us consider some of the coagulation mechanisms of natural coagulants. The effectiveness of tannin as an eco-friendly coagulant depends on the chemical structure of the extracted tannins and their degree of modification. If more phenolic groups are available in a tannin structure, the coagulation capability will increase (Yin, 2010). The high coagulation ability of the cactus is due to the presence of mucilage. It assumes as sticky and complex carbohydrates. Surface cactus pads have high water retention capability. Cactus mucilage is made up of galacturonic acid, galactose, arabinose, xylose, and irhamnose. It is stored in internal and external parts of the cactus (Sáenz et al., 2004; Theodoro et al., 2013). According to Miller et al., 2008, cactus mucilage coagulation occurs by forming chemical bridges via hydrogen bonds or dipole interactions. Polygalacturonic acid present in mucilage is responsible for forming chemical bridges (Miller et al., 2008). Polygalacturonic acid structure consisted of an anionic chain, Chemisorption is involved between the charged particles and –OH and –COOH groups due to their partial de-protonation in aqueous solutions (Theodoro et al., 2013; Yin, 2010).

Plant-based natural coagulants-

The use of natural plant extracts dates back to 2000 BC, where Egyptians have inscribed the evidence of plant materials used for water treatment (Sivaranjani and Rakshit, 2016). According to Fatombi et al., 2013, it is clear that nuts such as beans, almonds, and Strychnospotatorum were used in Sudan, Egypt, and India, respectively. These nuts are reported to stimulate the coagulation of turbid waters (Fatombi et al., 2013). Since the late 1970s, various plant-based polyelectrolytes and polymers have been researched as coagulants. Plant-based coagulants are generally derived from the various parts of the plants and are organic, water-soluble, ionic, and non-ionic polymers in nature (Bodlund et al., 2014; Dezfooli et al., 2016; Fatombi et al., 2013). In the colloid-free aqueous state and the colloidal particle solution consisting of restricted irreversible loop arrangements, they maintain random configurations and help in destabilization by forming micro or macro flocs through charge neutralization (Hameed et al., 2016). Some plant-based materials may also behave as flocculant by strengthening the flocs for better settleability (Al-Hamadani et al., 2011; Awang and Aziz, 2012). Several works of literature have reported applying plant-based coagulants for water and wastewater treatment (Kansal and Kumari, 2014; Kristianto, 2017; Oladoja et al., 2017). Most of the investigated coagulants are from family Fabacea, primarily extracted from the leaves (Rak et al., 2012) and seeds (Jayalakshmi et al., 2017). One of the most popular and extensively researched plant-based coagulants is Moringaoleifera belonging to the family Moringaceae (Baptista et al., 2017; Camacho et al., 2017). The other common coagulants are Nirmali seeds, Tannins, Roselle seeds, Hyacinth bean etc, which have been studied for turbidity reduction (Saharudin et al., 2014; Fermino et al., 2017; Choubey et al., 2012). As in Table 3 is shown, they are low cost, non-toxic, locally available, readily implementable, and show great potential. Plant-based coagulants are advantageous because i) They are not dependent on chemicals; ii) they generate smaller amounts of sludge and biodegradable; and (iii) less toxic and not corrosive (Rocha et al., 2019). Many wastewater treatments have substituted chemical coagulants with plant-based coagulants because of their low price, abundant source, multipurpose, and biodegradability (Othmani et al., 2020).

Comparison of natural coagulants efficiency-

Roselle seeds (Hibiscus sabdariffa) were high in proteins (28 %) and soluble in water. When in solution, they carry an overall positive charge. These positively charged proteins bind to the turbidity causing negatively charged particles in the solution. According to the research, roselle seeds' highest turbidity removal efficiency is within 77 % - 87 % for synthetic wastewater at pH 10 and 81 % - 93 % at pH 4 (Saharudin and Nithyanandam, 2014). Moringaoleifera has been one of the best plant extracts for water purification. It is effective in removing Biological Oxygen Demand (BOD), turbidity, Chemical Oxygen Demand (COD), total coliforms removal, algal removal, Hardness, Total dissolved solids (TDS), and Total suspended solids (TSS) etc. According to the research carried out by (Choubey et al., 2012), Moringaoleifera removes turbidity from 100 NTU to 5.9 NTU and after dosing, and filtration to 5 NTU and total coliform remove by 96 % in synthetic raw water. Furthermore, in laundry, wastewater turbidity removed by 84 % and COD by 46% (Al-Gheethi et al., 2017). In Municipal wastewater, the reduction of turbidity, COD, BOD, hardness, TSS, and TDS are found to be 61 %, 65 %, 55 %, 25 %, 69 %, and 68%, respectively (Kumar Kaushal and Goyal, 2019). Hyacinth bean (Dolichos lablab) peels are characterized for usage as a protein source. Hyacinth bean peels have a moderate concentration of protein. Turbidity removal efficiency is 99% with the dosage of 20 mg/L in synthetic water (Bs and Papegowda, 2012). With the 200 mg/500 ml dosage, turbidity removes from 100 NTU (Nephelometric Turbidity Units) to 11.1 NTU and after dosing, filtration to 9.5 NTU, and total coliform removal 89% in synthetic water (Choubey et al., 2012). Cactus is another efficient natural coagulant. According to various research studies, cactus species prove efficient in removing turbidity, COD, and color. For example, in textile wastewaters, cactus removes turbidity by 92 %, COD by 89 %, and color by 99 % at the dosage of 40 mg/L and pH 7.25 (Bouatay and Mhenni, 2014). Nirmali seeds are another crucial natural coagulant used to remove turbidity and total suspended solids (TSS). It removes TSS by 76%, turbidity by 96% in laundry wastewater (Mohan, 2014). Watermelon (Citrulluslanatus) is the latest approach in developing an effective natural coagulant. The efficiency of turbidity removal was 88 % for the tannery effluent and 98% for synthetic wastewater. The other

physicochemical parameters of tannery wastewater, such as TSS, BOD, and COD, were also reduced significantly. The COD removal efficiency was 50%, and the BOD of the wastewater was reduced by 55%. When employed as a coagulant, the watermelon seeds significantly decrease the synthetic wastewater's TSS, turbidity, BOD, and COD, and the tannery effluent (Sathish et al., 2018). Table 4 summarizes the facts on potential applications of plant-based materials that can be used as natural coagulants. This is significant in developing new mixed natural coagulants which deliver maximum efficiency. Therefore, it can be said that natural coagulants have found their diverse application not only for physical and biological water and wastewater treatment but also as a disinfectant.

[1] Wastewater Treatment using Bio-Coagulant as Cactus OpuntiaFicusIndica – A Review,Reusing wastewater by effective treatment can contribute to counter the water scarcity. Conventional metal based coagulant treatment methods may prove inadequate to apply in aspects such as non-biodegradability and altered pH in post-treatment. There has been an extensive research on the use of biological plant material such as Agricultural waste, Chitosan, MoringaOleifera, Eichhorniacrassipes, Bark of acacia, Surjana seed, Maize seed, Tannin, Ciceraretinum, Cactus plant etc. as a coagulant. The present paper review to explore the use of cactus species in the bio-coagulation process and also it aims about investigation on effectiveness of cactus species OpuntiaFicusIndica as bio-coagulant which involve pH implication in post-treatment. In addition, the cactus had no significant effect on pH of treated water. This review highlights about optimum dosage and optimum pH at which turbidity removal is maximum. Some studies show the effectiveness of cactus in removing chemical oxygen demand (COD) and coloration in wastewater. Plantbased coagulants have the potential are effective in wastewater treatment which is sustainable and environmentally appropriate. The bio-coagulant proved to be efficient in turbidity and colour removal.It is concluded that the Cactus family species used for various purposes like treatment of wastewater, conditioning of sewage, heavy metal removal, adsorbent to remove pesticides and medicinal use also. Due to use of metal based coagulants causes diseases like Alzheimer's etc. and also there is change in pH of water after treatment occurs. To overcome these problems, cactus coagulant is the best replacing material. Biodegradability of cactus helps in sludge separation as well as degradation of organic material. But after use of cactus as coagulant, in treatment, there is decrease in dissolved oxygen level in water.

[2] Removal of Water Turbidity by Natural Coagulants obtained from Chestnut and Acorn, The ability of seed extracts of several species of chestnut and acorn to act as natural coagulants was tested using a synthetic turbid water. Active components were extracted from ground seeds of Horse chestnut and acorns of some species of family Fagaceae: Common oak, Turkey oak, Northern red oak and European chestnut. All investigated extracts had coagulation capabilities and their amounts depended on pH values and initial turbidities. The seed extracts from European chestnut and Common oak acorn were the most efficient expressing the highest coagulation activities, about 80% and 70%, respectively, in both low and medium investigated water turbidities at the lowest coagulant dose 0.5 ml/L.

[3] Reduction of Turbidity of Water Using Locally Available Natural Coagulants, Turbidity imparts a great problem in water treatment. Moringaoleifera, Cicer arietinum, and Dolichos lablab were used as locally available natural coagulants in this study to reduce turbidity of synthetic water. The tests were carried out, using artificial turbid water with conventional jar test apparatus. Optimum mixing intensity and duration were determined. After dosing water-soluble extracts of Moringaoleifera, Cicer arietinum, and Dolichos lablab reduced turbidity to 5.9, 3.9, and 11.1 nephelometric turbidity unit (NTU), respectively, from 100 NTU and 5, 3.3, and 9.5, NTU, respectively, after dosing and filtration. Natural coagulants worked better with high, turbid, water compare to medium, or low, turbid, water. Highest turbidity reduction efficiency (95.89%) was found with Cicer arietinum. About 89 to 96% total coliform reduction were also found with natural coagulant treatment of turbid water. Using locally available natural coagulants, suitable, easier, and environment friendly options for water treatment were observed. Using some locally available natural coagulants, for example, Moringaoleifera, Cicer arietinum, Dolichos lablab, significant improvement in

removing turbidity and total coliforms from synthetic raw water was found. Maximum turbidity reduction was found for highly turbid waters. After dosing, water-soluble extract of Moringaoleifera, Cicer arietinum, and Dolichos lablab reduced turbidity to 5.9, 3.9, and 11.1 NTU, respectively, from 100 NTU and 5, 3.3, and 9.5 NTU, respectively after dosing and filtration. It was also found that these natural coagulants reduced about 89–96% of total coliforms. Among the natural coagulants used in this study for turbidity reduction, Cicer arietinum was found most effective. It reduced up to 95.89% turbidity from the raw turbid water.

[4] Effectiveness of Natural Coagulant in Coagulation Process: A Review, In conclusion, there is a necessity to carry out studies to obtain more information on plant-based natural coagulants subjected to its potential application in treating water and wastewater. It also can be confirmed that most of the natural coagulants derived from plant-based materials possessed high potential ability in removing common parameter such as turbidity.

[5] Effectiveness of natural coagulants in water and wastewater treatment, Coagulants obtained from many natural sources have found their place in the water and wastewater industry world and are widely being used as primary coagulants or coagulant aids. Natural coagulants are environmentally friendly, inexpensive, less hazardous to human beings, and viable alternatives to chemical coagulants. Plant-based, animal-based, and microorganism-based coagulants have been researched for ages and have become popular in developing countries. This review summarized the efficiencies of common natural coagulants such as Roselle seeds, Moringaoleifera, Hyacinth bean, Cactus, Nirmali, Chitosan, Tannins and Watermelon seeds etc., used in the water and wastewater treatment and suggested that plant-based species showed good efficiencies in removing turbidity, color, organic matters as well as pathogens. It was noticed that many studies had investigated the application of plant-based coagulants in the primary treatment Table 6: Summary of the literary works on the modified natural coagulants Table 6: Summary of the literary works on the modified natural coagulants Natural coagulants Modifying agent Wastewater source Parameter Optimal conditions Removal efficiency (%) References Dosage (mg/L) pH Chitosan (CTS) Aluminum chloride (AC) Drinking water treatment (Microcystis aeruginosa) cyanobacteria removal 2.6 CS + 7.5 AC - 98 Ma et al., 2016 Acrylic acid Livestock wastewater Copper (II) removal 50 8 98 Zhang et al., 2014 Mercaptoacetic acid Turbid water (Synthetic) Turbidity 50 5 100 Copper ((II) Zhang et al., 2015 removal 50 7.3 90 N-methyl piperazinium chloride Tannery effluent BOD 5 6.7 86 Dharani and Balasubramanian, COD 5 6.7 96 2015 Moringaoleifera Turbid water (Synthetic) Turbidity 200 8 84 Vigneshwaran et al., 2020 Starch (2-hydroxypropyl) trimethylammonium chloride Synthetic wastewater Kaolin suspension removal 1000 4 93 % Li et al., 2015 112 S. Nimesha et al. for turbidity removal and secondary treatment for organic pollutant (TSS, BOD, and COD) removal. However, its disinfection aspect is not well explored. Studying the plant-based coagulants or plant species for the tertiary treatment of water and wastewater could be an exciting area for future research. Further, plant-based coagulants are advantageous due to their low toxicity and eco-friendly sludge production. Despite having significant benefits, some crucial barriers to the commercialization of natural coagulants are identified in this review. The significant barriers are environmental, technical, economic, and social challenges. However, there have been efforts made to commercialize natural coagulants through modified natural coagulants. There are two modified coagulants summarized in this work: Chitosan and starch, which are considered an alternative way to enhance the efficiency of the coagulants and increase its market demand. The concept of modified or composite coagulants could be taken as an indirect example for tackling these constraints. However, there are limited studies on these barriers, and this review recommends that more investigations and assessment methods are required to find the origin of these constraints and solve it through more scientific approaches. Further, from a sustainability perspective, the demand for natural coagulants is destined to increase. Therefore, more researches in the modified coagulants hold promising prospects.

4. RESEARCH GAP

Over the past several years there have been numerous research studies conducted concerning plant-based natural coagulants. However, several potential research gaps were identified regarding certain aspects of natural

coagulants in water and wastewater treatment processes. One of these is the relationship between increase in organic matter and chlorine use. As mentioned previously, using natural coagulants will inevitably result in an increase production of organic matters in the treated water and consequently encourage microbial activity which in turn would require higher chlorine use. However, limited documentation of how these parameters influence one another is available. Besides, use of natural coagulants are said to be cheaper than applying chemical coagulants, but an increase in chlorine use could possibly increase the cost of water treatment. This is rather an assumption as no research has been done regarding this matter. Furthermore, not much research has been done regarding the toxicity of the sludge produced from natural coagulant. As discovered form previous researched, natural coagulant can be extracted from many different sources and it is possible that the sludge produced could differ because the sludge is depended on the type of coagulant used.

5. FUTURISTIC APPROACH

The usage of plant based natural coagulants represents a fundamental development in sustainable environmental technology for the improvement of quality of life for communities. In an era of increasing environmental concerns, water scarcity admits the draw backs of chemical coagulants and poor sanitary facilities in most low income earning countries, the need to further develop natural coagulants as alternative environmentally favorable water purifying chemicals is exigent. The usage of bio-coagulants derived from plant based sources represents a vital development in 'grassroots' sustainable environmental technology through cost effectiveness.Design natural water purification techniques using plants extracts for bioremediation of turbid water. Application of this lowcost protocol will be recommended for simplified, point-of-use, low risk water treatment where rural and peri-urban people living in extreme poverty are presently drinking highly turbid and microbiologically contaminated water. The ultimate purpose of proposed research study is to come up with a compendium of plant coagulants that could be used as a technology that is cost effective and ecofriendly. It is felt that further research can be conducted by using the information described in this review as a platform to discover other plant species which are non-toxic and can be mass produced.

6. CONCLUSION

The waste generated by modern society when discarded in nature can make the water unfit for human consumption. Thus to obtain drinking water is necessary to perform a physical-chemical treatment which allow the removal of the turbidity and organisms harmful to health. Various methods are used to make water safe to the consumer. The method employed depends on the character of the raw water. For the treatment of surface water some traditional chemicals are used during the treatment of surface water at its various steps. Commonly used chemicals for various treatment units are synthetic organic and inorganic substances. In most of the cases, these are expensive since they are required in higher dose and do not shows cost effectiveness. Many of the chemicals are also associated with human health and environmental problems. The use of clean up technologies without producing other harmful waste products is required as best option using vegetation to remove, detoxify or stabilize persistent pollutant is an accepted tool for cleaning of polluted soil and water. Natural coagulants have been used for domestic household for water treatment in rural areas. Now a day some reports describe natural coagulants from plants are used for natural water purification. The use of plant seed materials is receiving attention for their effectiveness in wastewater treatment. The technologies involved are economical, traditional and easy to implement. These observations motivate me to analyze the biocoagulant property of some plant species Cactus Opuntia, Prosopisjuliflora were selected for further study. Natural coagulants have bright future and are concerned by many researchers because of their abundant source, low price, environment friendly, multifunction, and biodegradable nature in water purification.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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