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A review on Natural Coagulants in Wastewater Treatment

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Abstract

Particularly in a nation like Bangladesh, excessive storm runoff during the rainy seasons and land development are to blame for the unpredictable quality of river water and growing costs of water treatment. The seas are merging with the mountain's natural waterfalls. This water has been preserved by humans; after several uses, it degrades into sewage and completes the hydrological cycle. Industrialization, urbanization, population growth, and other factors that reduce their quality, such as sewage from houses, towns, institutions, hospitals, and enterprises, among others, lead natural streams to become polluted. Contaminated streams pose a number of concerns to the environment and public health. The coagulation-flocculation process requires the use of natural materials as often as is practical. Coagulation is one of the efficient fundamental chemical treatment methods that might be used to remove such contaminants. Natural coagulants have gained popularity in the water and wastewater treatment industry due to their benefits over chemical coagulants. Natural coagulants can be found in plants, animals, or microbes. Natural coagulants are the sole therapy, however this is insufficient because to the increased restrictions on their action. In reality, technological advancements and in-depth research are helping to grow them as successfully as chemical coagulants under these restricted settings. This study looks at the many coagulants that are used in the coagulation-flocculation of wastewater treatment, especially those having a natural foundation. The potential of natural materials as sustainable composite coagulants and their potential as aids are also covered in this review research.

Keywords: *Water treatment; Coagulation-flocculation process; Natural coagulants*

1 Introduction

Water is such the greatest gift of nature for the sustainability of ecological system and human beings. The cycle of water happens on Earth ensure the continuous supply for all forms of living organisms, from the mountaintops down into the oceans and to the smallest rivers. It is generally known that 71% of the Earth's surface is covered by water, but only 2.5% of the Earth's water is fresh water(Mohd-Salleh, Mohd-Zin, & Othman, 2019). The used fresh water is returned into the environment as wastewater, which not in the same sort of conditions when it was withdrawn anymore. Humans utilize and divert fresh waters a lot in many ways to drive significant economic, agricultural and support countless livelihood activities, thus unfortunately give tense pressure to the natural water bodies. Immense urbanization will lead to the raising of global populations and is expected to surpass nine billion by 2050, with 1 to 1.4 billion escalations in just a decade come from people living in slums alone(Nimesha et al., 2022). The growing population will cause more consumption of water thus generate larger volume of wastewater. The deteriorate quality of water resources cause more duty and pressure to the self-purification of streams and river bodies itself as well. The global coagulant and flocculants market are estimated to reach USD 6.01 billion by 2022 (USD 4.35 billion in 2016), observing a compound annual growth rate of 5.9% between 2017 and 2022(Alazaiza et al., 2022). Water is an important natural resource for human life. Increased population, economic development, and industrialization have resulted in not only increased fresh water consumption but also significant mismanagement of this natural resource. The researchers show that progress in the population's way of life in terms of production and consumption has resulted in an exponential increase in household waste(J, D, A, G, & K, 2017). The widely used coagulation and flocculation process is an important step in the treatment of water and wastewater because of how easy and inexpensive it is. Physical-chemical processes like flocculation and coagulation have been shown to reduce pollution and provide clean water that may be reused. Depending on the nature of the sample being treated (for example, different types of water or wastewater), and the overall treatment plan being employed, coagulation-flocculation is frequently incorporated either as a pretreatment phase or as a post-treatment step. It is possible to divide the full coagulation-flocculation treatment cycle into two distinct treatments that should be carried out one after the other(Alazaiza et al., 2022). The first method is known as coagulation, and it is used to destabilize a colloidal suspension or solution. The inclusion of destabilizing particles to come together, establish contact, and subsequently form big agglomerates, which can typically be more easily separated by settling gravity, is referred to as the second sub-process, or flocculation. In order for the contaminants to settle down at the bottom of the beaker and be separated from the water suspension, the individual colloids must aggregate and grow larger once the coagulant is added to the water(BINAYKE & Jadhav, 2013). Most industries frequently utilize coagulants made of aluminum and iron. Aluminum can, however, have a number of negative consequences on human health when employed as a coagulant in waste water treatment, including intestinal constipation, memory loss, convulsions, stomach colic, a lack of energy, and learning difficulties(J et al., 2017). Therefore, the development and application of natural coagulants in wastewater treatment are currently receiving a lot of attention. These organic coagulants can be created by or derived from plants, animals, and microbes. Acceptance of effluents released as a result of proper wastewater treatment. When effluents enter an ecosystem like a river, they may cause health effects like eye infections, skin disorders, and worm infections. However, by practicing good hygiene, these effects can be significantly reduced. When utilizing coagulation-flocculation, the wastewater's suspended particles and turbidity may be the cause of this impact. Chemical precipitation, lime coagulation, ion exchange, reverse osmosis, and solvent extraction are common methods for treating wastewater(Note, Naganathan, Musazay, & Nasional, 2014). The forces that stabilize colloidal particles and cause them to suspend in the water are removed using coagulants, which are added to the water. The benefits of using natural coagulants for developing nations are their affordability, ease of use, and environmental friendliness. The performance is unaffected by the pH of raw water, which is safe for human health, and by the effects of antibiotics on different bacteria and fungus(Desta & Bote, 2021). Compared to chemical coagulants, the alkalinity of wastewater can be greatly reduced. The use of natural coagulants is economical. The extensive use of chemical coagulants made of aluminum results in a number of neurological issues, whereas bio-coagulants have inherent qualities that make them harmful to aquatic life(Ang & Mohammad, 2020). Numerous studies investigated natural coagulants, including chitosan, gelatin, cellulose-based materials, microbial polysaccharides, Moringa oleifera, and Moringa oil. Natural coagulants are frequently employed as a point-of-use product in less developed populations since they are relatively more affordable than chemical coagulants(Mohd-Salleh et al., 2019). The strong demand and interest in the coagulation process has boosted the exploration of new generation of coagulants with better coagulation performance and efficiency(Note et al., 2014). This includes the search for natural coagulant as alternative option over chemical-based coagulants in the wake of sustainable development.

2. Methodology:

Based on a review of the literature, the scope of water treatment according to the mixing process was carried out, and properties of both natural and chemically based coagulants were examined. Treatment procedure evaluated dosage setting, molecular weight-based coagulant type, zeta potential, pH value to determine if coagulant is acidic or basic, temperature before and after dosage implementation, the amount of contaminants, and particle concentration etc. The coagulation and flocculation processes are coupled in either slow or rapid mixing when characterizing the mixing process. Finally drawing a conclusion from the data.

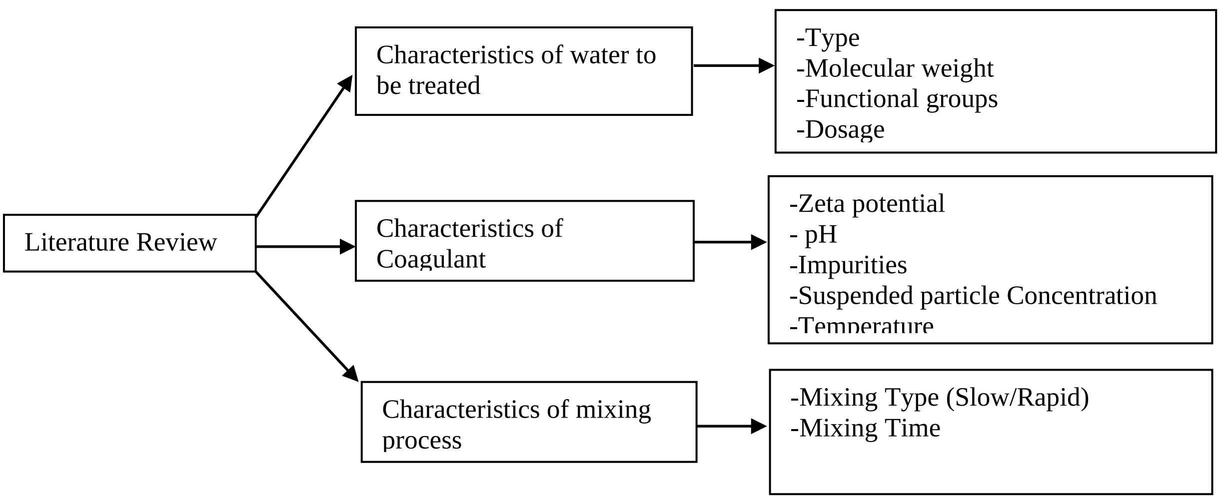

Figure 1. Road Map of the study

3 Waste water and its impact

Any liquid waste or sewage that is produced by homes, hospitals, factories, and other buildings that use water in their operations is referred to as wastewater. It is an unwanted consequence of using water. Therefore, if using a faucet or flush a toilet, the water that is consumed will eventually reach the ocean and other vast bodies of water(Nimesha et al., 2022). When individuals have to deal with sanitary issues and health concerns from drinking contaminated water, underdeveloped nations suffer the most(J et al., 2017). Wastewater can be redefined as useful sources thanks to modern evolving technologies and good management. Reusing wastewater in agriculture benefits farmers in a variety of ways, including by preserving fresh water resources and balancing economic effectiveness. The consequences of incorrect wastewater management can be rather severe. The current global crisis may have an impact on future water extraction needs unless wastewater management is rebuilt with advanced objectives. When it comes to mortality, human beings must contend with risks to their existence in order to survive. The fundamental factor preventing the global synergy between water and people is still water-borne diseases. Lack of resources and knowledge to build and maintain an effective sanitation system results in waterborne infections that propagate parasitic and ill bacteria into water bodies (BINAYKE & Jadhav, 2013). The increased rate of malarial cases is one example of how wastewater is continuing to have a negative impact. WHO (2017) estimates that malaria causes 429,000 deaths globally(Ang & Mohammad, 2020). It has been noted that the largest chunk of it is in Africa. In 2015, it was thought that 70% of fatalities involved youngsters under the age of five(Desta & Bote, 2021). Inadequate sanitation practices also contribute to the spread of bacterial diseases like cholera. This gets worse, especially after a civil unrest or a natural disaster, when community services and facilities fail and the clean water supply declines. There is a cholera outbreak in Haiti(Muyibi, Salleh, Salleh, & Gombak, 2009).

4. Coagulation and Flocculation Method

In wastewater treatment, coagulation has been practiced since earliest times and the main objective is to remove colloidal impurities hence also removing turbidity from the water. Coagulant is a chemical used that is added to the water to withdraw the forces that stabilizes the colloidal particles and causing the particles to suspend in the water(Alazaiza et al., 2022).
Chemicals for flocculation and coagulation are used in effluent wastewater water treatment procedures for solids removal, water clarifying, lime softening, sludge thickening, and solids dewatering(J et al., 2017). The negative electrical charge on particles is neutralized during coagulation, which weakens the forces holding colloids together. Positively charged molecules make up water treatment coagulants, which when added to the water and blended, achieve this charge neutralization(Do, Chemicals, & Coagulants, n.d.). For the purpose of removing suspended particulates from water, coagulant types that are either organic, inorganic, or combined are frequently used. An inorganic coagulant's cationic metal ion neutralizes the negatively charged electric double layer of the colloidal suspension when it is applied to water containing a colloidal suspension(Nimesha et al., 2022). Similar circumstances arise with an organic coagulant, except the positive charge most commonly comes from an amine (NH) group attached to the molecule. ChemTreat has both NSF-approved and GRAS-applicable coagulation products(Muyibi et al., 2009). Examples of ChemTreat coagulation products include aluminum salts, iron salts, and polyelectrolytes.

4.1 Perspective on Using Coagulant in Wastewater treatment throughout the years

Without the addition of coagulant agents, it is nearly impossible to eliminate the specific pollutants in wastewater. Colloidal or suspended particles are negative loads that need to be destabilized in order to collect in a bunch because stability prevents them from sinking to the bottom. Since the 19th century, coagulation has been a simple method for water filtration due to its comprehensible principles(Desta & Bote, 2021). Researchers have long engaged in heated discussions over the mechanisms, putting out theories about what it takes for them to function optimally. The Schulze-Hardy rule is known to have been the first mechanism to explain coagulation, and the particle collision function theory was created in the early months of 1917(Muyibi et al., 2009).The usage of coagulants in wastewater's physical-chemical treatment has even been recorded since the earliest times, but using natural-based as the prime material. It was way foretime the natural-based coagulants especially the one that extracted from plants were used as coagulant for water clarification(Desta & Bote, 2021). The globalization era starts to take over the consumption of old and aged treatment methods as sign of urbanization world, with massive technology and advancing knowledge, left the traditional ways behind. Over the years, obvious gaps are growing that differentiate the employment of natural and chemical coagulants. Both chemical and natural-based coagulants have been effectively acknowledged in various ancient records and past studies(J et al., 2017). However, it is sadly to be accepted that natural-based coagulants are no longer the main priority with the invasion growth of more advanced synthetic material, except the poor countries that have limitation in purchasing these goods(Mohd-Salleh et al., 2019). Nonetheless, there is arising concerns regarding chemical coagulants thus make researchers nowadays start to develop a more environmentally friendly water and wastewater clarification agent, likely from non-chemical based. Chemical coagulant agents such as polyaluminium chloride and aluminum sulphate are among the most well-known and used in wastewater treatment.

4.2 Types of natural coagulants

Natural coagulants contain properties that make them harmless to aquatic life. It contains gelatin, cellulose-based substances, microbial polysaccharides, bio-, alginate, and chitosan. Since polysaccharides make up the majority of natural coagulants, they are also known as polymeric coagulants(Alazaiza et al., 2022). Natural coagulants can be categorized into three groups based on their origin.

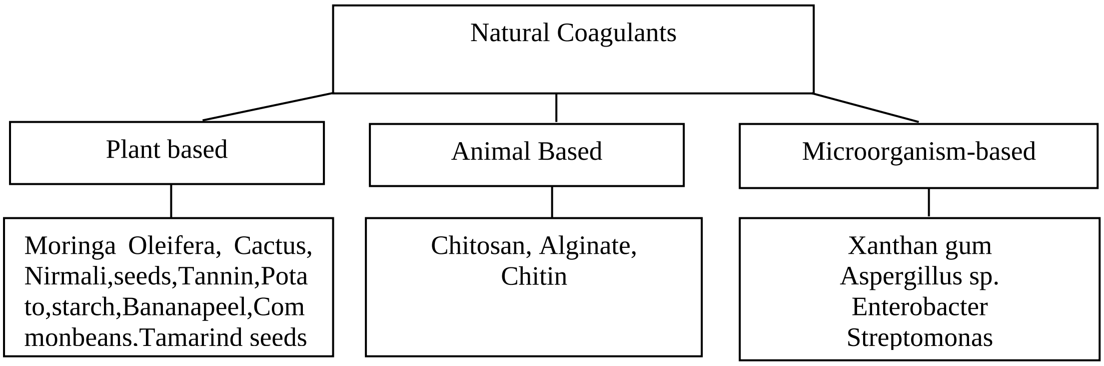

Figure 2. Classification of natural coagulants with example

4.3 Characteristics of natural coagulants

The characteristics of natural coagulants are given in table-1

Table 1. The characteristics of natural coagulants

Parameters	Characteristics
Carbon footprint	Environmentally friendly
Toxicity	Less toxic
Heavy Metals	Settling will occur along with the coagulation process
Sludge	Sludge volume/amount reduction, Low, sludge handling cost, and treatment, cost with good biodegradability.

5. Natural coagulants - barriers for the commercialization

Most natural extracts have proven their coagulation capabilities in removing COD, BOD, TSS, turbidity, etc.; not many have accepted and reached commercialization(Desta & Bote, 2021). The main barrier for the commercialization of natural coagulants is difficulty in bulk production of raw materials; plant species. Raw materials used to produce chemical coagulants such as aluminum, iron are abundant in nature. For a successful and realistic application, raw materials required to produce natural coagulant should be available in large scale(Alazaiza et al., 2022). Technical support, expert support and technologically advanced new equipment are necessary in sustainable implementation of natural coagulants so that production cost will ultimately increase(Desta & Bote, 2021). In short run this is not very economical so that market acceptance will be less. Hence the absence of mass plantation of recourses hiders steady supply of raw materials and the long-term applications.

Table 2. Barriers in the commercialization of natural coagulants

Environmental and Technical Constraints	Economic and Social Constraints
1.Complex extraction process	1. Lack of money and time to invest in research and development.
2.Absence of mass plantation for bulk processing	2. Lack of maintaining a steady supply of raw materials.
3. Due to the organic properties of natural coagulants, COD levels	3. Lack of meeting the minimum quality requirement.
4. .Lack of research regarding the practical usage and issues occurring during the operations within the plant.	4. Lack of knowledge on health improvements.
5. Lack of proper arrangements for storage of the natural coagulants in stock	5. Well established, competitive market & High initial establishment cost.

5.1 Mechanism of coagulation by natural coagulants

The hypothesis that there can be contact between the polymer and the dissolved particles in a solution was developed by the mechanism of coagulation because natural polymers have several charged functional groups that are located in their polysaccharide chains, such as -OH, -COOH, and -NH. In general, there are four processes involved in the processing of coagulant, including bridging mechanisms, charge neutralization, double layer compression, and sweep-floc mechanism(Muyibi et al., 2009). Natural coagulants are frequently made up of a combination of multiple macromolecules, including lipids, proteins, and carbohydrates. Amino acids and polymers of polysaccharides are frequently the main constituents. Numerous investigations utilizing different coagulants, such as cassia seed gum, sago starch, and moringa oleifera extract, have identified the bridging process(Alazaiza et al., 2022). Long chain polymers that are absorbed on particles might have heads and tails that enter the solution by different methods(Mohd-Salleh et al., 2019). A bridging mechanism needs a lot of area where polymer chain divisions can be attached and wrapped around other particles. Therefore, the significance of the most advantageous sum for the bridging mechanism is appropriate. Previous research has shown that the microbe extract from Nirmali contains lipids, alkaloids with -COOH and -OH groups, and carbohydrates that increase its coagulating activity(Do et al., n.d.). Galactomannan and galactan, which are capable of removing up to 80% of the turbidity in kaolin solution, were found in polysaccharide particle extracts from Nirmali seeds. Inter-particle bridging occurs as a result of the abundance of -OH adsorption sites next to the galactomannan and galactan chains seen in nirmali seed extracts(Nimesha et al., 2022).

5.2 Future Potential and Constraint of Natural Materials as Commercial Coagulant

The environment and society stand to gain from effective wastewater management, but finding environmentally benign and economically viable steps toward effective water treatment presents a genuine challenge. In addition to removing dangerous materials, giving nutritional value is another bonus in controlling wastewater through various studies that may be useful in the future. In contrast to chemical-based materials that endanger human health and harm the environment, naturally occurring materials are also extremely biodegradable, non-hazardous, and toxic free(BINAYKE & Jadhav, 2013). Coagulants made of natural materials are also widely available, especially when they are made of plant-based and agricultural waste. In areas with a lot of local resources, plants like Moringa oleifera and rice starch can be grown. Therefore, in an effort to replace the risks associated with utilizing inorganic metal salts, cheaper coagulating agents may be found in the future(Nimesha et al., 2022). There are several limitations in the commercialization of the coagulants made from these bio-based, though. In essence, the limited financial supply is caused by the reservations that potential investors have about investing in innovative products. The key to continuing research development is the in-depth analysis of new knowledge, which allows for the identification of its strengths and weaknesses. In order to find demands for substituting synthetic-inorganic coagulants, awareness of natural materials must also advance at the same time(Alazaiza et al., 2022). In addition, the conditions under which it works to attain its best results may be called into doubt. The precise target market must then be aimed at.

Conclusion:

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. The utilization of natural coagulants can be further commercialized by tackling its limitation factors via progressing them as aids or composite ones Despite the disadvantages of sole chemical coagulants and the limited ability of natural materials to work at their finest, the formation of coagulants from both materials might be the next big-key solution. Further, from a sustainability perspective, the demand for natural coagulants is destined to increase. This review highlighted that many potential advantages in using natural coagulants from various sources of plants, animal.

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